Study on effective utilization of irrigation water in Afghanistan

2016

Hayat Khan SHAMS

Doctoral Dissertation

Study on effective utilization of irrigation water in Afghanistan

Hayat Khan SHAMS

Supervisor : **Professor Dr. Fumio WATANABE**

Advisor : **Professor Dr. Hiromichi TOYODA**

Associate Professor Dr. Shinji SUZUKI

Dr. Masaaki SUZUKI

March 2016

Summary

Afghanistan has arid, semi-arid climate. Literally it has thousands of microclimates, where frequently conditions change from one valley to another, within a fairly short distance. Afghanistan has sloppy, high altitude hill as well as flat plains in other regions of the country. The change in altitude produce a climate with temperate and semi tropical characteristics, wide spreading temperatures variations are usual from season to season and from day to night. Summer temperatures are high with high evaporation rate and winter is cold with freezing condition. Afghanistan is an arid country, with more than half of the area receiving 100 to 300 mm precipitation per year, which mostly occurs in winter season with no agricultural activities. Afghanistan is rich in water resources, the main surface resources being Amu Darya basin, North river basin, Hari Rud river basin, Helmand river basin, and Kabul river basin. Surface water is estimated at 57BCM, and at present just 17BCM is used, and ground water is 18 BCM, and 3BCM is used. About 15% of Afghanistan's irrigated land gets water from traditional underground systems such as karez, spring and shallow well. Irrigation system in Afghanistan is divided into two division: informal and formal. Afghanistan is facing water management challenges, the irrigation water management is done through community based irrigation management system known as Mirab system. The Mirab system is not good in equity issues

especially in irrigation water distribution. There is great difference in the water rights and actual water distribution among the users. More than 80 % of people leaves in different agro climate and topography of the land engaged in agriculture and livestock, they have cultivated 2.72 million hectares under irrigation, and the economy of these people is directly or indirectly dependent on agriculture. But unfortunately, the country is not food self- sufficient yet. Which is a major problem for people, who have to import food from abroad, because during the past three decades of civil war and conflict most of the agricultural dams, canals, and land have also been destroyed, similarly farmers with experience have immigrated or died. The whole event has entered its negative impact on agriculture sector. And farmers mostly have been suffering from shortage of water, especially in the summer and fall season. This problems is more common in the country and more in drought years. The main aim of the Ministry of Agriculture, Irrigation and livestock of Afghanistan is self-sufficiency of food. To achieve self- sufficiency, it is necessary to investigate the existing problems especially in the irrigation sector and to increase water use efficiency.

The aim of this dissertation is to discuss the most convenient, effective and adoptable water loss control system utilizing irrigation water in Afghanistan. For achieving the above goal, the following researches were conducted;

A) To improve irrigation water use efficiency, through estimation of pan evaporation in Kabul, Afghanistan.

B) To estimate optimum irrigation discharge under furrow irrigation in Afghanistan.

C) To discuss mulching system for conserving irrigation water.

1. Improving irrigation water use efficiency, through estimation of pan evaporation in Kabul, Afghanistan

Afghanistan climate varies from arid in the south and southern to semi-arid in other part of Afghanistan. During the summer air temperature is very high and no rainfall, and without irrigation supplies, these areas cannot support any crop production. During winter temperatures are low and precipitation occurs in form of snow in which there is no need to irrigate. In Afghanistan, all agricultural production depends on availability of water. Unfortunately, Afghanistan lacking of irrigation planning, have lost meteorological station and due to lack of data quantification of water shortage during cultivation and growing season became difficult. In the country just a few meteorological stations have been installed now. The objective of this study is to clarify meteorological properties in Kabul, and to introduce a method for estimating pan evaporation. Pan evaporation is an important weather variable that has application related to decision making in agriculture and other field. Meteorological data were collected in Qargha Agricultural Experiment station in Kabul, Afghanistan. These data include air temperature, relative humidity, wind speed, sunshine hours, rainfall and pan evaporation. For estimating evaporation Penman method (Penman, 1963) was used. When evaporation obtained by Penman method and evaporation obtained by class A pan, there is large variation in the relationship between the estimated evaporation and the observed evaporation. Then evaporation is estimated with other meteorological parameters like relative humidity, air temperature, sunshine and wind speed. When evaporation was estimated from relative humidity and wind speed with pan evaporation there was a large imparity, but when estimation was made from sunshine with pan evaporation they had a good correlation. Similarly estimated air temperature and pan evaporation, and we found very important parameter for estimation of pan evaporation value, and determined the appropriate data set for estimating pan evaporation, which were average air temperature and pan evaporation values in 5 and 10 days period. There was a good relationship between 10 days air temperature and pan evaporation compared to 5 days air temperature and pan evaporation.

2. Field evaluation of furrow irrigation water infiltration for better water management

In Afghanistan water shortage is a result of war, inflicted damage to irrigation system, traditional irrigation system, and prolonged drought. Lack of irrigation scheduling and low knowledge of farmers about irrigation. Anyway in the country roughly 2.6 million hectare of irrigated land is under cultivation. This irrigated land produces 85% of all production, the water supply application efficiencies is very low, because high run off, deep percolation, losses of water through evaporation. Furrow irrigation is one of the surface irrigation system, and one of the oldest method in Afghanistan, this method has low application efficiency. The objective of this study is to introduce a method to estimate optimum irrigation discharge which it can reduce deep percolation for furrow irrigation. In this study a mathematical model of surface irrigation was used to determine optimum irrigation discharge in the cultivation of tomato and to compare irrigation application efficiency with existing furrow irrigation. Infiltration is one of the most important soil parameters in the design and evaluation of the surface irrigation methods. There are a number of infiltration equations available that to explains the process of infiltration. In this study the volume balance equation during the irrigation is used. Water advance test was conducted at the Badam Bagh agriculture research station in Kabul, Afghanistan. The irrigation discharge for tomato crop was $0.00148m^3$/sec, which is like the amount of water the farmers have been using to irrigate agricultural field. After calculation application efficiency was 57.4%, to determine the maximum value of irrigation application efficiency, we have done calculation of infiltration amount with different irrigation discharge such as $0.0011m^3$/sec which is less than actual water discharge, $0.002m^3$/sec and $0.003m^3$/sec which is more than actual water discharge. In order to compare application efficiency to conventional irrigation discharge (0.00148m^3/sec). Crop water requirement for tomato was 4.2 mm/day on August 2014 using FAO CROPWAT program 8.0. The value of application efficiency were 54.2, 60.5 and 59.2% respectively. The maximum water application efficiency was 60.4% with irrigation discharge 0.002m^3/sec. in this case we can save 5.1% irrigation water in each irrigation scheduling.

3. Mulching system for conserving irrigation water

As mentioned in the previous chapter, Afghanistan climate varies from arid in the south and southwest to semi- arid in most other part of the country. The more than half of the country annual precipitation ranging from about 100- 300 mm and remaining part of the country receives 300 to 800 mm of precipitation and mostly occur in winter season. The seasonal variation of temperature (35-40°C) is obvious all over the country. In different ecological zone of Afghanistan, in spring season sometime temperature is below zero degree and bring sever damage to plant. Also in cold areas some crop are cultivated late and certain time plants do not reach maturity. In summer season evapotranspiration rate are high and daily peak of 6-8 mm. In the country around 90,000 ha of land is under vegetable. One of them is tomato crop, tomato crop growing during the spring and summer seasons in many regions. Also tomato cultivation has many issues due to low temperature in early spring and water deficit in summer. To get a good harvest, use of plastic mulch is effective increasing soil temperature, conserving soil moisture and weed control.

The objective of this study is to measure the influence of mulch surface color on reflected light and determine the effects of various mulch surface colors on yield of fresh market tomatoes planted in the spring. The experiment was conducted for three years at Qargha research station of Kabul, Afghanistan. Three colors of mulch material along with control were considered. The experimental plots consist of 27 m long and 0.7m wide. Trickle irrigation tubing were applied in all plots under mulches, each mulch plot was 45 hole with spaced 0.6m, plant were transplanted on the middle of May in 2009, 2010 and 2011, and soil temperature were measured at 7 cm depth at 9:30 am. The soil temperature were in average 23.3, 22.9, 22.2°C for black, red and white mulch respectively. Applying plastic mulch could increase soil temperature 2.4 to 4.2°C as compared to control namely bare soil. For the reliable soil temperature, we extended our study and used soil temperature data logger, soil temperature were 31, 30.6, 28.1 and 26.9°C for black, red, white and bare soil in the month of August. The soil temperature in bare soil was always lower than that of under mulches, and the maximum soil temperature were under black plastic mulch, followed by the red mulch and white. Surface reflected light was determined using pyranometer, and the reading were from black mulch 6.7, red mulch 35.5 and white mulch 48.3%. Tomato size harvested under the white plastic mulch was larger than that of for black, red plastic

mulch and bare soil. Three year average yields were 39, 37, 35, and 25 ton/ha for white, black, red and control respectively. All colored plastic mulch gave significantly higher yield than that of control, there was no significant difference in the average fruit weight among mulch treatments.

JAPANESE SUMMARY

論文の要旨

アフガニスタン国における灌漑水の有効利用に関する研究

アフガニスタンの農業は、数十年に及んだ内戦によって灌漑施設の破壊や老朽化、さらに農業普及を担う人材の不足などにより、極めて低迷している。また、慢性的な水資源の不足で同国の耕作可能な面積 790 万 ha の 50 %しか、農地として利用されていない。一方、同国の灌漑農地面積は農地面積の 67 %に過ぎないが農産物の 85%は灌漑農地から生産されており、今後の農業生産の改善には灌漑農業の更なる発展が最も重要である。

そこで、本論文では、同国の地形や気象特性などから灌漑農業の問題点を分析し、アフガニスタンにおける灌漑農業における水の有効利用の視点から 3 つの問題を指摘するとともに、それらの課題解決のための現場実証試験等を実施し、その結果から具体的な対策の提案を行った。まず、灌漑水の有効利用には不可欠な灌漑計画の基礎データである水面蒸発量の推定法について検討し、これまでのペンマン法から推定する方法より、良好な相関性を示す 10 日間の平均気温から求める水面蒸発量の推定式を提案した。これにより、作物の日消費水量の推定が旬毎に推定可能となり、無駄のない灌漑計画策定ができることを示した。

次に、同国の灌漑農業で最も利用されている地表灌漑での灌漑中の浸透損失について注目し、畑地での灌漑中の浸透ロス抑制のための適正給水量の推定法を現場水足試験から試みた。その結果、現行の農家のトマト畑での畦間灌漑での適用効率を現行の 57.4 %から 60.5 %まで向上させること、さらに 1 ha あたりで約 5 m^3 の灌漑水の節約が可能であることを明らかにした。

最後に、将来の灌漑農地の拡大には、さらなる節水が不可欠である

ことを指摘し、灌漑水の蒸発防止と節水が期待できる点滴灌漑とフィルムマルチを利用したトマト畑での実証試験を試みた。その結果、フィルムマルチなしの対照区に対して、フィルムマルチ区はトマト収量を 40 t/ha に増加させることが可能であること、さらに 3 年間の平均でもマルチ区は統計的にも有意差があることを明らかにした。加えて、本研究成果の現地での技術普及の方法について、同国の農業普及員とミラブ（水番人）との連携の重要性も提言した。

Acknowledgement

First of all I am thankful to my almighty God to have given me the strength to continue and facilitated me to complicated matter.

This dissertation could not have been completed were it not for supports from many people. I would like to express my deepest gratitude to all those who have contributed in any way. I would like to express my extremely thankful to Professor Dr. Fumio WATANABE, for his great support, advices and guidance throughout the work of the Doctoral study in Tokyo university of Agriculture. He kindly shared his valuable time in outlining the research's procedure, analysis and site application method. I would like also to thank Professor Dr. Hiromichi TOYODA, Associate Professor Dr. Shinji SUZUKI and Dr. Masaaki SUZUKI for their suggestions and comments.

Also big thanks go to Professor Dr. Satoru TAKAHASHI for his kindness and overwhelming support he provide for me over the two years. We were able to share together. His outstanding experience provides as table foundation on which my success today was laid. This will not go without mentioning all my colleagues in the laboratory of soil and water environmental technology, Mr. Mitsuru KASHINO, Masaharu KIMURA, Naoto TSURUMAKI, Shiori WATANABE and others for their assistance during all my research and stay in Japan Special appreciation to the JICA and JICE of JAPAN for their support

to Afghanistan for the promotion and enhancement of the afghan capacity for effective development, under (PEACE) project. And I am extremely thankful to all staff of JICA.in JAPAN and Kabul Afghanistan.

I am extremely thankful to JICAF of JAPAN, especially Professor Dr. Ryuzo, NISHIMAKI, Mr. Masahiro YONEYAMA, Dr. Yuzo KOBAYASHI, Miss. Mari TANAKA, Ms. Akiyo NISHIYAMA for their heartfelt support, cooperation and encouragement during my stay as well as Tokyo University of Agriculture and my family.

I am extremely grateful and pleased by Japan people from their hospitality and admiration during our stay in Tokyo

I am grateful to government Afghanistan, Ministry of Agriculture, irrigation and livestock, Ministry of high education, and Ministry of foreign affairs for support and for giving me the opportunity to prepare my Ph.D. thesis in Japan, especially at Tokyo University of Agriculture.

I thankful to my lovely family, for their mural support and dedicating their time to share with me in the pursuit of this noble course.

Last but not least, for those whom I might not have been able to mention, my thanks and appreciation comes your way, I acknowledge the time you took to make this a success. For that I say thank you.

Table of contents

List of Figures

List of Tables

Chapter 1

Introduction of Afghanistan and objectives

1.1 Introduction

1.1.1 Background

Afghanistan is an entirely landlocked country located in southern Asia and is located to the east of Iran and both north and west of Pakistan. Other countries making up the border include Turkmenistan, Uzbekistan, and Tajikistan, on the eastern side of the country, Afghanistan also shares a small section of the border with China, with a total boundary length of 5,529 km. Afghanistan has a total land area of roughly 652,000 km^2, extending 1,240 km NE–SW and 560 km SE–NW (Geography 2001) (Fig 1-1). The topography of Afghanistan is divided primarily into three regions: the pastoral farmland in the north, the central highlands in the middle section of the country (including the majority of the Hindu Kush Mountains), and the mostly barren and windswept desert of the southern plateau. Afghanistan is characterized by typical climate varying from arid to semi-arid land. At greater altitudes, precipitation is high and the growing seasons are shorter due to frost hazard in mountainous zone of the country where precipitation is sufficient, the availability of agricultural land is a limiting factor. In the flat areas, growing seasons are sufficiently long even for double cropping but the limiting factors are effective rainfall and irrigation water availability. The climate of Afghanistan is not favorable for rain-fed agriculture. During winter, temperatures are low and precipitation occurs in form of snow whereas during summer, temperatures are high and rainfall is virtually zero. Without irrigation supplies these arid to semi-arid areas cannot support in agriculture. The history of irrigated agriculture in Afghanistan goes back to more the 4,500 years ago. Except for a few areas where rain fed agriculture can be practiced, agricultural production in most of the country is not possible without irrigation as the rainfall is either meager.

Afghanistan is an agrarian country with more than 80 % of the population living in the rural areas. The economy of the country is based on agricultural products and livestock. About 85 % of all crops in Afghanistan are grown under irrigation. The major staple crop is wheat, of which 80 % is sown as a winter crop. Other grains include maize, rice, barley, pulses, potatoes, onions, tomatoes, and several fruit crops including melons, water melons, apricots, pomegranates and grapes are also produced both for domestic consumption and experts.

Afghanistan arable land is about 8 million ha, which is 12 % of total land area. There are only 50 % of the total cultivable land which is not cultivated because of the lack of sufficient of water. There are roughly 3.9 million ha of cultivated land in Afghanistan, 1.3 million ha of which is rain-fed and 2.6 million ha is irrigated. Water is the lifeblood of the people of Afghanistan, not just for living, but also for the economy, which has traditionally been dominated by agriculture. The prolonged situation of violent conflict and political instability created serious problems with agriculture and irrigation activities. The effects of war and neglect, FAO of 1997, estimates about 1.7 million ha required rehabilitation, and another 0.68 million ha required improved on- farm water management conditions. About 46% of the irrigation structures are damaged, and 88% of the irrigation structures are traditional which are responsible for 40 % of the total water loss. Irrigation priority problems include loss of water within the system, poor distribution of water over the growing season, poor agronomic practices, and farmers usually have poor knowledge about crop water requirements and over irrigation of crops is a common practice. Overall efficiency is only about 25 to 30 %. Due to low use efficiency and lack of input, crop yields are very low. Afghan farmers use centuries old farming techniques and little knowledge on new irrigation technologies and cultural practices is available to the farmers.

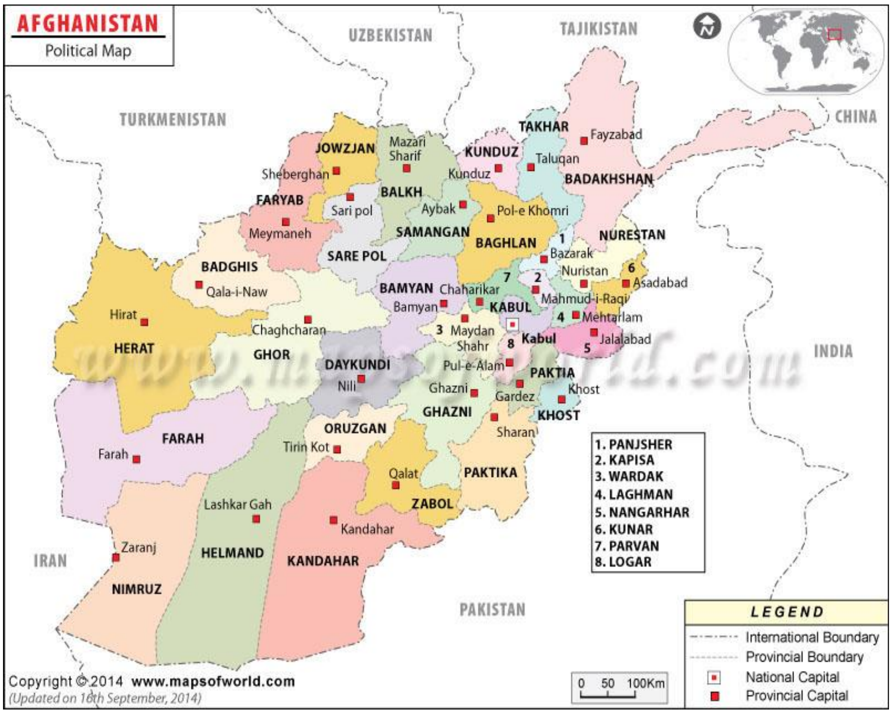
Source: Qureshi, 2002

Fig. 1-1 Map of Afghanistan with surrounded countries

Administratively, Afghanistan is divided into 34 provinces, each province consisting in a number of districts. Within these districts most families live within villages. Rural households make up some 80 % of the total national population of approximately 27 million (ICARDA, 2003). They live in approximately 20,000 villages scattered across Afghanistan. Majority of the rural population is small subsistence farmers who live on small plots of land (Wegerich,K. 2009) Afghanistan's capital city, Kabul, is located in the east central part of the country (Fig. 1-2).

The average holding was 3 ha in 1987. The vast majority of holding fall in the range of 0.5 to 6 ha. Holding under 20 ha accounted for 60 % of land ownership in 1987 and those over 100 ha for 8 %.

Distribution of farm size in irrigated and rain-fed agricultural areas is given in Table1-1 (Thakkar, 1999).



Source: maps of world.com

Fig. 1-2 Political map of Afghanistan

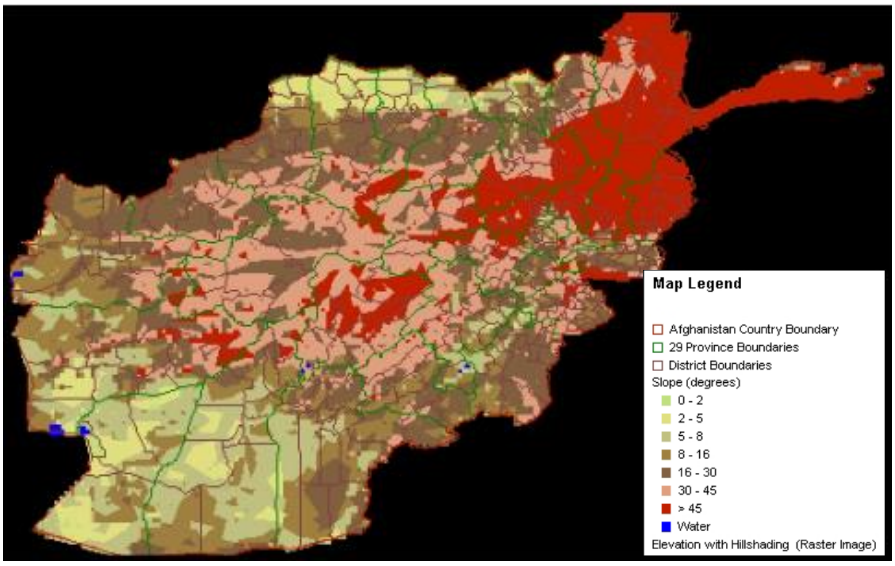
Table 1-1 Farm size distribution in Afghanistan

Farm size(ha)	Irrigated farms(%)	Rainfed farms(%)
<3	83	8
3-6	14	8
>6	3	84
Mediam	1.4 ha	6-7 ha

Source: Qureshi, 2002

1.1.2 Topography

Afghanistan is mountainous topography with high slope and high elevation. Although the average altitude of Afghanistan is about 1,200 m, the Hindu Kush mountain range rises to more than 6,100 m in the northern corner of the Wakhan panhandle in the northeast and continues in a southwesterly direction for about 970 km, dividing the Northern provinces from the rest of the country (Fig. 1-3). Central Afghanistan, a plateau with an average elevation of 1,800 m, contains many small fertile valleys and provides excellent grazing for sheep, goats, and camels. To the north of the Hindu Kush and the central mountain range, the altitude drops to about 460 m, permitting the growth of cotton, fruits, grains, ground nuts, and other crops (Meredith, L, .Runion, 2007). Southwestern Afghanistan is a desert, hot in summer and cold in winter.



Source: united Nations 2001

Fig. 1-3 High elevations and slopes of Afghanistan

1.1.3 Agro ecological zone

Agro-ecological zones and watersheds are the most significant criteria for zoning of agriculture. However, the identification and delimitation of agro-ecological zones in Afghanistan is rather difficult. Afghanistan has a very varied geography, with literally thousands of microclimates and micro- watersheds, and frequently conditions change from one valley to another, within a fairly short distance. The main instrument for analyzing agro-ecological zones in the Afghanistan land cover Atlas, prepared by FAO, published in 1999 on satellite and ground information dating from 1990-93. As land use somewhat changed over the intervening years, and normally varies from one year to the next according to rainfall and climatic conditions (Adil, 2001, FAAHM. FAO, 2003).

However, in certain areas of the Afghanistan there is some information about current land use patterns, and this was used complementarily to the land cover atlas in those particular locations. Changes concern several factors: encroachment of rain-fed cultivation into grassland, changes in water rights denying access to water by farmers at the tail of certain irrigation systems, destruction or deterioration of some irrigation systems during the wars of the 1990s, and changes caused by population displacement because of changing cropping patters. For instance, some areas had been classified in the atlas as irrigated areas with one crop per year, because at the time they were devoted to cotton (one crop per year) but now they are devoted to other crops that allow for two crops per year, such as wheat followed by maize, rice or pulses (UNEP, 2003).

The most usual classification of agro-ecological zones for Afghanistan includes a total of eleven zones, of which only nine have any agricultural significance (the other two are the deserts in the South- West and the Wakhan Corridor leading to the Pamir Knot in the Northeast (ICARDA, 2002).

The broken relief and wide range of altitude in Afghanistan leads to a great variation in climate within relatively small distances. A simplified version of the eleven geographical zones is shown in Table 1-2 (FAO, 2006, Mail, FAAHM, FAO, 2003), and the UN planning regions consist of provinces is shown in Table 1-3 and number of farms, irrigated land and rain fed land of each agro-ecological zone and region of Afghanistan is shown in Table 1-4.

Table 1-2 Climatic types of Afghanistan

Reguin	Climate type
1.Extern North	Continental desert climate
2.South	Sub- tropical desert climate
3.Northwest	Continental semi- arid mediterranean climate
4.Lower central and Southeast	Warm semi- arid mediterranean climate
5.North East Central	Continental semi- arid to moist mediterranean with winter frost
6.Lower Kabul Valley	Dry steep frost
7.Hige mountains,center and NE	Alpine

Source: Ministry of Agriculture, Animal Husbandy

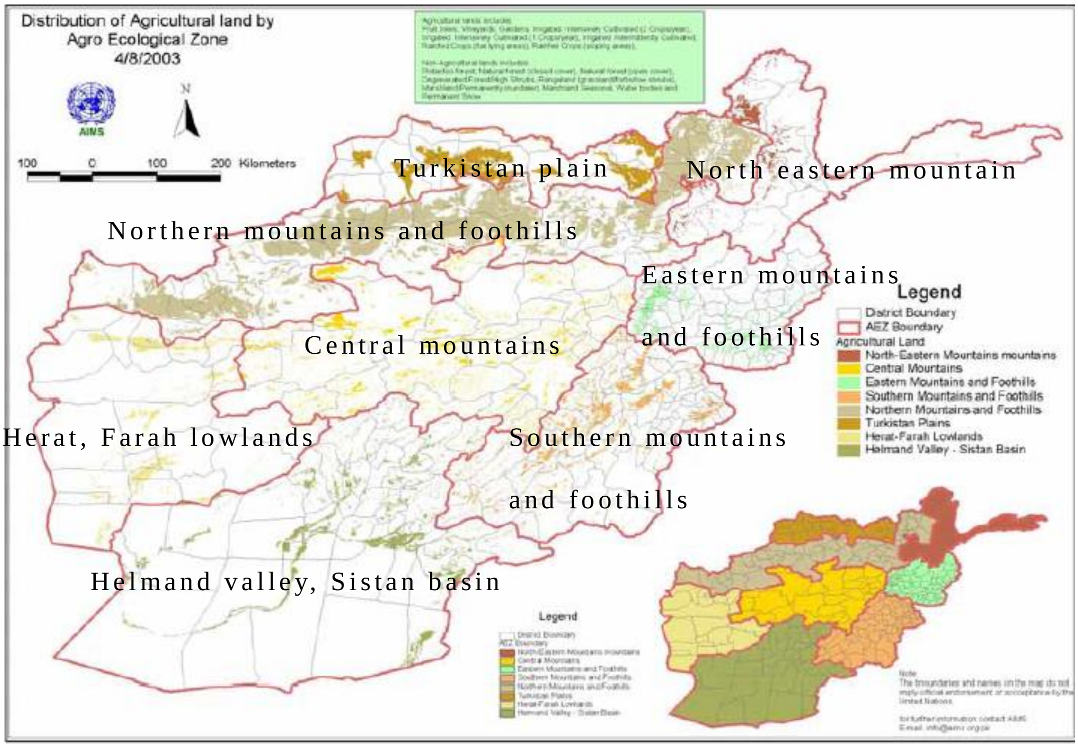
Table 1-3 UN planning regions in Afghanistan

Region	Provinces
North	Balkh, Faryab, Jauzjan, Samangan, Sar-i-pul
Northeast	Badakhshan, Baghlan, Kunduz,T akhr
West	Herat, Farah, Badghis
west-Central	Ghor, Bamyan
Central	Kabul, Parwan, Kapisa, Logar, Wardak
South	Paktika, Paktya, Khost, Ghazni
East	Nangarhar, Laghman, Kunar, Nuristan
Southwest	Nimroz, Helmand, Kandahar, Zabul, Uruzgan

Table 1-4 farms with irrigated or rain-fed land

	Farms	With irrigated land	With rainfed land
Total	1,063,269	944,561	444,169
Agro-ecological zone			
Badakhshan mountains	35,346	26,006	30,218
Central mountains	167,168	151,940	97,797
Eastern mountains	175,327	172,583	14,964
Southern mountains	79,426	79,426	18,021
Northem mountains	281,048	202,864	233,774
Turkistan plains	74,857	67,520	24,417
Herat- Farah lo wlands	146,759	143,815	14,718
Helmand River valley	103,338	100,406	10,260
Region			
North	177,504	129,862	134,809
Northeast	164,134	132,761	105,027
West	196,371	177,583	63,291
west-Central	75,463	60,235	60,911
Central	104,796	104,546	18,193
South	72,871	72,871	24,711
East	125,946	123,452	10,724
Southwest	146,183	143,252	26,504

For the purpose of the present analysis, the geographical subdivision of the Afghan agricultural sector into eleven agro-ecological zones were adopted. These zones reflect basic ecological properties of land and climate, plus some supplementary criteria about accessibility and prevailing agricultural activity. In fact, arable land is only a fraction of each zone's territory. Fig. 1-4, shows main classes of land cover in each agro-ecological zone. The zones indeed have designations that allude to a broad stretch of territory, such as "Northern Mountains and Foothills". However, given the mountainous geography of Afghanistan, agricultural activity does not occupy a contiguous and homogeneous stretch of the country. Agriculture is possible only in specific patches or strips of land in the numerous mountain valleys and the thousands of micro-watersheds created by numerous streams coming down from the mountain ranges. More or less contiguous and relatively extensive agricultural areas only exist in some parts of the territory (such as the Turkistan Plains or the Northern Foothills) where flat or gently undulating land prevails, but even there the actual conditions of the terrain and the capricious nature of water supply impose at the best of times only a patchwork of cultivable and uncultivable land rather than a continuous pattern of cultivation (ADB, 2003).



Source: Mail, FAAHM, FAO, 2003

Fig. 1-4 Main classes of land cover in each agro-ecological zone of Afghanistan

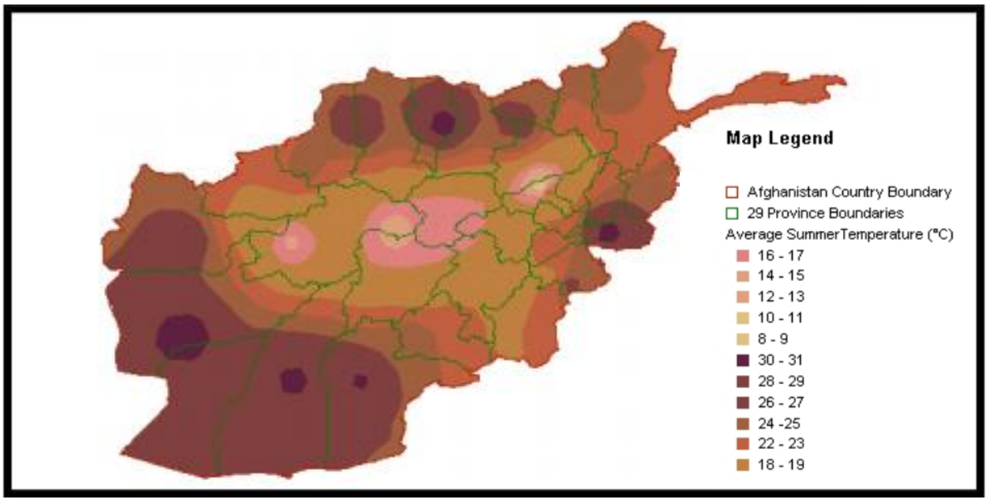
1.2 Climate

The ranges in altitude produce a climate with both temperate and semitropical characteristics, and the seasons are clearly marked throughout the country. Wide temperature variations are usual from season to season and from day to night. Typical of a semi-arid steppe climate, winters are bitterly cold with heavy snow in the mountains, and summers are hot and dry. (Afghanistan in perspective, 2012).There is much sunshine, and the air is usually clear and dry. Wind velocity is high, especially in the west part of the country.

1.2.1 Temperature

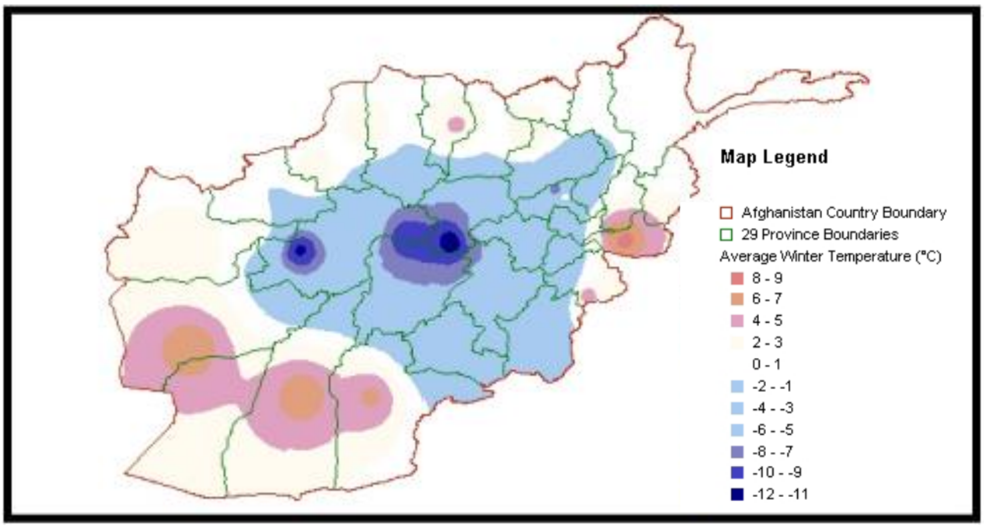
The daily and the seasonal variations of temperatures prevailing all over the country lead to different lengths of growing seasons, and require a careful selection of the most suitable crop for an area. This is reflected in many regions well known for their particular agricultural products (e.g. grapes, melons, rain-fed wheat) or their natural forest cover (pistachio trees, pines). In the south-western desert plains, frost can occur in any month of the year even when temperatures reach a daily maximum of up to 40 °C. Daily minimum temperatures in the Northern plains can be as low as -20 °C in winter and as high as +50 °C in summer at one and the same location.

The annual temperature ranges will impact climate specific supply cycles because of Afghanistan's very warm summers and cold winters (Fig. 1-5 and 1-6, respectively). The temperatures in Afghanistan vary widely due to the variability in topography. Altitude has a dramatic effect on temperatures. Air temperatures decrease as elevation increases as a function of the environmental lapse rate, which averages about 6.5 °C per 1,000 m of elevation. With much of Afghanistan dominated by the Hindu Kush Mountains, altitude must be considered carefully. With peaks exceeding 5,000 m, these mountains have temperatures that may vary by 10 to 20 degrees Celsius over relatively short horizontal distances. Such variability in temperatures makes it very difficult to characterize broad regions as having uniform climate types.



Source: united Nations 2001

Fig. 1-5 Afghanistan’s summer temperature extremes



Source: united Nations 2001

Fig. 1-6 Afghanistan’s winter temperature extremes

1.2.2 Precipitation

Precipitation regimes in Afghanistan are largely controlled by surface pressure changes and the effect of orographic precipitation. Winters are influenced by the Siberian high pressure system which spreads cold, dry continental air outward in all directions and pushes the subtropical jet stream south of the Himalayas. During this period prevailing winds are typically from the northwest or north. This results in the potential for storms from the western Mediterranean to track across Afghanistan every few days. As a result, the potential for precipitation is greatest in the winter and early spring and is often in the form of snow.

Afghanistan is essentially an arid country, with more than half of the area receiving 100 mm to 300 mm of precipitation. The remaining 50 % of the country (having altitude of more 2,000 m asl) receives 300 mm to 800 mm of precipitation. About 50 % of the precipitation occurs in winter (January to March), much of which falls in the form of snow. A further 30 % falls in spring (April to June) and the remaining 20 % during summer and autumn (Qureshi, 2002). Table 1-5, and 1-6 presents general features of six climatic zones, and the average records of precipitation, temperatures, and evapotranspiration respectively in different provinces of the country.

Table 1-5 General features of 6 climatic zones of Afghanistan

Zone	Name	Precipitation (mm)	Dry (months)	Frost (months)
1	Badakhshan(without wakhan)	300- 800	2-6	1-9
2	Central and Northern mountains	200- 600	2-9	0-8
3	Eastern and Southern mountains	100- 700	2-9	0-10
4	Wakan corridor and Pamir	< 100- 500	2-5	5-12
5	Turkistan plains	< 100- 400	5-8	0-2
6	Wester+ South-Western lowlands	<100- 300	6-12	0-3

Source: Qureshi, 2002

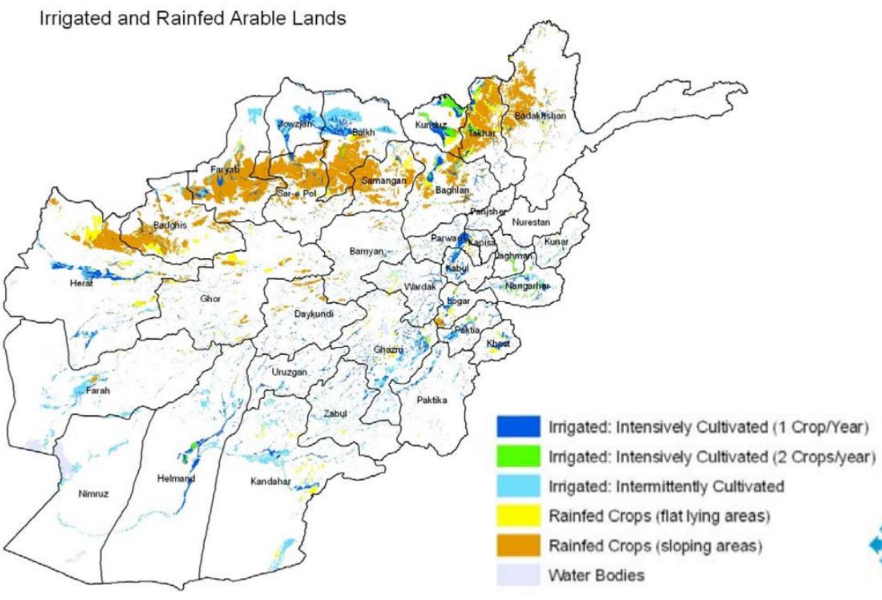
Table 1-6 Precipitation, temperatures and evapotranspiration at different locations of Afghanistan

Locations	Altitude (m asl)	Precipitation (mm/a)	Temperature (^{o}C)	Annual ETP (mm/a)	Daily ETP (mm/d)
Shiberghan	360	214	-2-+38	1,420	8
Mazar-i-shar	378	190	-2-+39	1,530	9
Kunduz	433	349	-2-+39	1,390	8
Baghlan	510	271	-2-+37	1,100	6
Jalalabad	580	171	-3-41	1,350	7
Farah	660	77	0-+42	1,610	8
Lashkargha	780	89	0-+42	1,720	8
Maimana	815	372	-2-+35	1,310	7
Herat	964	241	-3-+36	1,720	10
Qandahar	1,010	158	0-+40	1,790	8
Khost	1,146	448	-1-+35	1,390	6
Faizabad	1,200	521	-5-+35	1,020	6
Qadis	1,280	323	-3-+30	1,240	6
Jabul-saraj	1,630	499	0-+31	1,610	9
Kabul	1,791	303	-7-+31	1,280	7
Karizmir	1,905	433	-7-+31	1,100	6
Ghalmin	2,070	222	-8-+29	1,100	6
Ghazni	2,183	292	-11-+31	1,420	7
Lal- sarjanga	2,800	282	-21-+25	950	5

1.3 Agriculture

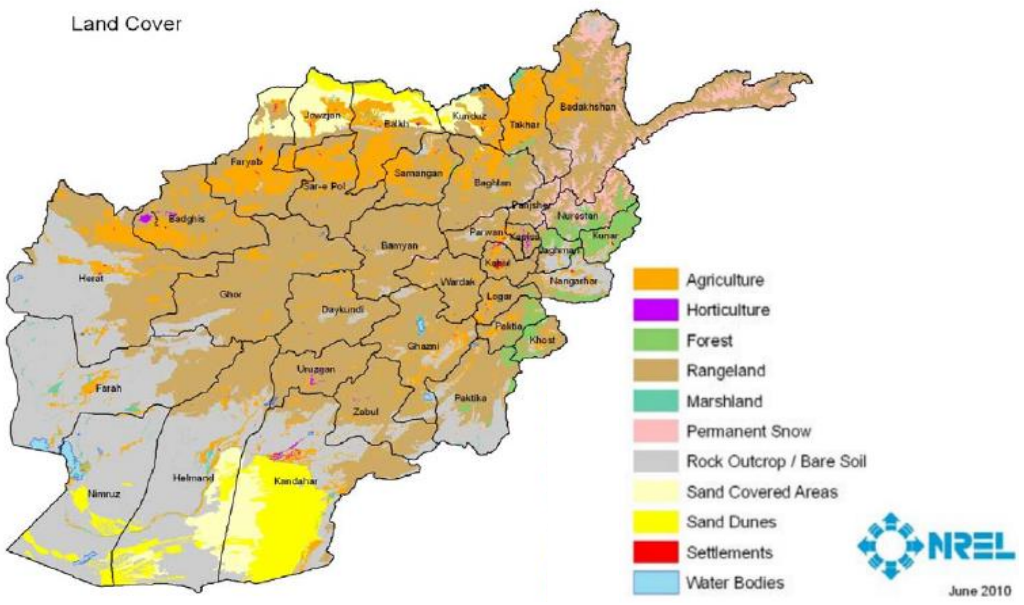
The arable agricultural resource base of Afghanistan is about 8 million ha, which is 12% of the total land area. Major arable lands for permanent crops are located in the north and western parts of the country. The irrigated land is usually located in the river basins of the north, west and the southwest. There are roughly 3.9 million ha of cultivated land of which 1.3 million ha is rain- fed and 2.6 million ha is irrigated, but the yield on irrigated lands is almost three times higher than that on rain-fed lands: 2.95 t/ha compared to 1.18 t/ha in years with good rainfall, Fig. 1-7 (MAIL, 2009). The irrigated area produces almost 85 % of all agricultural productions. In 1978, the total area (irrigated and rain-fed) under cereal crops was about 3.4 million ha. Afghanistan grew about 95 % of its needs in wheat and rye, and more than met its needs in rice, potatoes, pulses, nuts, and seeds, it depended on imports only for some wheat, sugar, and edible fats and oils. Fruit, both fresh and preserved (with bread), is a staple food for many Afghans. Agricultural production, however, is a fraction of its potential. Agricultural production is constrained by an almost total dependence on erratic winter snows and spring rains for water, irrigation is primitive. Relatively little use is made of machines, chemical fertilizer, or pesticides.

The variety of the country's crops corresponds to its topography. The areas around Kandahar, Herat, and the broad Kabul plain yield fruits of many kinds. Corn is grown extensively in Paktia and Nangarhar provinces, and rice mainly in Kunduz, Baghlan, and Laghman provinces. Wheat forms the staple food source (used in bread) and hence cultivated in many regions both through rain fed and irrigated making up to 80% of all grain production. Total wheat production in 2013-14 was estimated at 5.17 million tons, Following wheat, the most important crops in 2013-14 were barley (514,000 t) maize (312,000 t), rice (512,094 t), potatoes (302,980 t), sugar beet (14,765 t), sugar cane (89,880 t) (ASY, 2013-14) and Nuts and fruit, including pistachios, almonds, grapes, melons, apricots, cherries, figs, mulberries, and pomegranates are among Afghanistan's most important exports. A wide variety of vegetables including onions and potatoes are cultivated both for subsistence and as commercial crops. Potatoes are particularly significant in the Bamiyan, Maidan and Jalalabad regions (UNEP, 2003). The economy of the country is based on agricultural production and livestock. The agriculture sector contributes up to 50 % of the GDP depending on the weather (FAO/WFP, 2004, Levin, 2009). Afghan farmers use centuries old farming techniques with oxen providing the drought power. The majority of women in Afghanistan work in agriculture. They constitute a large portion of the agricultural labor force. Estimates indicate that they account for over 70 % of the labor. Tragically, several decades of war, lack of governance and drought have depressed the agricultural activities in Afghanistan and contributed to the degradation of natural resources. Fig. 1-8 is shown land cover of Afghanistan (NEPA-UNEP, 2009).



Source: AIME

Fig. 1-7 Irrigated and rain-fed arable lands



Source: AIME

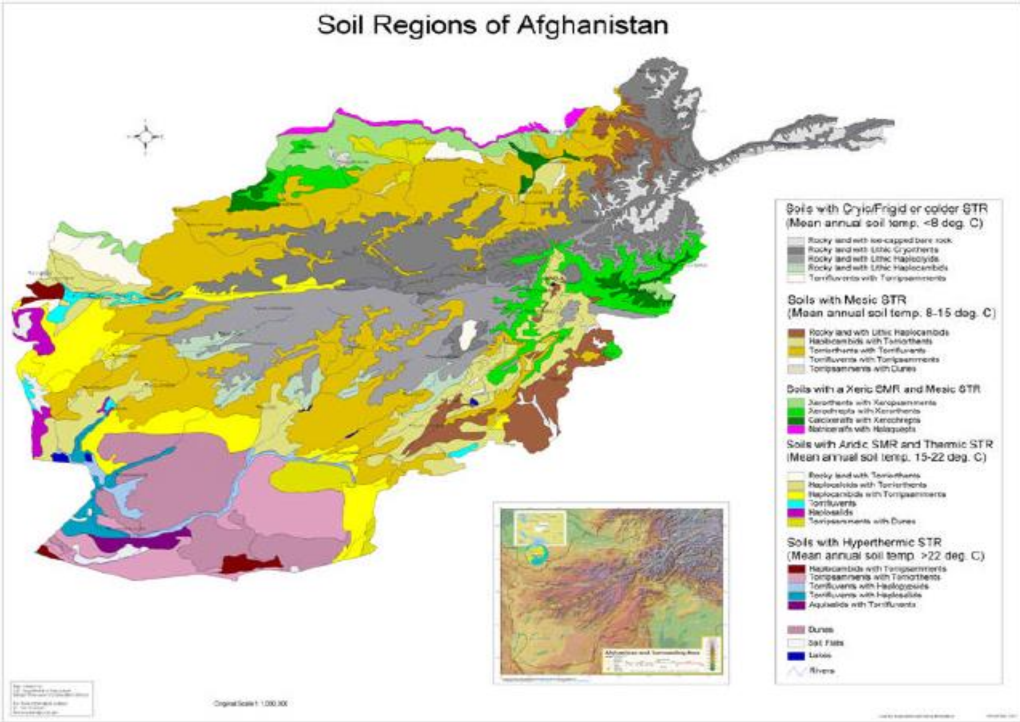
Fig. 1-8 Afghanistan land cover

1.4 Soil

Afghanistan's soils are formed under arid and semi- arid climatic conditions. They are significantly characterized as zonal soils and put in the great soil groups such as desert soils (grey desert soil, red desert soils), sierozem reddish brown soils and brown soils. Some other great soil groups under the orders of A zonal and inter a zonal are comprised of regosols, lithosols, alluvial solonchak and solonetz soils. These soils are mainly have unstable structure and more porous than alluvial soils with low water holding capacity and permeability. Infiltration rate are high due to coarse texture, and limited content of organic matter (Salem, MZ, and Hole, E.D., 1969). Fig.1-9 is shows soil region of Afghanistan.

The most important physical characteristics of these soils under arid and semi- arid regions are: structure, soil- water, temperature, aeration, infiltration rate, permeability, density, and pore-size distribution. There is a wide range of variation regarding physical properties of these soils in the country. Due to the limited amount of precipitation, especially on the alluvial deposits in arid regions of Afghanistan, the soils owe their distinctive character to the fact that they contain excessive amounts of either soluble salts or exchangeable sodium or both. For agricultural purposes such soils are regarded as problem soils which require special management practices.

In general, organic matter content even in the alluvial deposits is not higher than 2.5%, while the organic content in sandy soils is less than 0.2%. It has been recognized that organic matter and clay fractions are both responsible for the major portion of soil aggregation. Organic matter also has an effective influence on the release of macro nutrients which make them more available to the plant use. Soil reaction is one of the most important factors which affects the uptake of plant nutrients in a large extent. The pH of the soils, except in forest areas is generally higher than 7. Soil reaction is dependent upon the composition of exchangeable cations, the nature of the cation exchange materials, and the composition and concentration of soluble salts in the soils. Soils having pH greater than 8.5 indicate an exchangeable sodium percentage of 25 or more. In Afghanistan where annual precipitation is limited, and more than half area of the country receives from100 -300 mm, organic matter content is very rare in the desert soils, lithosols, and regosols, but in the sierozems, brown and alluvial soils, the organic matter content is present up to 2.5%. All these beneficial effects on soil aggregation stability, formation of the clay particles and release of micro-elements are originated from the integrated activity of soil micro-organisms, decomposition of organic matter and other related factors (FAO, 1993).

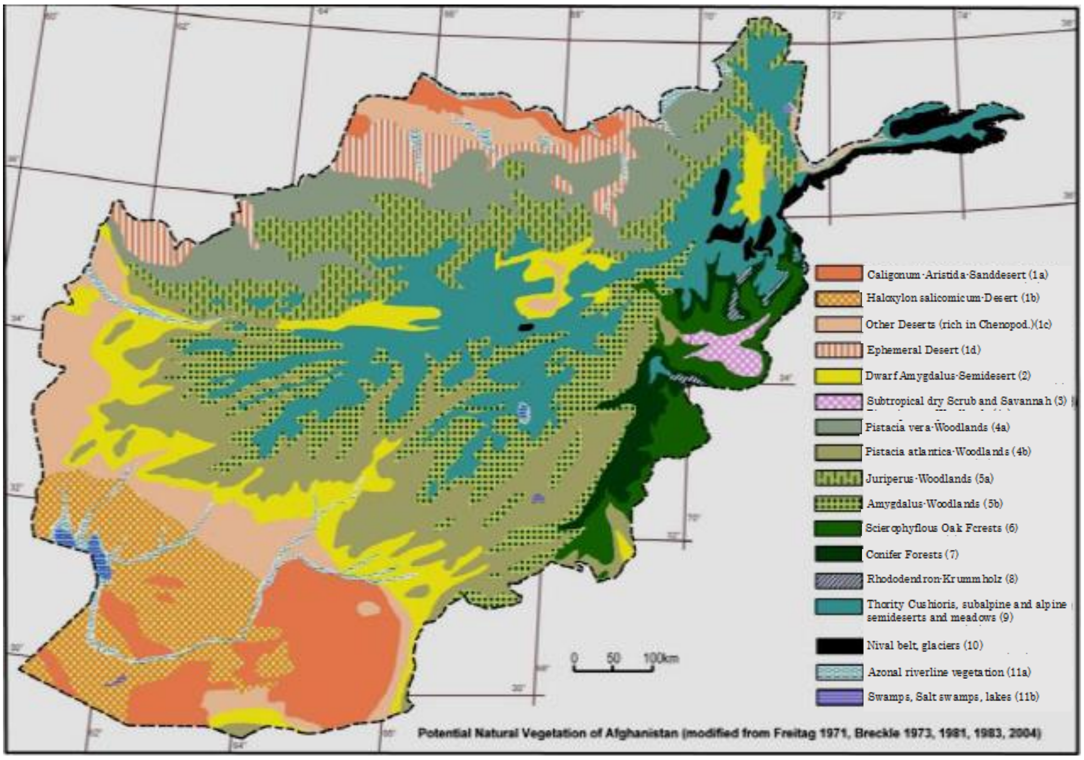


Source: NRCS

Fig. 1-9 Soil regions of Afghanistan

1.5 Vegetation

The plant cover of Afghanistan has been influenced highly by diverse ecological conditions, ranging from barren deserts (sand dune areas), to sub-tropical regions to steppes (the most important grazing areas), to the river valleys (areas of vegetation and cultivated fruit orchards), to the higher mountains including areas of semi desert (Nancy, 1991). Thus, the precipitation and altitude are the main factors resulting in the diversity of the country's flora. A limited part in the south east which belong to the sub-tropical zone, receive the impact of the Indian monsoons (Breckle, 2007). The diver's ecological conditions in Afghanistan have favored the establishment of a complex and varied floral compositions. Groombridge (1992) gives an estimate of 3,500 species of vascular plants and 30-35 % of endemic. Due to the last three decades of war condition coupled with a six year long drought the agriculture sector in Afghanistan has been greatly damaged and that way its productivity have decreased by 50 % (Pir.M.Azizi, 2002). To compensate for this loss, rural people have started to utilize the free natural resources. Smuggling of timber deliberate burning of forests, overgrazing, cutting of woodland, uprooting of medicinal plants and conversion of rangeland to rain-fed cropping has become the daily business of the people. This is an excessive removal or extermination of some indigenous species or endemic to Afghanistan. The coniferous and Oak forest which covered 1.3 million (FGP, 1971) and 450,000 ha of land (UNCCD, 2006) has decreased by between 50 % and 50-70 % respectively (UNEP, 2002). Vegetation of deserts, steppes and mountainous areas, covering 70 % of the total land area have decreased by 45 % (UNCCD, 2006) because of extraordinarily strong exploitation. If the situation continues in the same way, Afghanistan will lose some of its valuable wild plant genetic resources in the near future (Naseri, 2003). In their natural habitat even now the following plant species are endangered: Pistacia vera, Pinus gerardiana, Cedrus deodara, Taxus baccata, Glycyrrhiza globra, Ferula asafetida, Carum carviet. Prior to the war some of these wild tree species such as pistacia vera and Pinus gerardiana stands were consciously protected because their seeds were used by the local people and even exported in remarkable quantities Fig. 1-10 shows vegetation of Afghanistan.



Source: ag- afghanistan.de

Fig. 1-10 Vegetation map of Afghanistan

1.6 Drought

Many parts of Afghanistan with the exception of northeastern highlands are facing frequent droughts (Kamal, B.et.al, 2004). Drought which occurred previously had affect only to some part of the country and had lasted for only maximum period of 2 years. But the current drought has so far continued for 3 to 4 years. This has affected rural and urban areas of Afghanistan, except for few places located in the valley along the perennial rivers. The droughts recorded so far in the country can be categorized as:

1- Local drought in small parts of the country; occurring each 3 to 5 years.
2- Regional (zonal) drought occurring each 9 to 11 years.
3- Countrywide droughts occurring each 20 to 30 years.

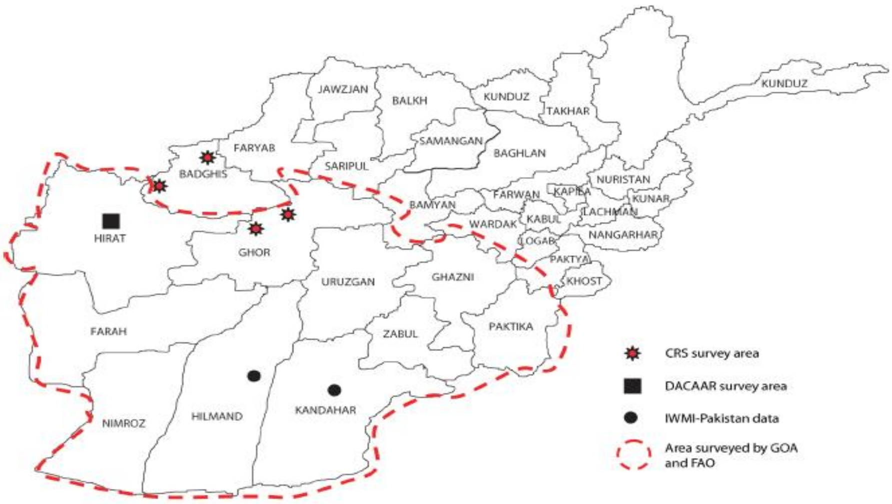
Preliminary estimates suggest that the current drought has imposed negative impacts on the at least half of the population (Beurs .K. M., 2008, Alim, A. k. et al, 2010). 3 to 4 million people are affected several, 8-12 million are under threat of famine and starvation. An estimated 700,000 people abandoned their houses in search of food, water and fodder (pasture), around 300,000 have fled to neighboring countries and more than 400,000 people (IDPs) have moved to the closes and safest places.

All valleys and low land plains with an altitude lower than 2,000 m asl except for the valley of main rivers crossing the area, which consist most of the rain fed lands are seriously affected by the drought. According the reports from the field, all ephemeral rivers dried out in early spring and perennial rivers in early or mid-summer.

During the recent drought water level in the existing reservoirs of the country has reached to the critical and even some of them have dried completely. The effect of drought surface water resources and groundwater resources is also noticeable. As per an estimate, all traditional irrigation system have reduced or dried up completely. 60-

70 % of Karez are not currently in use and 85 % of the shallow wells were dried out. The main reason for low discharge or failure is the low groundwater recharge. In addition to this, digging of deep wells close to karez and shallow wells imposed adverse effects on the discharge of these traditional irrigation systems (WFP, 2003. Keshawarz, 2002).

Many fruit trees and vineyards have died. Yield reductions of up to 75–100 % of the normal harvest have been recorded in these areas. In many areas, people are facing shortages of safe potable water due to the decrease of water in the underground aquifers, and part of country which effected drought are shown in Fig. 1-11 (Akhtar. M., 2004, Grace. J., Pain. A., 2004). Livestock numbers have been greatly reduced over the last few years due to continuous drought, while animal birth rates have also gone down due to poor-quality pasturelands (Anonymous, 2004).



Source Alim 2002

Fig. 1-11 Drought effect area surveyed by different organization

1.7 Objectives

1.7.1 Overall objectives of this dissertation

Shortage of water can be defined as the losses of agricultural productivities through various processes, such as high evapotranspiration rate, high on-farm distribution losses, high run-off, over irrigation, poorly leveled land, and deep percolation, low knowledge of farmers about crop water requirement, and lack of agro-meteorological data. The objectives of this research entitled as “Study on effective utilization of irrigation water in Afghanistan” are:

(1)To improve irrigation water use efficiency, through estimating pan evaporation in Kabul Afghanistan.

(2)To estimating optimum irrigation discharge under furrow irrigation in Afghanistan.

(3)To discuss mulching system for conserving irrigation water.

1.7.2 Objective of each chapter

In order to achieve the overall objectives and to make clear the following research structure were formulated as shown in Fig. 1-12 and carried out.

Chapter 1 dealt general situation of Afghanistan like irrigation water problems, topography, agro ecological zone, climate, agriculture, soil, and vegetation expressed as a background. Topography of the country varies from high mountain to low desert, with different agro-ecological zones, as well as altitude temperature which varies from season to season and from day to night, and the half of the country receiving 100 mm to 300 mm precipitation per year, therefore, agricultural productivities is very low. The main problems in Afghanistan are explained in background statement.

Chapter 2 dealt in present condition of irrigated agriculture in Afghanistan. Most of the crops in Afghanistan are growing under irrigation. The irrigation system in Afghanistan are traditional and it is very poor condition at present with low efficiency. The rivers regime in Afghanistan depend on annual rain and snow melt in highland above 2,000 m in elevation, at present surface flow at those rivers have been reduced compared with normal year. Lowland in desert part of the country faced shortage of water. Due to the war, canal management system has been collapsed, and 0.68million ha of on farm water management is required to be improved. The canals over there are completely silted, breached, and they are not functioning as the past. About 46 % of the irrigation structures are damaged and 88 % of the irrigation structures are traditional which are responsible for 40 % of the total water losses. The meteorological and hydrological stations were the main source of data .However, all these stations have been completely destroyed during the year of war and conflict. Although Afghanistan has limited water resources, and due to last drought ground water discharge decreased, and drop in the groundwater table, most kareze and shallow well dried. Farmers are ignorant on actual crop water requirements, and over- irrigation of crop is a common practice. Overall efficiency is only about 25-30 %.

Chapter 3 had focused on meteorological properties to estimate evaporation in Kabul Afghanistan. Pan evaporation was measured daily and the data was used to estimate crop evapotranspiration and estimate water requirement of crops. Pan evaporation can be estimated easily, so that evapotranspiration of the crops (ETcrop) could be estimated for irrigation scheduling of crops. In this study Penman model was adapted to estimate evaporation, by comparing the data obtained from pan evaporation and observed evaporation with a pan, and other meteorological parameters, such as air temperature, relative humidity, sunshine hours and wind speed.

The objective of this chapter was to explain meteorological properties and to develop an applicable method for estimating pan evaporation in Afghanistan.

Chapter 4 deal with estimating irrigation discharge under furrow irrigation in Afghanistan. From the viewpoint of optimum application efficiency in furrow irrigation system in Afghanistan, farmer's irrigation discharge were analyzed and compared with simulated irrigation discharge. For confirmation, an experiment was conducted at Badam Bagh agriculture research station in Kabul, Afghanistan, and the area is semi-arid with average annual rainfall of 350 mm. The furrow was 40 m long with 0.7 m bed width, furrow surface width 0.7m and furrow depth 0.3 m respectively, and the furrow slope was 0.02 % along the direction of irrigation. The farmer's irrigation discharge was measured, advance times were measured at each 5 m distance along the furrow in order to estimate intake coefficients and cumulative infiltration amount. Tomato crop water requirement calculated by FAO CROPWAT program No.8.0. After the result of irrigation calculate and found the irrigation water application efficiency. To find the optimum irrigation efficiency compared with less and more than actual water discharge.

Chapter 5 had focused on effect of different colors of mulching material (plastic film) which were inferred to influence soil temperature, soil moisture and yield of tomatoes, because climate of arable land in Afghanistan is characterized by arid to semi-arid, and the half of the country receiving 100 mm to 300 mm precipitation per year, and air temperatures daily 20- 30 °C.

The experiment adapted from May to October in Kabul Afghanistan. The treatment were black, red, white colors plastic mulch and bare soil. Soil texture was measured by triangle classification of international society of soil science, additionally, soil pH was measured. The experiment design was a randomized complete block with three replication, the experiment plot was consisted of 27 m-long, 0.7 m wide and 0.15 m high raised bed. By thermometer during the growing season soil temperature measured 0.7 m depth, as well as reflected light from each surface color mulch was determined using a pyranometer. Fruits were harvested each week and size were recorded, finally data were analyzed statistically.

Chapter 6 summarizes the outcome from each chapter stating the overall conclusions in this research entitled "Study on effective utilization of irrigation water in Afghanistan".

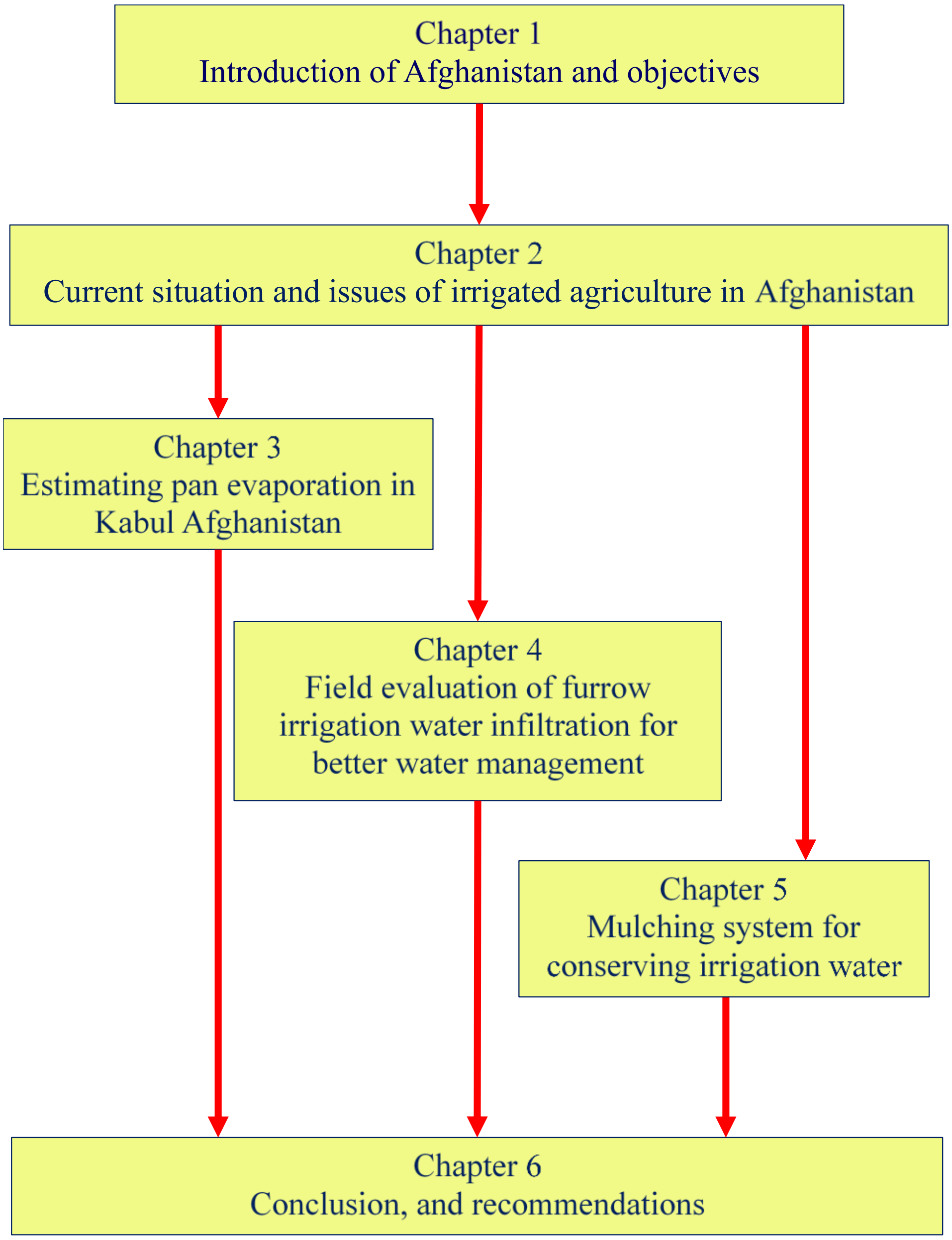


Fig. 1-12 Research structure of this dissertation

Reference of this chapter

ADB 2003 Rebuilding Agricultural Sector. South Asia Department, pp.14-25.

Adil, A. W. 2001. The Integration of Biodiversity into National Environmental Assessment Procedure: National Case Study on Afghanistan. Prepared for the Biodiversity Planning Support Program in collaboration with GEF, UNDP, UNEP, and World Bank.

Afghanistan perspective 2012 An orientation guide, technology integration division

Akhtar, M, Qureshi, A. S.; 2004. Drought coping in Helmand and Khandahar provinces of Afghanistan. Internal report. (Duplicated).

Alim, A.K., Shobair, S.S., 2010. Drought and Human Suffering in Afghanistan. SAARC Workshop on Drought Risk Management in South Asia, 8-9 August, 2010, Kabul Afghanistan. pp 44-49

Anonymous. 2004. Emergency drought assessment in 12 vulnerable southern provinces. Internal Report. Kabul, Afghanistan, Ministry of Irrigation, Water Resources and Environment.

ASY, 2013-2014 Afghanistan statistical year book

Azizi,Pir M. 2002. ”Special lecture on water resources in Afghanistan” Ministry of Irrigation, Water Resources and Environment, Kabul, Afghanistan

Beurs,K.M., and Henerbry,G.M. 2008. War, drought and phenology: changes in the land surface phenology of Afghanistan since 1982.vol.3, No.2-3:95-111

Breckle. W.S. 2007. Flora and Vegetation of Afghanistan. Basic and Applied Dryland Research 1, no.2:155-194

FAO.2006. Food and Agriculture Organization of the United Nations, Afghanistan

FAO/WFP. 2004. Special report crop and food supply assessment mission to Afghanistan. FAO global information and early warning system on food and agriculture world food program.

FAO, 1973. Noori, Dost M., and Afghanistan Kabul. Sandy soils: report of the FAO/UNDP Seminar on Reclamation and Management of Sandy Soils in the Near East and North Africa, Nicosia.

FAO, 2006. Country Pasture/ Forage Resource profile Afghanistan.by Olaf, T. pp5-9

Geography and Environmental Engineering Department, 2001. Afghanistan a regional geography, faculty of the geography program. United States military academy west point, New York.

Grace, J.; Pain, A. 2004. Rethinking rural livelihoods in Afghanistan. Issue paper series of Afghanistan Research and Evaluation Unit (AREU). Kabul.

Groombridge.B 1992 Global Biodiversity Status of the Earth’s living resources.

ICARDA 2002. Needs Assessment on Soil and Water in Afghanistan, Future harvest consortium to rebuild agriculture in Afghanistan.

ICARDA, 2003. Needs Assessment on Horticulture in Afghanistan. Future Harvest Consortium to Rebuild Agriculture in Afghanistan.

Kamal. B.; Azizi, P. M.; Shobair, S. S.; Mohsini, M. Y. 2004. Drought impacts and potential for their mitigation in southern and western Afghanistan, Working Paper 91. Colombo, Sri Lanka: International Water Management Institute.

Keshawarz. M. S. 2002 Rapid Assessment of water sector-Afghanistan. Chairman Department of Civil and engineering University of Hartford West Hartford, CT 06117 USA. pp 1-13.

MAIL (Ministry of Agriculture, Irrigation and Livestock) 2009. "Agriculture Prospects Report," Kabul, Afghanistan.

Mail, FAAHM, FAO 2003. Agriculture and food production in post ware Afghanistan.

Maletta.H.E, 2004. Food and agriculture in Afghanistan: along term outlook, PP1-9.

Meredith, L, .Runion, .2007.The history of Afghanistan, Encyclopedia of the Nation.

Nancy (1991). Opportunity for Improved environmental Management in Afghanistan. Switzerland.

Naseri, Gh, N. 2003. Natural Woodland and Forest of Afghanistan. Kabul, Afghanistan development, OMB No: 0704-0188.

Qureshi. A. S. 2002. Water resources management in Afghanistan; the issues and options.

Salem, M.Z. and Hole, E.D. 1969, Soil Geography and Factors of Soil Formation in Afghanistan. Soil Science, Vol. 107, No.4.

Thakkar H, 1999. Contribution of Large Dams in food production, Food security in India.

UNCCD.2006.United nation’s convention to combat desertification.

UNEP, 2003. Post-Conflict Environmental Assessment Afghanistan, pp.19-25.

UNEP.2003 Afghanistan Post – Conflict Environmental Assessment, United Nations Environment Programmed, 2003, pp.1- 9.

UNEP.2009 In Afghanistan

UNEP 2002. Afghanistan’s environmental recovery a post-conflict plan for people and their natural resources.

Wegerich K, 2009. Water strategy Meets Local Reality Published by Afghanistan Research and Evaluation Unit (AREU): pp. 1-25.

WFP (World Food Program). 2003. Afghanistan countrywide food needs assessment of rural and settled populations. Kabul, Afghanistan: World Food Program.

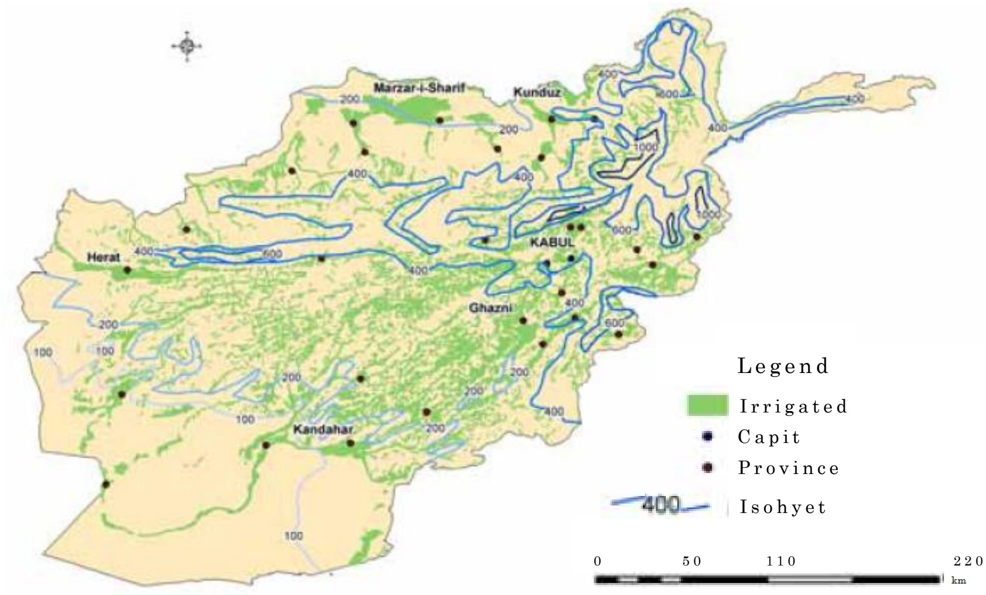
Chapter 2

Current situation and issues of irrigated agriculture in Afghanistan

2.1 Introduction

2.1.1 Background

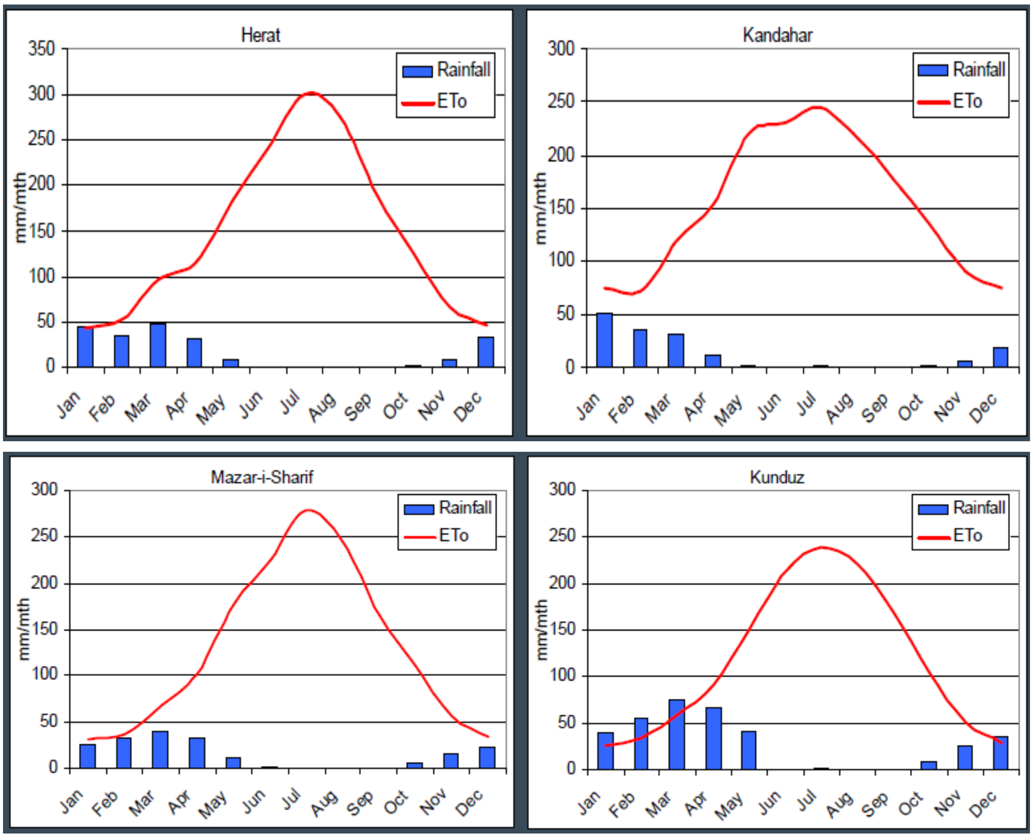
Afghanistan has a mainly dry continental climate and 90 % of the country's annual precipitation occurs during the winter months between December and April, The quantity, timing and distribution of precipitation are key factors in determining water availability for irrigation (Vincent W.Uhi et al, 2003, Olaf. T., 2006). Over 80 % of precipitation occurs as snow during winter in areas where elevation is greater than 2,500 m above sea level. While annual precipitation exceeds 1,000 mm in the upper mountains of the northwest, it is less than 400 mm over 75 % of the country and virtually all of the cultivable lands. The timing and duration of snowmelt is a key factor in determining the quantity and duration of water availability in streams and rivers for irrigation in lower valleys. Fig. 2-1 shows the distribution of irrigated lands and rainfall isohyets in Afghanistan. During the main growing period in the late spring and summer (May to September), a gap exists between the amount of rainfall and the demand for water, resulting in a dependence on irrigation to meet the majority of crop water requirements (Bob Rout, 2008).



Source: A typology of irrigation system in Afghanistan

Fig. 2-1 Distribution of irrigated lands and rainfall isohyets

This is illustrated in Fig. 2-2, which shows the average monthly rainfall and potential evapotranspiration at different locations with large irrigated areas like Herat, Kandahar, Kunduz and Mazar-i-Sharif. In the summer, irrigation demand peaks at about 250 mm to 300 mm per month while there is little, if any, reliable rainfall.



Source: Favre and Kamal, Watershed Atlas of Afghanistan

Fig. 2-2 Rainfall and Potential evapotranspiration (monthly values)

2.2 Water resources of Afghanistan

Although Afghanistan is located in half desert area, it is still rich in water resources mainly due to the series of high mountains such as Wakhan, Hindukush, and Baba. In the winter season, the Hindu Kush stores water in the form of snow. At the beginning of spring, snow starts melting. Usually snow melt start to melt at the beginning of April, and gradually increased during summer (May-Jun) and then gradually decreased in autumn (Sep-Nov). The snow melt belong to weather condition (Qureshi, 2002).

According to the Aini. A. 2007.and Matthew king .et.al 2010. The main surface water resources of Afghanistan are divided into the following five river basins:

1. The Amu Darya river basin in the north of the country flowing from east to west.
2. The North flowing river basin that either disappear inside or outside of the country.
3. The Hari- Rud river basin flowing toward the west, then north and entering Turkmenistan.
4. The Helmand river basin flowing toward the south-west and ponds in Hamun-i-Sabiri.
5. The Kabul river basin flowing toward the east and joining the Indus River in Pakistan, Fig. 2-3.

1. Amu Darya river basin:

The Amu Darya River, also called the Oxus in Afghanistan, originates in the Afghanistan part of the Pamir River formerly called the Abi-Panja, it form over 1100 km of Afghanistan's northern border with Tajikistan and Turkmenistan. Two main tributaries drain Afghanistan, the Kunduz River (and its tributary the Khanabad) and the Kokcha River, both originate in northeastern Hindu Kush. The rivers are perennial with substantial flow snowmelt in the months. These two rivers basins, and the upper drainage are of the Amu Darya, cover 14% of Afghanistan or about 91,000km^2.

2. Northern flowing rivers:

These Rivers originate from on the northern slope of the Hundu Kush and flow northwards towards the Amu Darya River. Most of these rivers die out of Turkistan plains before reaching the Amu Darya. From west to east, the main rivers include the Shirin Tagab, the Sarepul, the Balkh and the Khulm rivers. These rivers basin cover 12% of Afghanistan, or about 75,000km^2.

3. Hari-Rod and Murghab river basins:

The Hari- Rod River, which has drainage area of about 40,000 km^2, or 6 % of Herat and into the Islamic Republic of Iran. At the Iranian border, the river turns northwards and eventually empties into to Tejen Oasis in Turkmenistan. Because of the narrow and elongated configuration of this river basin, the Hari- Rod doesn't have significant tributaries. Another river, the Murghab River, with drainage area 40,000 km^2, or 6 % of the area of Afghanistan, also dies out in Turkmenistan.

4. Helmand river basin and western flowing rivers:

The Helmand basin is the largest in Afghanistan. The 1,300 km long Helmand River rises out of the central Hindu Kush Mountains, close to the headwaters of the Kabul Rivers. The rivers flow in the south westerly direction, then westwards to its terminus in the Sistan marsh or depression along the border with the Islamic Republic Iran. The Helmand river flow in mostly supplied by the upper catchment areas that receive snowfall in the winter months. The rivers flow in mostly supplied by the upper catchment areas that receive snowfall in the winter months. The river and its tributaries, such as the Arghandab and Ghazni rivers, drain about 29 % of Afghanistan's area or about 190,000km^2.the Adraskan or Harut- Rod the Farah Rod and Khask Rod rivers also drain into the Sistan marsh. These rivers drain the southwestern part of Afghanistan. Which is 80,000km^2 or 12 % of Afghanistan's area.

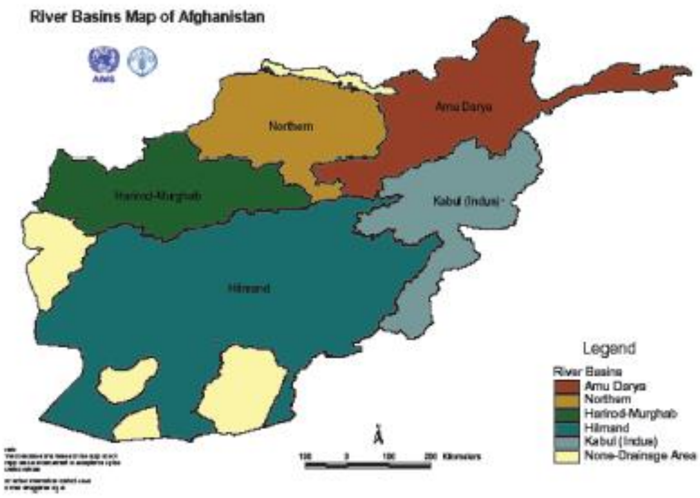
5. Kabul River basin:

The Kabul River originates in the central region of the Hindu Kush, about 100 km west of Kabul, and has a drainage area of 54,000km^2 in Afghanistan. It flows eastward through Kabul and, after entering Pakistan, joins the Indus river east of Peshawar. Its main tributaries include the logar, Panjsher (with its own major tributary the Ghorband), Loghman- Alingar and Kunar rivers Table.2-1 explain river basins of Afghanistan. Most of the these rivers are perennial with peak flow during the spring months as their drainage area encompasses the snow- covered central and northeastern parts of the Hindu Kush . The Kabul River is the only river in Afghanistan that is a tributary to another river system, the Indus River, which reaches the Indian Ocean. Other minor Indus tributaries, with a combined drainage area of 18,600 km^2, drain southeastern Afghanistan and all eastwards into Pakistan and eventually join the Indus River. The Kabul River, and tributaries of Indus together drain 11 % of

Afghanistan.

Present status of water resources, obviously, extended drought has not only caused the reduction of the surface water but severely diminished the capacity of ground water, too (ADB, 2005). The later reduction is manifested in drastic drop of the level of underground water, particularly in the south and south-west of the country where drought is more severe than any other parts. As a result, many Karezes (underground tunnel) and springs are either dried- up or produce minimum quantity of water.at present surface flow at different rivers all over the country is reduced from 40 % to 65 % of the normal year capacity (WHO, 2004, Azizi, 2002). The present status of fresh water flow in the main river basins is shown in Table 2-2, and indicated that there is an over 50 % reduction of fresh water at the country level.

The river regimes in Afghanistan depend on annual rain and snow melt in highland above 2,000 m in elevation and represented 80 % of Afghan water resources (excluding ground water) of the country. The annual water received from snowmelt in highland is estimated to be 150,000 million m^3 and the rest of the country received only 30,000 million m^3 through rainfall results a total of 180,000 million m^3 for the whole country. Out of total runoff in Afghanistan, only 15 % contributes to recharge ground water in the country. The total annual discharge of the river basins is 84,000 million m^3 (47 %) of the total precipitation in the country. details is shown in Table 2-3.



Source: AIMS

Fig. 2-3 River Basins in Afghanistan

Table 2-1 River basins in Afghanistan

River Basin	Mean annual volume(million m^3)	Drainage area(km^2)
AmuDarya basin	41,000	53,030
Desert basin	328,000	9,300
Kabul river basin	73,000	21,670
Total	442,000	84,000

Source: Qureshi2002

Table 2-2 Main river basin and estimated mean annual volume (million m^3)

River basin	Area (%)	Water (%)	Rivers
Amu Darya	14	57	Amu Darya, Panj, Wakhn, Kunduz, Kokcha
HariRod –Murghab	12	4	Hari Rod, Murghab, Koshk
Helmand	41	11	Helmand, Arghandab, Tarnak, Ghazni, Farah,Khash
Kabul (Indus)	11	26	Kabul, Konar, Panjshir, Ghorband, Alinigar,Logar
Northern	11	2	Balkh, Sar-i-Pul, Khulm
non-drainage area	10		

Source: Qureshi2002

Table 2-3 Annual discharge of each river basin in Afghanistan

River Basin	River name	River regime	Discharge in million m^3	Percentage of total
Amu Darya	Abi- Panja	Snow/glacier-fed	36,420	43
	Kokcha	Snow/glacier-fed	5,700	7
	Kunduz	Rain/ Snow-fed	6,000	7
Total Amu Darya			48,120	57
Kabul/ Indus	Gomal	Rain/ Snow-fed	350	
	Margo, Shamal, khuram	Rain/ Snow-fed	400	
	Panjshir	Rain/ Snow-fed	3,130	4
	Kunar	Snow/glacier-fed	5,250	18
	Kabul, itself	Rain/ Snow-fed	2,520	3
Total Kabul/ Indus			21,650	26
Nortern Rivers	Khulm	Rain/ Snow-fed	60	
	Balkhab	Rain/ Snow-fed	1,650	2
	Abi-i-Safid	Rain/ Snow-fed	40	
	Shirin Tagab	Rain/ Snow-fed	100	
	Amu Darya desert	Rain/ Snow-fed	30	
Ttal Northern			1,880	2
Helmand	Farah Rod	Rain/ Snow-fed	1,250	1
	Adraskan Rod	Rain/ Snow-fed	210	
	Khuspas Rod	Rain/ Snow-fed	40	
	Khash Rod	Rain/ Snow-fed	170	
	Kaj Rod	Rain/ Snow-fed	60	
	Ghazni rod	Rain/ Snow-fed	350	
	Helmand at Kajaki DAM	Rain/ Snow-fed	6,000	7
	Musa, Qala Rod	Rain/ Snow-fed	220	
	Arghandab	Rain/ Snow-fed	820	1
	Lower, Helmand	Rain/ Snow-fed	110	
	Southern	Rain/ Snow-fed	70	
Total Helmand			9,300	11
Har-i- Rod	Murghab	Rain/ Snow-fed	1,350	2
	Kashan and Kushk Rod	Rain/ Snow-fed	110	
	Har-i-Rod	Rain/ Snow-fed	1,600	2
Total Har-i-arod			3,060	4
Grand Total			84,010	100

Source: Watershed atlas of Afghanistan

2.3 ground water resources

Approximately 15 % of the total water volume used annually originates from Karezes, spring and shallow wells (locally called as Arhads). Alluvial groundwater aquifers, and springs, contributes almost 85 % from rivers and streams. Ground water used from deep wells accounts for less than 0.5 % (Favre and Kamal, 2004). Afghanistan's water resources are still largely underused which is supported by the data presented in Table 2-4.

Estimations of groundwater average annual recharge and usage within the five river basins are shown in Table 2-5. The total recharge for confined and unconfined aquifers is roughly 10.6 billion m^3 per year while usage is 2.8 billion m^3 per year.

Table 2-4 Estimate surface and groundwater Balance (billion m^3/year)

Water resources	Potential	Present use	Balance	Future use	Balance
Surface water	57	17	40	30	27
Ground water	18	3	15	5	13
Total	75	20	55	35	40

Table 2-5 Groundwater in Afghanistan (million m^3/year)

River Basin	Recharge	Usage
Kabul	1,920	530
Helmand	2,480	1,500
HariRod-Murghab	1,140	460
Northern	2,140	210
Amu Darya	2,970	100
Total	10.650	2,800

Source: Uhl, An Overview of Groundwater Resources and Challenges

In Afghanistan, groundwater has traditionally been developed and utilized for irrigation purposes. Afghanistan possesses huge reserves of groundwater. According to FAO 1996, estimates of the annual potential of the groundwater in the country is about 20 billion m^3/year (BCM). At present, only 3 BCM is being used. In more recent years, deep drilled wells have become a more common means of extraction for irrigation usage particularly in the Tarnak, Ghazni, Kabul and Logar river valleys.

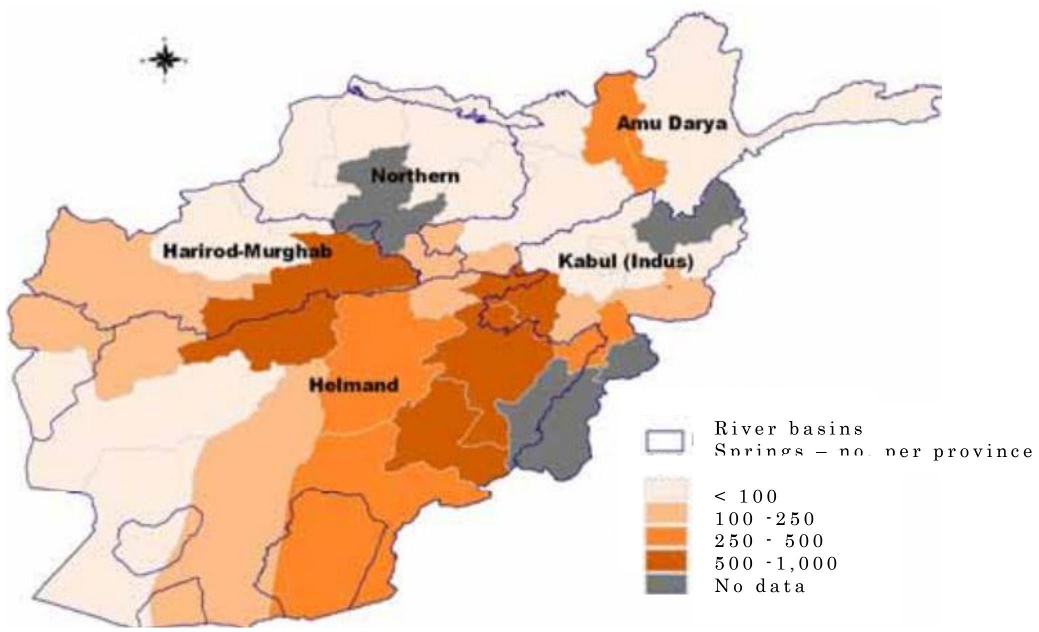
Karezes are underground systems, which tap groundwater by gravity from the aquifer to provide water for irrigating crops and domestic purposes. Ten top provinces of Afghanistan having highest percentage of area irrigated with groundwater irrigation are given in Table 2-6.

2.3.1 Shallow wells (arhad) system

Groundwater is lifted from large diameter shallow wells with the help of wheel (arhad) with animal power supplying irrigation water to the fields of an individual farmer. The size of the irrigated is used it land does not exceed 3 ha. The total number of shallow wells in Afghanistan is 6,598 that irrigate around 12,060 ha of land.

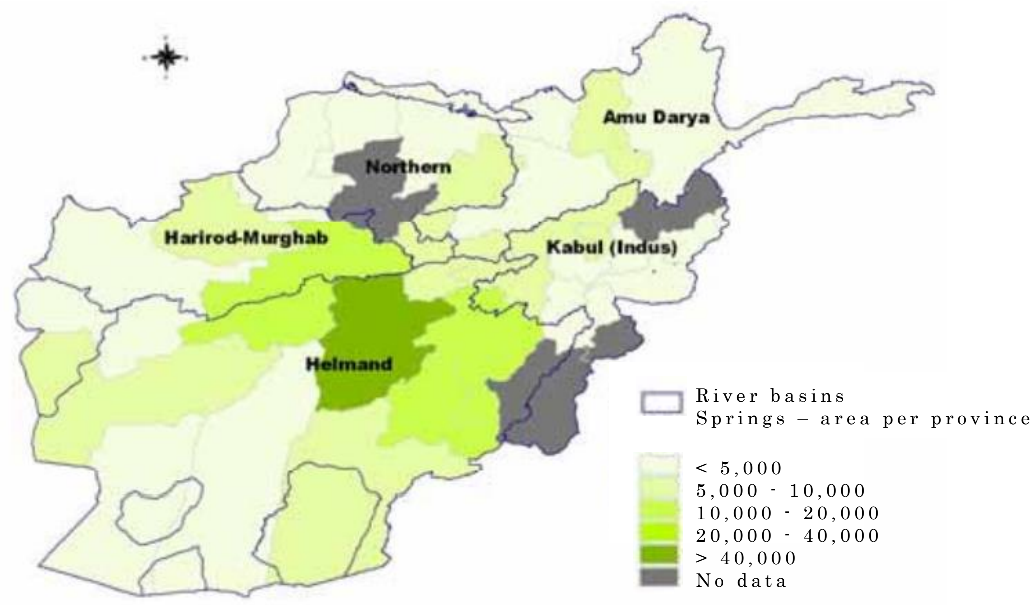
2.3.2 Springs

When groundwater table reaches above the ground surface, it starts flowing on the surface and form springs. Numerous rural communities depend on spring water for irrigation and other uses. For these communities, the spring is often the only perennial water supply and, therefore, essential to household and community sustainable. There are about 5,558 springs in the country, which irrigate about 188,000 ha of land. Irrigated area per spring averages roughly 30 ha but ranges up to more than 200 ha. The number of spring-fed irrigation systems and associated irrigated area per province is shown in Fig. 2-4 and Fig. 2-5. Springs are directly dependent upon the groundwater level. When the groundwater level goes down, e.g. during drought years, it results in a reduction of outflow from springs. That is why, some of the worst drought stricken areas of the country are located in region where they depend heavily on spring water for irrigation. Spring irrigation is common in the east and in the south (Keshawarz. M.S., 2002).



Source: Gov. of Afghanistan, 1980 statistical yearbook

Fig. 2-4 Number of spring- fed systems per province



Source: Government of Afghanistan, 1980 statistical yearbook

Fig. 2-5 Irrigated area of spring- fed systems per province

Table 2-6 Ten provinces with the highest percentage of irrigated area with groundwater

Name of the province	Area under ground water irrigation (ha)	Percentage of total area (%)
Uruzgan	3,910	58.2
Ghazni	43,170	36.7
Farah	36,890	29.3
Helmand	27,280	16.8
Zabul	24,870	39.8
Kandahar	21,870	18.5
Kabul	18,270	32.5
Ghor	16,940	23.3
Nangarhar	13,820	32.6
Badghis	13,050	39.2

Source: ICARDA, 2002

2.3.3 Karez (qanat) systems

Karezes are underground galleries that tap groundwater from the aquifers of alluvial fans. Underground tunnels with gentle slopes carry water from the source to the settled areas. Karezes are usually small in dimensions but may be many kilometers in length (Fig. 2-6). The technique has been used for thousands of years in Afghanistan, Iran, the Middle East and North Africa. It is one of the most economical methods of tapping groundwater for irrigation purposes. It is environmentally safe and water is drawn by use of gravity. On average, their discharge varies between 0.01 m^3/sec to 0.2 m^3/sec but in some cases can reach up to 0.5 m^3/sec. Karez water is used for irrigation purposes, irrigated area ranges from 10 ha to 200 ha. As well as for drinking water supply.

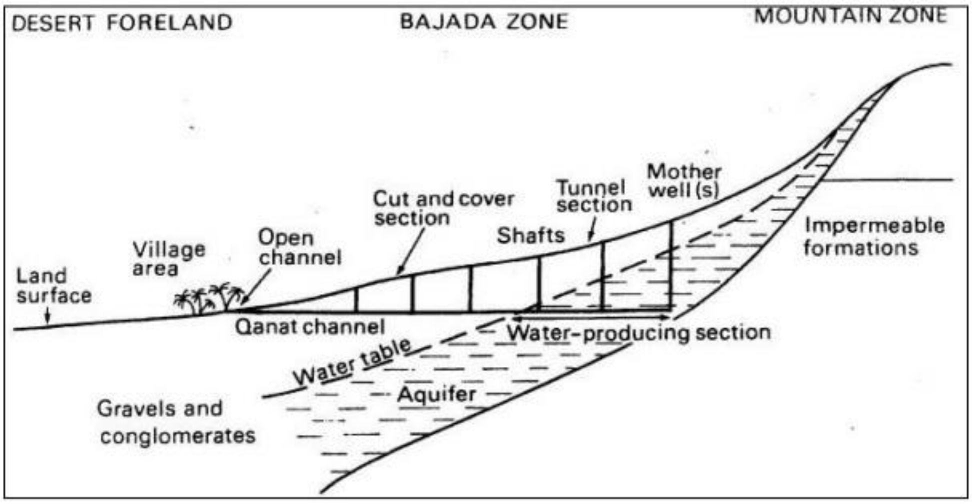
In Afghanistan there 6,741 Karezes and these Karezes irrigate about 163,000 ha of land. Karez irrigation is common in the south and southwest of the country and less in the north of the country, Karez irrigated area per province is shown in Fig. 2-7. One of the disadvantages of the Karezes is that there is no mechanism to stop water from flowing during winter or when there is no need for irrigation. In each Karez about 25 % of total annual volume of water is wasted. Province wise distribution of different irrigation systems in Afghanistan is given in Table 2-7. The key point to note is the concentration of Karez in the provinces within the Helmand river basin, which accounts for more than half of all Karez and more than

70 % of total Karez irrigated area.

Table 2-7 Province- wise distribution of different irrigation systems in Afghanistan

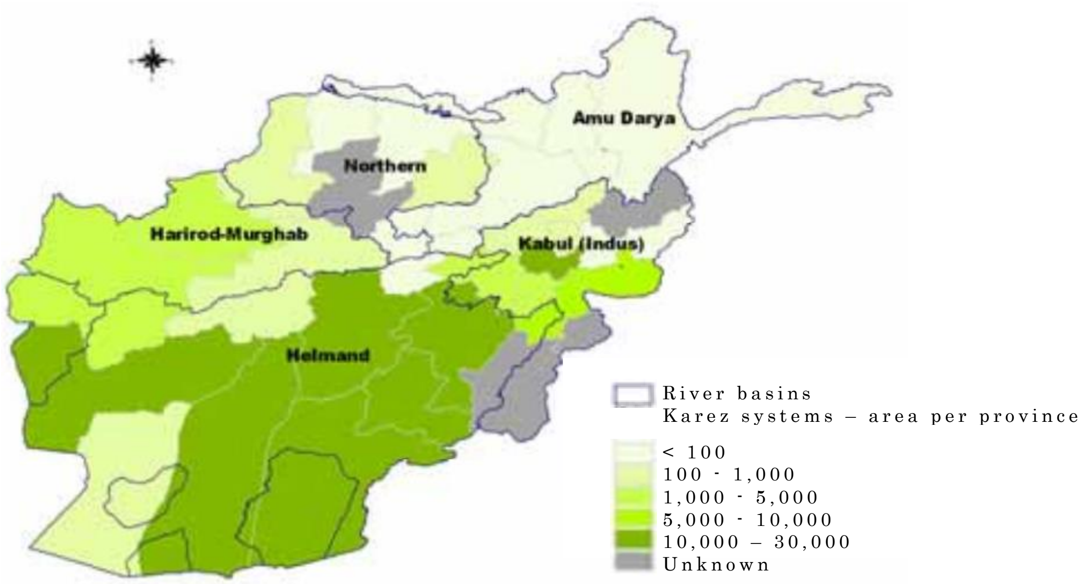
No	Province	Canal	Spring	Kareze	Well	Mils
1	Badakhshan	212	82		54	730
2	Badghis	120	50	30		500
3	Baghlan	109	63			565
4	Balkh	250	92	3	82	912
5	Bamyan	179	137		300	651
6	Farah	312	94	352	327	260
7	Faryab	157	79	960	867	1,030
8	Ghazni	818	604	1,516	636	994
9	Ghor	804	570	4	263	500
10	Helmand	227	135	276	60	516
11	Herat	302	153	228	450	1,302
12	Jawzjan	382	87	2	443	475
13	Kabul	177	81	321	436	616
14	Kahdahar	279	258	631	252	383
15	Kapisa	285	72	49	176	638
16	Kunarha	223	67		13	681
17	Kunduz	88			55	363
18	Laghman	45	3			561
19	Logar	154	169	124	91	433
20	Nangarhar	274	210	495	15	1,001
21	Nimroze	193	2	18	140	133
22	Paktia	625	392	528	800	171
23	Parwan	120	93	34		756
24	Samangan	20	73	7	271	190
25	Takhar	316	288		509	653
26	Urozgan	363	429	84	210	1,266
27	Wardak	586	519	336		822
28	Zabul	199	756	743	148	373
	Total	7,822	5,558	6,741	6,598	17,475

Source: ICARDA, 2002



Source: overview of water resources, issues 2011

Fig. 2-6 Cross section of idealized karez

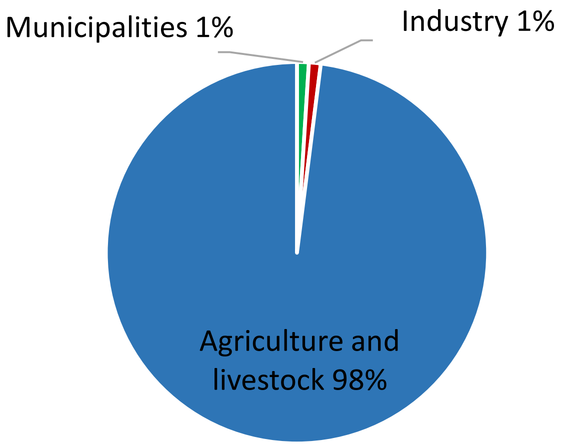


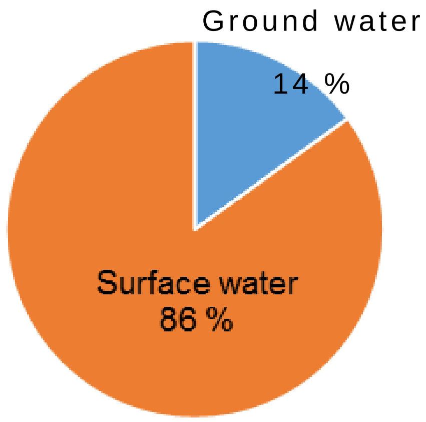
Source: Gov. of Afghanistan statistical yearbook 1980

Fig. 2-7 Area irrigated by Karez per province

2.4 Water use in Afghanistan

In 1998, total withdrawal was estimated at 20.373 billion m^3, of which 20 billion m^3 or 98 % was for agriculture, 1 % for municipal and 1 % for industrial purposes (Fig. 2-8). Of total water withdrawal 17.317 billion m^3 or 86 % was from surface water sources and the remainder 3.056 billion m^3 or 14% from groundwater (Fig. 2-9). (Rout, 2008, FAO, 2010)





Source: Government of Afghanistan statistical yearbook

Fig. 2-8 Percentage of water withdrawal with surface and ground water

Fig. 2-9 Percentage of water withdrawal by sectors

2.5 Irrigation in Afghanistan

The history of irrigated agriculture in Afghanistan goes back to more than 4,500 years ago (ICARDA, 2002). Except for a few areas where rain-fed agriculture can be practiced, agricultural production in most of the country is not possible without irrigation as the rainfall is either meager or unreliable. The allocation of water and land is closely related to customs and traditions of the sedentary population, and maintenance works of irrigation schemes have always been a well-defined activity in the farmers' seasonal calendar. The annual amount of water used for irrigation accounts for 98 % for the entire water usage. Irrigation systems in Afghanistan can be divided into two categories: informal or traditional irrigation systems (surface water systems,underground water systems like karez, springs and wells) and formal or modern irrigation systems (Qureshi.A. S., 2002).

Informal or Traditional 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. Within informal systems, irrigation is the main usage of water by volume but they also serve as a source for domestic and livestock water supply, either directly or through local recharge of shallow wells. These multiple uses of water are an important factor in system operation and maintenance. In larger systems, an additional issue is access to and across canals for the movement of people and goods by both foot and vehicle.

Informal also divided to small scale informal surface water systems and large scale informal surface water systems.

Small scale Traditional Irrigation Systems: These are centuries old systems. Water is supplied by stream flow diverted with the help of Temporary weirs, which are often located in remote valleys along a stream or river and vary in size (up to 100 ha). These systems are constructed and maintained in a traditional Informal method on a communal village basis and water rights are also determined and recognized in the similar manner.

Large-scale informal or modern surface water systems: These systems are mainly located in the plains and along the main river valleys. Many villages can share water from such a system. According to the water laws of 1981, the amount of water needed for irrigation is determined according to the area under cultivation, the kind of crop, the irrigation regime, the water rights document, the local practices and the amount of water in its source. However, in practice water is distributed according to the local tradition and agreements between farmers, Mirab, and the government. Each village has at least one water master (Mirab) who delegates his authority to sub-water masters responsible for the allocation of water to different fields of the scheme.

For the past 30 years war and civil unrest, irrigation system structures have been damaged, Rout, 2008 it was estimated that 27 to 36 % of all irrigation systems were directly affected by war before 2000 AD. Irrigated land is usually located in the river basins of the country. FAO satellite survey, conducted in 1993, Table 2-8 shows total irrigated area as 3.21 million ha, of which 48 % is intensively cultivated and 52 % intermittently with one or more crops each year. In 1967, a survey estimated the total irrigation area to be 2.72 million ha. The survey 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 like springs, Karez and wells (Rout, 2008) (Fig.2-10). While surface water systems made up less than one-third of the total number, they covered 86.5 % of the irrigated area, confirming the importance of surface water as main irrigation water source. Springs account around 7 % of the area, Karezes near 7 % and shallow and deep wells about 0.5 % (Favre, et all, 2003 and Kamal, et all, 2004). In 2002 it was estimated that 18 % of the total area equipped for irrigation on 3.21 million ha and 16 % of actually irrigated area on 1.73 million ha were irrigated using ground water.

Table 2-8 Area equipped for irrigation

Water basin	Irrigation areas(ha)				
	Intensively cultivated (2 crops/year)	Intensively cultivated (1 crops/year)	Intermittently cultivated	Total	Total (%)
Kabul	62,000	244,000	178,100	484,100	15
Helmand	95,000	380,800	900,200	1,376,000	43
Hari Rod-Murghab	34,500	138,000	128,400	300,900	9
Northern	40,000	197,800	387,000	624,800	19
Amu Darya	106,200	247,800	48,100	402,100	13
Non- drainage area	3,880	10,000	6,700	20,580	1
Total	341,580	1,218,400	1,648,500	3,208,480	100

Source: Rour, 2008

They have undergone social and physical changes, and expand or contract based on water availability or challenges arising from years of conflict. Informal systems account for around 90 % of the country's irrigated area (Rout, 2008). They are divided into four categories (Table 2-9). Also Percentage by system type of total number of informal systems and total area irrigated is shown in Fig. 2-11.

Table 2-9 Irrigated area by different water resources

System and area	River and stream	Spring	Karez	Well	Total
System(No.of)	7,822	5,558	6,741	8,585	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	

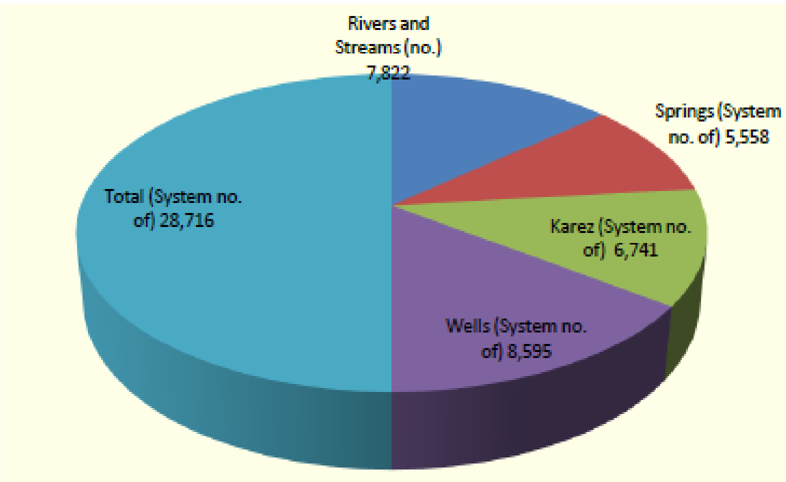
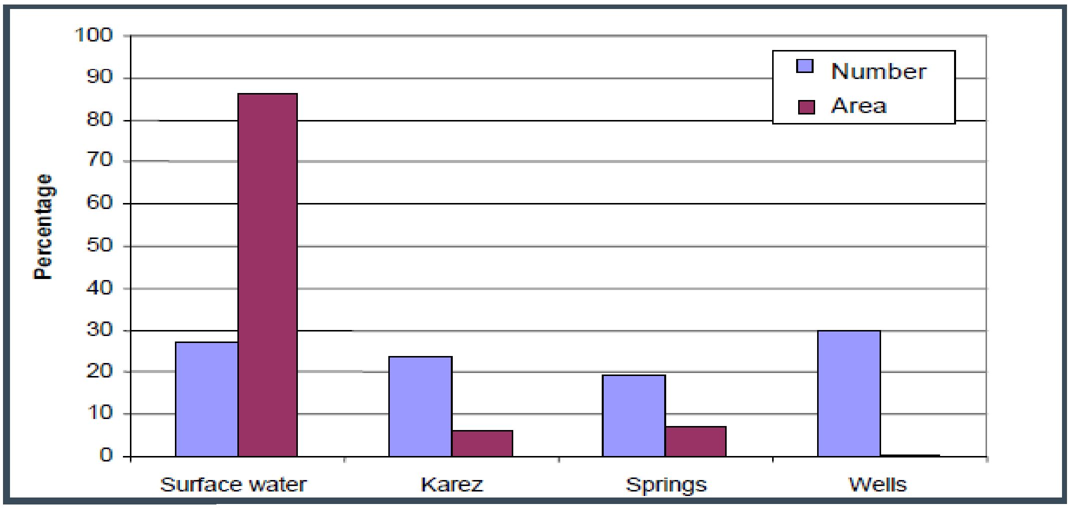


Fig. 2-10 Number of system in Afghanistan



Source: Computed on the basis of data give on Table 2-8

Fig. 2-11 Percentage by system type of total number of informal systems and total area irrigated

2.6 Formal or modern irrigation systems

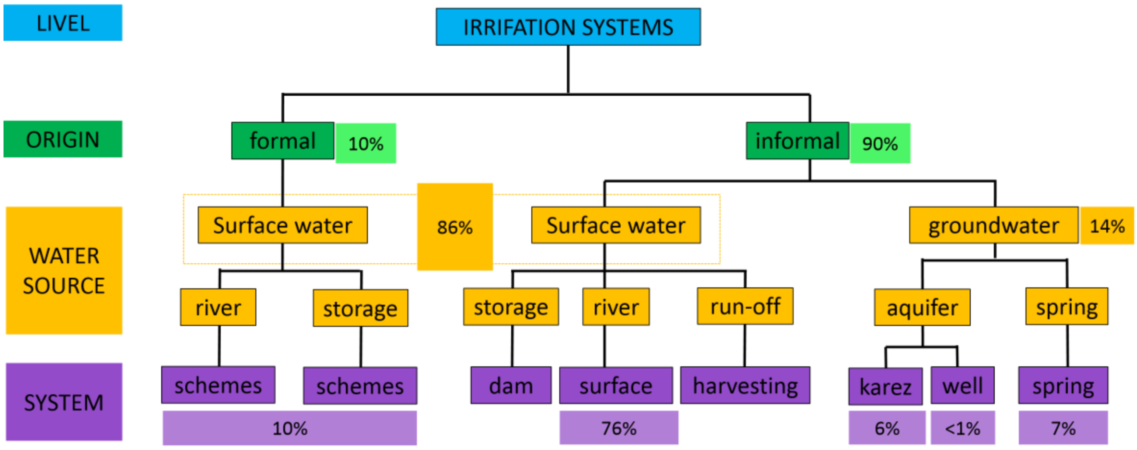
Modern irrigation system have a permanent intake structure, which is operated and maintained by the irrigation department. Created largely from the late 1940 to the 1970, these schemes combine “green fields” and traditional systems. They were aimed at expanding the agricultural production base by developing new irrigated lands as well as conglomerating and improving existing informal systems. The significant difference is that the regulation of water flow to the system depends on the interaction between government authorities and the village communities.

Water source is key determinant of where and how irrigation system developed in Afghanistan. There are major differences between surface and groundwater sources in terms of quantity of supply, timing and quality. In turn, these influence, the area to be irrigated, crop types and intensities, infrastructures for water collection and distribution, water allocations, the organization, operation and maintenance of system. The classification of system types is based on the following:

1- The origins of development distinguishing between informal and formal system.
2- Water sources, which is categorized into surface water and groundwater, and
3- System, which is classified by infrastructure related to primary water sources such as large formal government schemes as well as systems involving surface sources, karez, springs, wells, dams and heaviest. These may be further subdivided into subsystems or specific schemes.

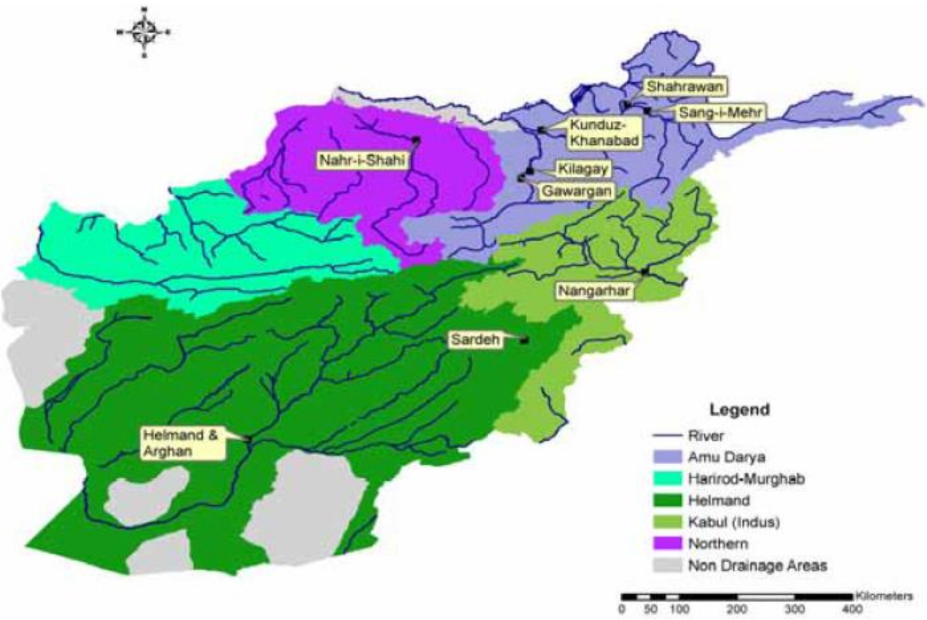
The hierarchy of classification approximates share of total irrigated area for water sources and system types (Fig. 2-12). It shows the importance of informal systems, which account for 90 % of irrigated area, as well as the significance of surface water, which supplies 86 % of irrigated area estimates of areas irrigated by small dams or diverted surface water run-off currently do not exist. While the formal systems supply less than 10 % of the country’s irrigated area. Fig. 2-13 shows location of formal irrigation schemes in Afghanistan. When classified by river basin, two are in Helmand

(Helmand-Arghandab and Sardeh); two in Kabul (Nangarhar and Parwan); five in Amu Darya (Gawargan, Kelagay, Kunduz- Khanabad, Shahrawan and Sang-i-Mehr); and one in Northern (Nahr-i-Shahi).



Source: Afghanistan Research and evaluation unit (AREU)

Fig. 2-12 Classification of irrigation systems in Afghanistan



Source: Afghanistan Research and evaluation unit (AREU)

Fig. 2-13 Location of formal irrigation scheme

The last available census-based inventory of irrigated areas dates back to 1967, giving a total of 2,385,290 ha. However, land-cover maps, recently produced through the collaborative efforts of FAO, the United Nations Development Program (UNDP) and the Afghan Geodesy and Cartography office (Kabul), indicate that the extent of irrigated areas has not changed much in the last 35 years. Therefore, about 190,000 ha are classified as intensively irrigated (two crops, rice–wheat), about 1,370,000 ha as cropped and irrigated at least once a year, and about 1,640,000 ha is irrigated occasionally (every two or three years). Table 2-10 provides a comparison of the 1967-reported irrigated areas with the results of the land-cover mapping at province level

Table 2-10 Comparison of irrigated area in Afghanistan

Province	comparison of irrigated areas in surveys 1967 and 1990-1993			
	Irrigated area 1967(ha)	Irrigated area two seasons 1990-1993(ha)	Irrigated area one season 1990-1993(ha)	Irrigated area occasionally 1990-1993(ha)
Kabul	57,600	30	39,327	20,762
Kapisa and Parwan	75,140	1,704	69,335	9,583
Lowgar	26,650	0	22,649	12,931
Vardak	25,600	0	30,838	26,568
Konar	23,320	2,684	9,373	12,973
Laghman	23,580	13,482	5,659	4,212
Nangarha	42,340	26,143	40,847	29,414
Balkh	224,500	5,369	85,790	145,596
Faryab	121,600	0	53,894	83,581
Jowzjan	184,600	0	99,207	131,264
Samangan	44,330	201	21,442	37,003
Badakhshan	61,760	3,122	30,964	17,720
Baghian	80,180	14,356	58,224	17,098
Konduz	209,590	66,910	58,856	6,426
Takhar	61,860	39,086	68,278	2,077
Ghazn	117,490	88	129,347	160,452
Paktia	56,350	665	62,760	54,977
Helmand	162,720	13,462	104,959	119,444
Kandahar	117,920	441	51,365	203,560
Nimruz	60,300	0	0	76,778
Oruzgan	126,580	0	65,988	57,689
Zabol	62,540	74	22,367	72,326
Badghis	33,300	416	19,802	30,756
Farah	125,730	23	45,937	176,232
Herat	163,700	394	123,324	64,090
Bamian	23,150	0	18,921	31,645
Ghowr	72,860	0	29,575	36,676
Afghanistan total	**2,385,290**	**188,650**	**1,369,028**	**1,641,833**

2.7 Irrigation water management in Afghanistan

The main problem facing rural parts of Afghanistan is the management of irrigation system. The availability of water is not a problem, but there main challenge is in the management of irrigation system. (Thakkar, H, 1999)

In Afghanistan, the irrigation water management is done through community based irrigation management system known as Mirab system and the person who is managing this system is also called Mirab. The Mirab system managed irrigation water accounts for 90% and the remaining 10 % is done formally through government agencies. The informal management of irrigation water is carried out by Mirab. Mirab is a person selected by the community (Thomas and Sabawon 2011). According to Qureshi 2002, the formal irrigation system has permanent intake structure, which is operated and maintained by the Irrigation Department. The management of the irrigation scheme itself follows the rules of the large-scale traditional surface water schemes. However, the significant difference is that the regulation of water flow to the system depends on the interaction between government authorities and the village communities (Pain, 2004).

2.8 Mirab System

The Mirab system vary in different part of the country depending upon the community. The Mirab system consisted of Mirab the person in charge of irrigation water management), water users and community elders. Therefore, Mirab plays major role in water distribution, operation and maintenance of irrigation infrastructure while the role of water users was to contribute the labor for a common work and participate in Mirab selection. However, not all water users participate in the selection process. The selection process is not always clear. It is a traditional and not 100 % democratic process. Community elders appoint a person with the agreement of water users.

Basically water allocation and distribution is done according to the land size. The water users use their traditional units for water distribution. These traditional units vary in different part of the country depending upon the type of the water user's community. The Mirab system is not good in equity issues especially in irrigation water distribution. There is always great difference in the water rights and actual water distribution among the users. The upstream water users are favored and receive more water. The downstream people receive less water, that there is always conflict over water in Mirab system among the water users. The water users violate the water rights and raising conflicts over water, especially in the time of water scarcity.

2.9 Current Mirab system

Mirab system is not effective now as compare to past, but it's no longer working at present due to weakness of government.

Therefore, there is no support of government provided to Mirab system. Such as guidance, supervision, bonus, rewards and tools that have been provided. According to CPHD 2011, DAI 2006, the Mirab systems has survived during the three decades of war and rapid change in the political environment, but it has not adapted successfully to the new challenges. A great gap exists between the water right and actual water distribution among the users. According to Pain 2004, Roe 2009. The Mirab are always not fair in equitable distribution of the resources due to the presence of powerful people who frustrate the distribution of common pool resources both between the village and within the villages.

In addition, there is no social collaboration among up, mid, and downstream, and conflicts among water users have arisen. The system had been held based on inheriting process when a person had died or retired and his son becomes Mirab for unlimited time (Roe, 2009).

2.10 Tasks of Mirab

Mirab is responsible for the construction and maintenance of related canals with the help of community members. He also coordinates with the people delegations, called Wakils to ensure flow of water into the secondary canals. Respondents of each up, mid and downstream revealed that Mirab system is responsible for distribution of water, conflict resolution specifying water turn for each village, announcement for water turn and maintenance, mobilizing and organizing laborers for cleaning canal and contact with actors such as government, NGO and community elders.

The typical everyday tasks of a Mirab include: checking any unauthorized breaching of the canal upstream; collecting and mobilizing people for maintenance activities; maintaining the diversion and regulatory structures, and coordinating and mobilizing labor for main canal and river bed maintenance activities (Riemann, 2005). The tertiary canal network that takes water from secondary canals to individual farms is the responsibility of the Mirab to supervise, but individual farmers may choose to coordinate with the Mirab in relation to the construction of their canals and during the diversion of water. Water diversion and monitoring of the quantity of water flow is done entirely through look closely monitoring according to the individual water rights that correspond to their landholdings, (Thomas. V., 2009).

2.11 Conclusions of this chapter

Afghanistan has dry continental climate and precipitation occurs as snow during the winter months, the quantity, timing and distribution of precipitation are key factors in determining water availability for irrigation. The river regimes in Afghanistan depend on annual rain and snow melt in highland above 2000 m in elevation and represented 80 % of Afghan water resources (excluding ground water) of the country. The main surface water resources of Afghanistan are the Amu Darya, the Helmand River, the Kabul River, the Hari Rod- Murghab Rivers and Northern River.

In Afghanistan, groundwater has traditionally been developed and utilized from Irrigation purposes through the use of karzes, springs and shallow hand dug open wells. Substantial drought and a growing demand for water in more recent years, deep drilled wells have become a more common means of extraction for Irrigation usage. In 1998, total withdrawal was estimated are more than 20 billion m^3 of which 98 % was for agriculture, of total withdrawal about 86 % was from surface and about 14 % from groundwater. In Afghanistan there are traditional irrigation systems, and centuries old systems. These systems are constructed and maintained in traditional informal manner based on communal village.

Water is a prime resource potential for the growth of Afghanistan's agriculture. Lack of assured and timely water supply at the farm levels is perhaps the most important constraint to agricultural growth. Irrigation infrastructure as well as many supporting community-based and government institutions have seriously deteriorated or broken down in the years of conflict, lack of maintenance, and more recently drought.

Present status of irrigation systems: - Traditional surface systems, with intakes from rivers and streams, account for about 80 % of the irrigated area. While these systems have generally survived, their community-based mechanisms for water management and maintenance have been adversely affected by local commanders who frequently do not respected water rights or the authority of the farms elected and employed Mirabs (water masters).

Food security is dependent on the achievement of water security, because food and water are highly interconnected in Afghanistan. More than 80 % of Afghan live in rural areas subsisting on natural resources such as land and water, although some would argue that the key income determinants are labor migration, wages and remittances. Twenty-five years of war and destruction, combined with 4-7 years of substantial drought and a growing demand for water, have created a significant challenge for the Afghan government and development agencies. Irrigation intensity same provinces is very high. On the other hand low and moderate intensity of irrigation was found in the remaining provinces of Afghanistan, currently the afghan agriculture water use efficiency is about 25- 30 %, the irrigation method and system could be one of the causes for this inefficiency, the main problem for afghan agriculture is lack of good irrigation practice, techniques like land leveling, shaping the structure of field. Also there are problems in the management of irrigation system.

References of this chapter

ADB 2005. Natural Resources Management and Poverty Reduction, Draft Inception Report, pp.34-50.

Afghanistan Ministry of Agriculture and Animal Husbandry (FAAHM) & Food and Agriculture Organization of the United Nations (FAO), Kabul, pp.33-46.

Ahmad, M. and Wasiq, M., "Water Resources Development in NorthernAfghanistan and its Implication for Amu Darya Basin", World Bank, 2004.

Aini. A. 2007.Water conservation in Afghanistan, Journal of Developments in sustainable Agriculture vol.2 No.1 p51-58.

Azizi,Pir M. 2002. "Special lacture on water resources in Afghanistan" Ministry of irrigation, water Resources and Environment, Kabul, Afghanistan.

Bob Rout, 2008. Water management, livestock and the opium economy. How the Water Flows: A Typology of Irrigation Systems in Afghanistan.

CPHD. 2011. An overview of key messages, Afghanistan Human Development Repot. The forgotten front; water security and crisis in sanitation.

DIA. 2006. Water users association in Afghanistan. Development Alternative Inc. USAID.

FAO, 1996. Afghanistan, Promotion of Agricultural Rehabilitation and Development Programs, Water Resources and Irrigation.

FAO. 2013. Irrigation in Central Asia in figure- AQUASTAT Survey-2012, Regional report, water report 39.

Favre, R. and Kamal, G. M. 2004. Watershed atlas of Afghanistan. First edition- working document for planners Kabul.

Favre. R., and Maletta, H.2003. Agriculture and food production in post-war Afghanistan: A report on the winter agricultural survey 2002-2003.

Habib 2011.Increasing Crop Productivity; From the Prospects of New Community Based Institutional Settings in Irrigation Management Van hall larenstein part of Wageningen ur

ICARDA 2002. Needs Assessment on Soil and Water in Afghanistan, Future harvest consortium to rebuild agriculture in Afghanistan.

Kamal,B., Azizi, Pir Mohammad, Shobair, Sayed Sharif and Mohsini, Mohammad Yasin. 2004. Drought impact and potential for their mitigation in southern and western Afghanistan. Working paper 91, International Water Management Institute, Colombo, pp.43-53.

Keshawarz. M. S. 2002. Rapid Assessment of water sector-Afghanistan. Chairman Department of Civil and engineering University of Hartford West Hartford, CT 06117 USA. pp. 9-12.

M. king, Sturtewagen, B, 2010. Making the most of Afghanistan’s river basin opportunities for regional cooperation. pp. 4-10.

Maletta. H., 2004. Food and agriculture in Afghanistan: along term outlook.

Mokgope, K., Pollard, S. and Butterworth, J. 2001. Water resources and water supply for rural communities in sand river catchment, South Africa 27 th WEDC conference on people and system for water, sanitation and health Lusaka, Zambia.

MAIL. 2009. Agriculture Prospects Report. Kabul, September 2009.

National Environmental Protection Agency of the Islamic Republic of Afghanistan (NEPA) and the United Nations Environment Programme (UNEP). (2009). “Afghanistan’s Environment 2008,” Kabul, November 2009.

Nakashima, M. 1998. Water users’ organization for institutional reform in Pakistan’s irrigation sector faculty of international studies, Hirshima University, Japan.

NPBC, 2009. Water challenges a crucial issue in Central- South Asia. Norwegian peace building center.

Olaf. T. 2006. Country Pasture/ Forage Resource profiles Afghanistan.

ODI (overseas development institute, humanitarian policy group.2004.Agricultural rehabilitation in Afghanistan: linking relief, development and support to rural livelihoods.

Pain. A. 2004. Understanding village institutions, Case studies on water management from Faryab and Saripul, Afghanistan Research and Evalution Unit, Kabul, Afghanistan.

Qureshi. A. S. 2002. Water resources management in Afghanistan; the issues and options.

Reimann, C. 2005. Assessing the state of the art in conflict transformation research center for constructive conflict management, Berghof.

Roe, A., 2009. Water management, livestock and the opium economy, challenges and opportunities for strengthening licit agricultural livelihoods.

Rout. B. 2008. Water management, livestock and the opium economy Kabul: Afghanistan Research and Evaluation Unit, Kabul, Afghanistan.

Sadiqi, M., 2002. Irrigation development and Avoiding water losses, Publication of ministry of Rural Rehabilitation and Development, Kabul, Afghanistan.

SEI 2009. Socio-Economic Impacts of Climate Change in Afghanistan. Oxford, March 2009 TCP/AFG/4552. November 1996. AREU.

Thakkar H, 1999. Contribution of Large Dams in food production, Food security in India.

Thomas. V. and Sabawon. N. 2011. Sharing irrigation water equitable, human development report, Afghanistan.

Thomas. V. 2009. Historical Perspective on Mirab System, A case study of Jangharoq Canal, Baghlan, Afghanistan research and evaluation unit.

Uhl, Vincent W. and Tahiri, M. Q. 2003, Afghanistan: An Overview of Groundwater Resources and Challenges, Working Paper, Uhl, Baron, Rana Associates, Inc., 60p.

USDA 2002. Afghanistan: Limited Improvement in Spring Harvested Grain. July 2002.

UNEP. 2003. Afghanistan Post-Conflict Environmental Assessment. Nairobi, January 2003.

Vincent W.Uhi. 2003. An Overview of Groundwater Resources and Challenges (Washington Crossing, PA, USA: Uhl, Baron & Rana Associates, Inc.).

WHO 2004, the effect of calamities on water resources and consumption in Afghanistan. khabir Alim WHO Afghanistan and Shobair FAO, Afghanistan.

Chapter 3

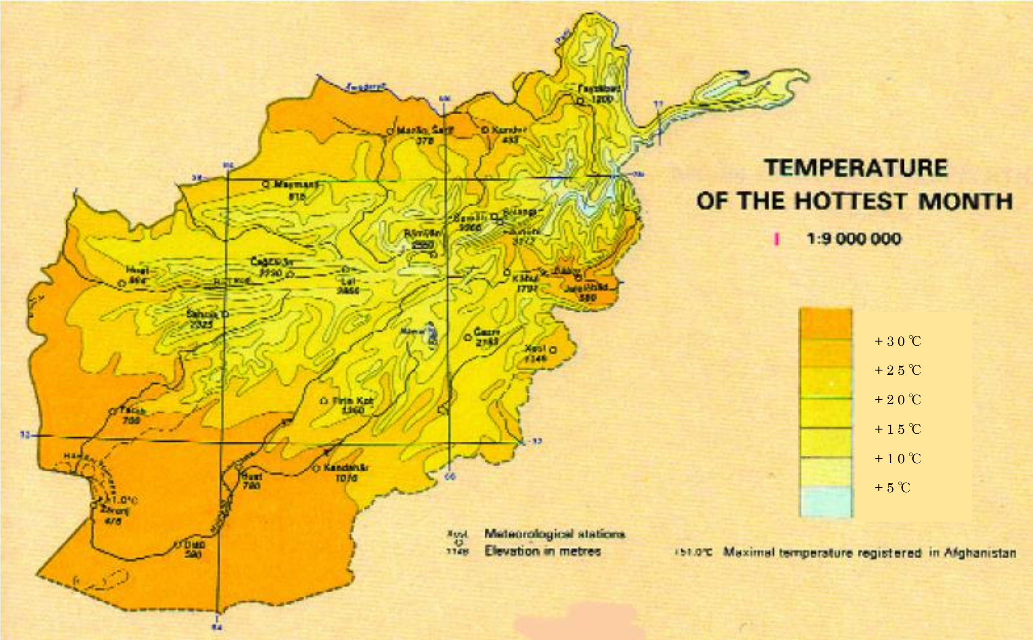
Meteorological properties and estimating Pan Evaporation in Kabul Afghanistan

3.1 Introduction

3.1.1 Background

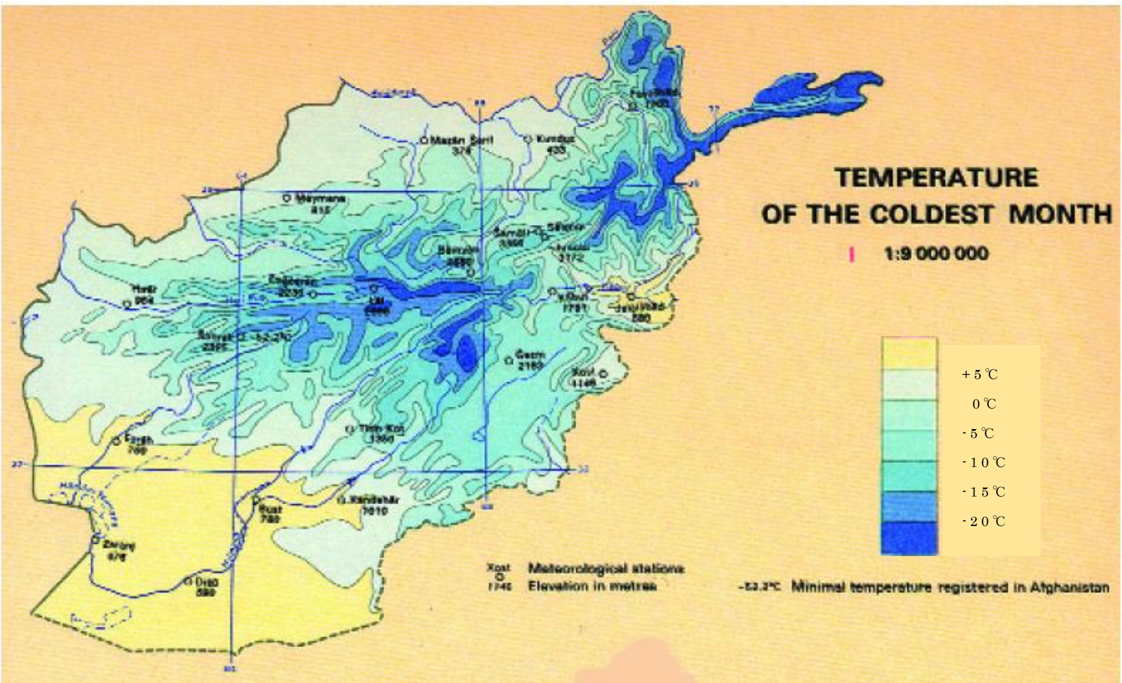
Afghanistan is a land locked country that is located approximately in the center of Asia and continental climate, although the presence of mountains causes many local variations. The typical climate varies from arid in south and southern parts, to semi- arid in most other parts of the country. The climate is not favorable for rain-fed agriculture. During winter, temperatures are low, getting down negative 20 °C and precipitation occurs in form of snow where no need to irrigate whereas during summer, temperature are high , getting up to 30 °C and rainfall is zero (Fig. 3-1 and 3-2) without irrigation supplies, these arid to semi-arid areas cannot support any agriculture. In the country, a total of 31 locations for metrological data collection (rainfall, temperature, relative humidity, snow, wind and sunshine) were available at least one in each province center, unfortunately during the civil war they were looted and destroyed. The agricultural production depends on the availability of water, either as direct rainfall or in the form of irrigation. However, prolonged drought, civil war destroyed irrigation systems and gardens of trees, especially vineyards and livestock numbers were greatly diminished. Afghanistan lacks of irrigation planning and the challenges of water shortages during the cultivation and growing season, the agricultural productivity is low. Moreover, demands on the resources have grown and FAO (1997) has been estimated that long- term water availability is about 2,800 m^3 head per year, enough to irrigate 4 million ha, which is significantly higher than the current 2.6 million ha command area. Otherwise Afghanistan is an arid to semi-arid country whose agricultural production depends on the availability of water, either as direct rainfall or in the form of irrigation. Fig. 3-3 shows Kabul, Afghanistan climate graph. In Afghanistan, rainfall data is difficult to access due to the fact that most of the old time-series was stopped in 1977 or, in some cases, in 1992. Meteorological stations have been damaged and no rainfall data are being collected (except from four agro-meteorological stations: Kabul, Jalalabad, Mazar-ISharif, and Herat installed in 1999 under the FAO project. The Meteorological Department and the Institute of Meteorology are not functioning regarding field observation. Due to this particular situation, agro-meteorological observations have become a very important task for the country. Due to the area of the country (652,000 km^2) and the very erratic spatial distribution of rainfall for mountainous regions, data from a large network of rain gauges are required. In addition to rainfall, other parameters are highly important and needed in Afghanistan. They are snowfall and snow cover upon which most of the country's irrigated sector depends, and frost and low temperature. Accurate and timely information on agro- meteorological observations, including all weather parameters, actual planting time, areas planted, harvested crop, and crop conditions and pasture are highly needed for each agro-ecological zone and each district in

Afghanistan. In other words, the agro- meteorological approach to helping agriculture can only be effective if reliable, real time, and timely data are Available. The timely collection and the proper utilization of agro- meteorological information help promote increased farm profits under favorable weather conditions or decreased farm losses under unfavorable conditions. It is necessary to get it on the orbit of sustainable agricultural development for the stability and the property of this country. Pan evaporation is an important weather variable that has application related to decision making in agriculture, forestry ecology, hydrology and other fields. The objectives of this chapter is to clarify meteorological properties in Kabul and to introduce a method for estimating pan evaporation with provision of results and discussion as well as providing conclusion on results.



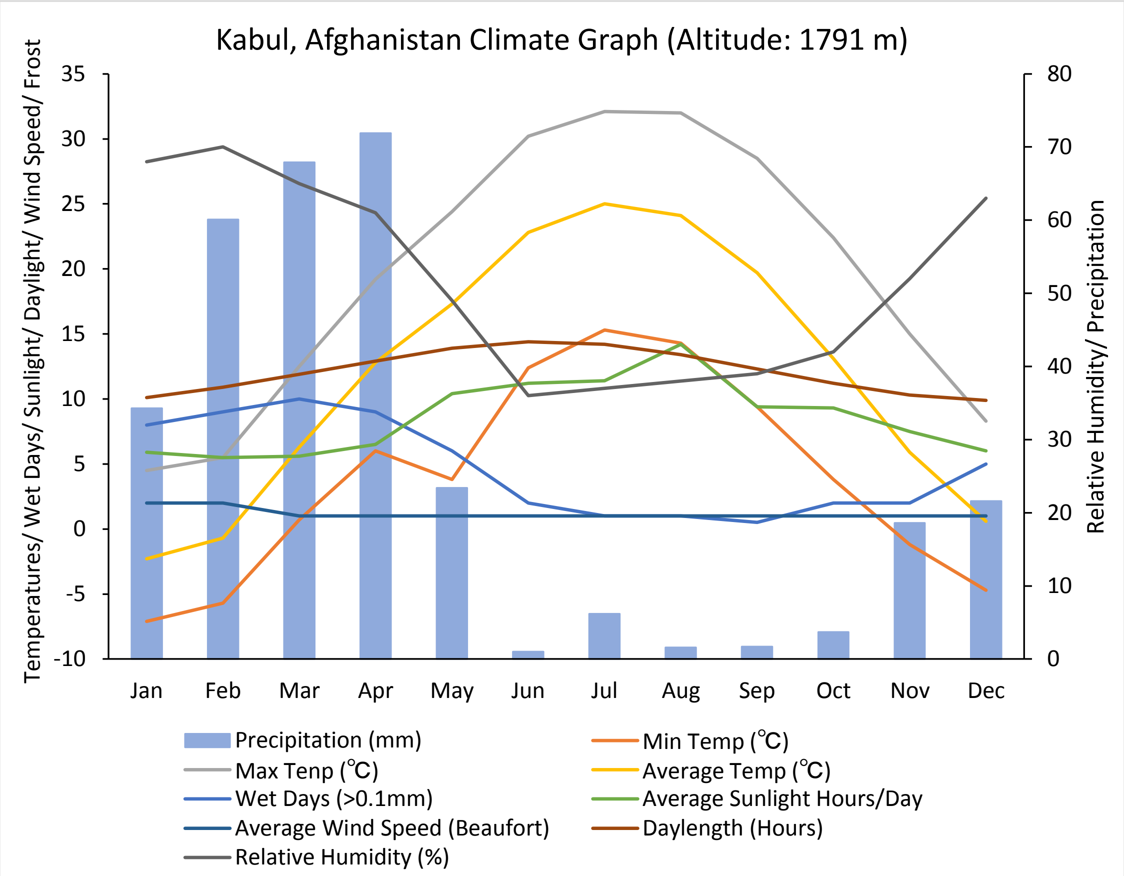
Source: GEOCART, "National Atlas of the D .R .of Afghanistan", Warsaw, 1984

Fig. 3-1 Afghanistan hottest month temperature



Source: GEOCART, "National Atlas of the D .R .of Afghanistan", Warsaw, 1984

Fig. 3-2 Afghanistan coldest month temperature



Source: Climatemps.com

Fig. 3-3 Climate of Kabul Afghanistan

3.2 Materials and Methods

Meteorological data were collected in the Qargha experimental research center in Kabul, Afghanistan. This center is managed by the Research Institute of MAIL (Ministry of Agriculture, Irrigation and Livestock), where is located 10 km west from the city center of Kabul, Latitude 34◦53N, longitude 69◦8E and altitude 1834 m (Fig. 3-4). The data were collected during a period of three years from January, 2010 up to the end of December, 2012. These data consist of air temperature, relative humidity, wind speed, sunshine hour, rainfall and pan evaporation (Fig.3-5) the three years average monthly data is shown in Table 3-1.

The water requirement of crop is the amount of water required by a specific crop to grow optimally. This varies according to the climate, crop type and growing stage. This crop water need (ET crop) is expressed in depth of water required to compensate the water loss through evapotranspiration.

The effect of climate on the crop water need is expressed as reference crop evapotranspiration (ET_o). The measurement unit is millimeter per unit time, which can be a day, month or growing season. The daily water need of the reference crop depends on the rainfall regime and daily temperature.

For calculation of crop water requirement the following formula is used:

$$ET\ crop = ETo \times Kc$$

Where

$ET\ crop$: Crop evapotranspiration (mm/day)

ETo: Reference evapotranspiration (mm/day)

Kc: Crop coefficient.

In this case for irrigation scheduling and calculation crop water requirement, we need to know about the values of reference evapotranspiration.

Daily Pan Evaporation data were also observed in this research station.

Evaporation is difficult to measure directly, and there for many theoretical approaches have been developed. Some of the commonly used techniques.

Penman method (Penman, 1963) was used for estimating evaporation

Following equation, namely

Penman or combination equation:

$$ET_p = \frac{\Delta}{\Delta + \gamma} \cdot \frac{\mathrm{S}}{l.pw} + \frac{\gamma}{\Delta + \gamma} f(\mathrm{u}_2) \cdot (e_{sa} - e_a)$$

In This equation the mass-transfer and energy-balance approaches could be combined to arrive at an evaporation equation that did not require surface temperature data. The first term shows net radiation and the second term shows mass transfer.

Δ: saturation vapor pressure at air temperature hPa/$^\circ$C,

S: net radiation MJ/m^{2}day

l: Latent heat (2,453 MJ/Kg)

pw: Density of water (1,000kg/ m^3)

γ: psychometric constant hPa/C

f (u_2) : wind speed at 2 m height m/s

e_{sa}: saturation vapor pressure at air temperature hPa

e_a: vapor pressure hPa

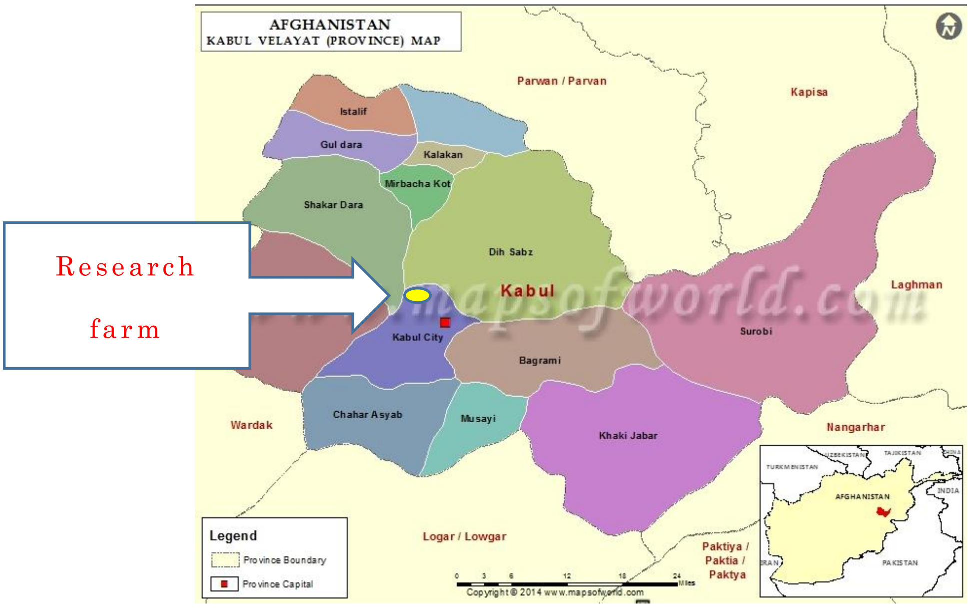


Fig. 3-4 Kabul Qargha research center

Fig. 3-5 (Upper-Left) Sunshine hour, (Upper-Right) Air temperature and relative humidity, (down–Left) Rain gage and. (Down –Left) Wind speed

Table 3-1 three years monthly average Air temperature, Relative humidity, Sun shine, Wind speed, Rainfall

Months and years	Tempereture (ºc)	Relative humidity (%)	Sun Shine hours (h)	Wind speed (m/s)	Rainfall (mm)
Jan-2010	1.2	42.7	5.7	2.5	1.0
Feb-2010	0.2	54.0	0.2	7.6	1.6
Mar-2010	10.3	41.3	7.5	9.6	1.3
Apr-2010	13.3	44.1	0.3	13.7	0.7
May-2010	14.8	44.2	0.4	13.1	1.6
Jun-2010	18.1	36.2	0.4	0.3	0.1
Jul-2010	21.5	36.6	0.4	0.1	0.9
Aug-2010	20.8	44.3	0.3	3.3	0.9
Sep-2010	17.5	35.4	0.4	7.4	0.2
Oct-2010	12.9	31.5	0.3	5.3	0.0
Nov-2010	6.7	30.2	0.4	2.1	0.0
Dec-2010	1.3	28.9	0.3	2.6	0.0
Jan-2011	-0.8	35.7	0.2	2.5	0.0
Feb-2011	-0.6	51.6	0.2	1.9	3.4
Mar-2011	6.3	40.5	0.3	1.7	0.8
Apr-2011	10.6	40.2	0.3	2.7	1.6
May-2011	17.9	32.3	0.4	2.9	0.3
Jun-2011	20.8	27.2	0.5	3.7	0.0
Jul-2011	22.7	28.5	0.4	13.6	0.0
Aug-2011	21.5	37.5	0.4	3.4	0.5
Sep-2011	18.5	36.7	0.4	0.0	0.3
Oct-2011	11.4	43.3	0.3	0.0	1.3
Nov-2011	7.3	46.9	0.2	11.3	1.1
Dec-2011	0.6	32.9	1.0	8.7	0.0
Jan-2012	-6.3	48.2	5.3	12.8	1.1
Feb-2012	-7.9	50.2	5.3	12.7	2.0
Mar-2012	3.1	45.0	5.7	15.4	1.5
Apr-2012	10.9	45.7	6.7	15.7	1.7
May-2012	14.3	39.3	8.9	15.2	1.2
Jun-2012	18.0	31.9	9.4	18.2	0.6
Jul-2012	21.2	29.3	9.7	18.4	0.0
Aug-2012	21.4	30.6	9.7	14.6	0.3
Sep-2012	17.7	39.2	7.9	11.9	0.4
Oct-2012	11.7	34.2	7.9	9.9	0.0
Nov-2012	5.7	36.2	6.4	8.6	0.4
Dec-2012	0.2	45.2	5.5	9.9	1.6

3.3 Results and discussion

Most of Afghanistan has a subarctic mountain climate with dry and cold winters, except for the lowlands where have arid and semi-arid climates. In the mountains and few of the valleys bordering Pakistan, a fringe effect of the Indian monsoon, coming usually from the southeast, brings moist maritime tropical air in summer. Afghanistan has clearly defined seasons; summers are hot and winters can be bitterly cold. Summer temperatures as high as 49 °C have been recorded in the northern valleys. Midwinter temperatures as low as -9 °C are common around the 2,000 level in the HinduKush. The climate in the highlands varies with elevation. The coolest temperatures usually occur on the highest of the mountains. Temperatures often ranges greatly within single day. Variations in temperature during the day may range from freezing conditions at dawn to the upper 30 °C at noon. Most of the precipitation falls between the months of October and April. The deserts receive less than 100 mm of rain a year, whereas the mountains receive more than 1,000 mm of precipitation, mostly as snow. Kabul is also semi- arid region, temperatures in summer are high and hot Maximum average temperature in summer is 21.8 °C in July, very hot, and high evapotranspiration, all crops requires irrigation but winter is very cold with Minimum average temperature in winter being -2.8 °C in February, for that there exist no farming activities. Kabul has maximum humidity of 51.5 % in February and minimum of 31.5 % in

July (Fig. 3-6). This leads to high evaporation. Average annual precipitation is around 250 mm/years (Fig. 3-7) maximum rainfall 65.5 mm in February. Winter season of the year is non-useable for agricultural purpose. Around 7 mm in June or July of rain is received, but generally it hardly rain from May to December, additionally productivity has declined further because of the decreasing water resource, precipitation deficit and traditional inefficiency, therefore it is essential that all plants be irrigated, lower relative humidity, higher temperatures cause more evaporation of water. Table 3-2 show three years monthly average potential and actual evaporation and Fig. 3-8 shows the comparison between the estimated evaporation using Penman method and observed evaporation with class A pan. There is large variation in the relationship between the estimated evaporation and the observed. Because Afghanistan has difference climate, from November up to April temperatures are usually low and at the same times can go to below zero degrees which leads to very low any evapotranspiration.

Also tried to estimate evaporation with other meteorological parameters such as air temperature, relative humidity, sunshine and wind speed, Table 3-3 show three years monthly average metrological parameters. When estimated relative humidity with pan evaporation there was a large inequality, the R^2 value was equal to 0.57, because Afghanistan is located in dry areas, mostly relative humidity is between 30– 35 %. When estimated wind speed with pan evaporation.

There was also a large difference, in the R^2 value which was equal to 0.001. There was no so much high wind speed in Kabul, and wind speed ranged between 0.1 up to 18.4 m/s. As well as pan evaporation with sun shine was estimated, they have a good relationship compared to relative humidity and wind speed, the R^2 value was equal to 0.5579, because sunshine hours during the winter season decreased. It was four and half hours at minimum per day, but it increased in summer season and reached maximum to 10.4 hours per day in July. Similarly air temperature and pan evaporation was estimated, then, finally we found that air temperature was a crucial parameter for estimating pan evaporation value, and the R^2 value was equal to 0.8349 (Fig. 3-9) because in winter season air temperature were zero or below there was no evaporation, but air temperature increased from march up to August and reached to 22 ^oC per day. Based on the information, the appropriate data set was determined for estimating pan evaporation, which were average air temperature and pan evaporation values in 5 and 10 days period (Fig. 3-10 and 3-11). There is good relationship between 10 days air temperature and pan evaporation, the R^2 value was 0.7646 compared to 5 days air temperature and pan evaporation which is the R^2 value was equal to 0.7017.

Table 3-2 Three years monthly average potential evaporation and actual evaporation

Months and years	Potential evapotranspiration(mm/day)	Actual Pan evaporation(mm/day)
Jan-2010	0.8	
Feb-2010	1.0	
Mar-2010	2.6	0.6
Apr-2010	2.4	0.7
May-2010	2.7	1.0
Jun-2010	2.8	2.1
Jul-2010	3.0	2.8
Aug-2010	2.7	2.1
Sep-2010	2.5	1.5
Oct-2010	2.0	0.7
Nov-2010	1.3	
Dec-2010	1.0	
Jan-2011	0.9	
Feb-2011	0.9	
Mar-2011	1.6	
Apr-2011	2.1	0.4
May-2011	2.8	2.0
Jun-2011	3.2	3.5
Jul-2011	3.6	3.4
Aug-2011	2.9	2.3
Sep-2011	2.3	1.4
Oct-2011	1.6	0.7
Nov-2011	1.3	0.4
Dec-2011	1.0	
Jan-2012	0.7	
Feb-2012	0.9	
Mar-2012	1.9	
Apr-2012	3.1	0.9
May-2012	4.3	1.3
Jun-2012	5.1	2.0
Jul-2012	5.4	2.6
Aug-2012	4.9	3.0
Sep-2012	3.5	1.7
Oct-2012	2.2	0.9
Nov-2012	1.3	0.2
Dec-2012	0.8	

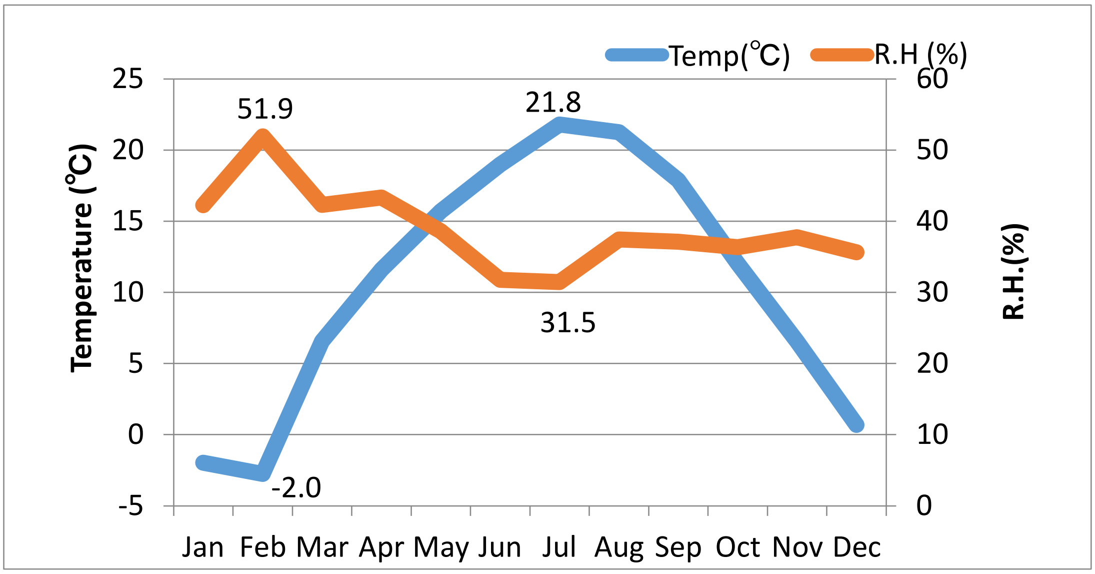


Fig. 3-6 Changes of three years average monthly air temperature and relative humidity in Kabul

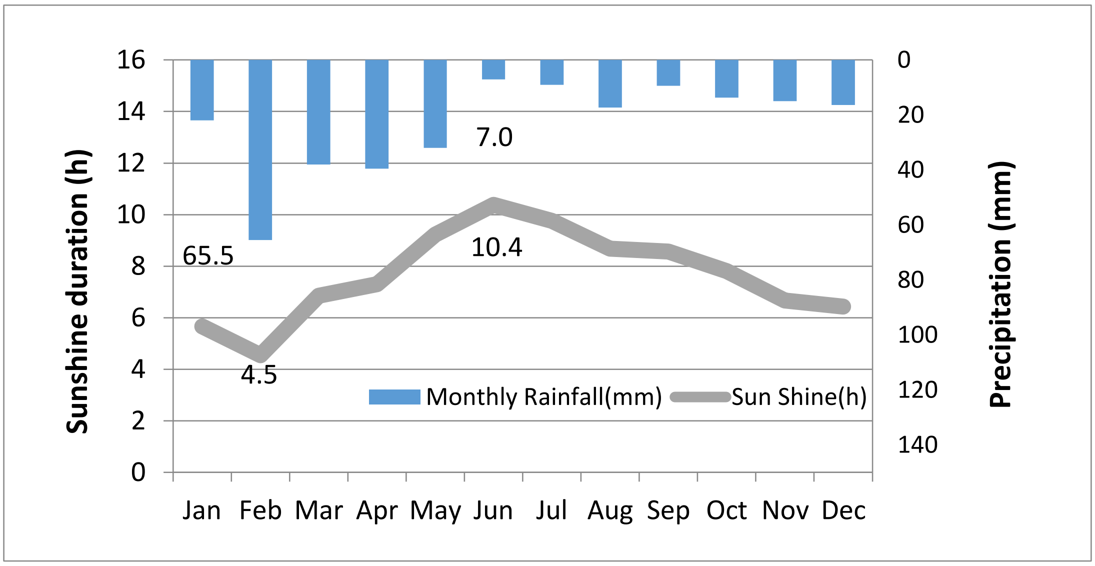


Fig. 3-7 Changes of three years average monthly precipitation and sunshine duration in Kabul

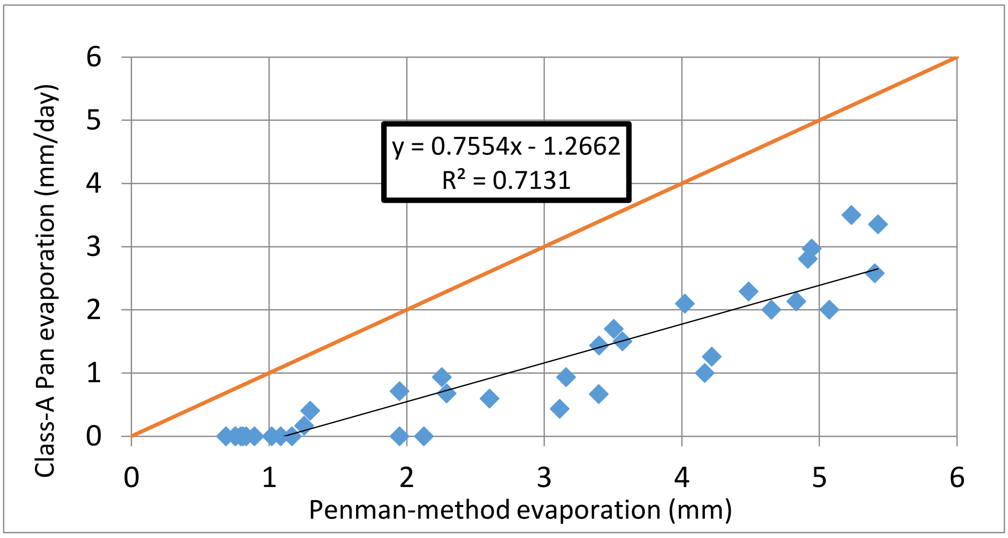


Fig. 3-8 Comparisons of three years average to estimated evaporation using Penman-method and observed evaporation by class A-pan

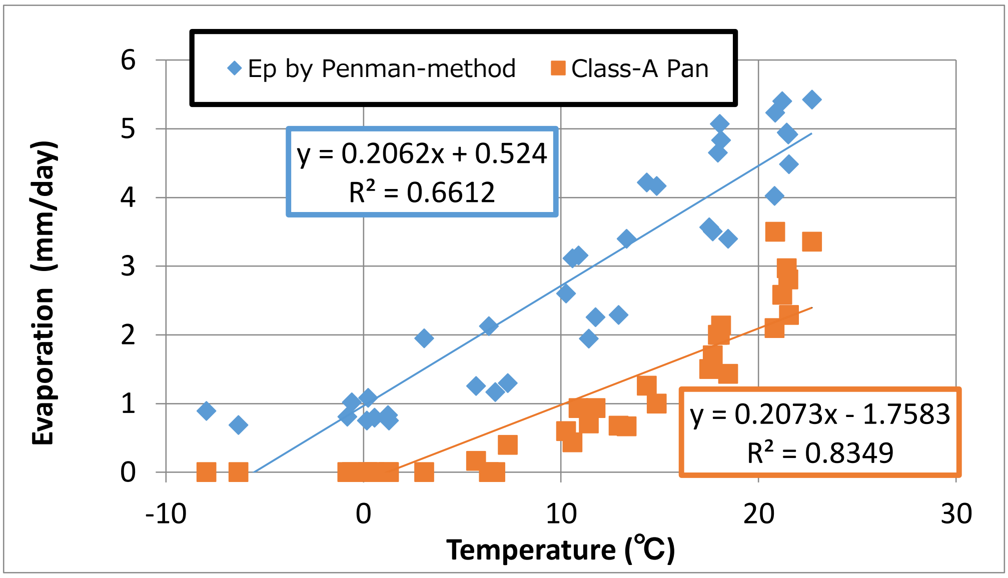


Fig. 3-9 Relationship between three years monthly average air temperatures an pan estimated evaporation

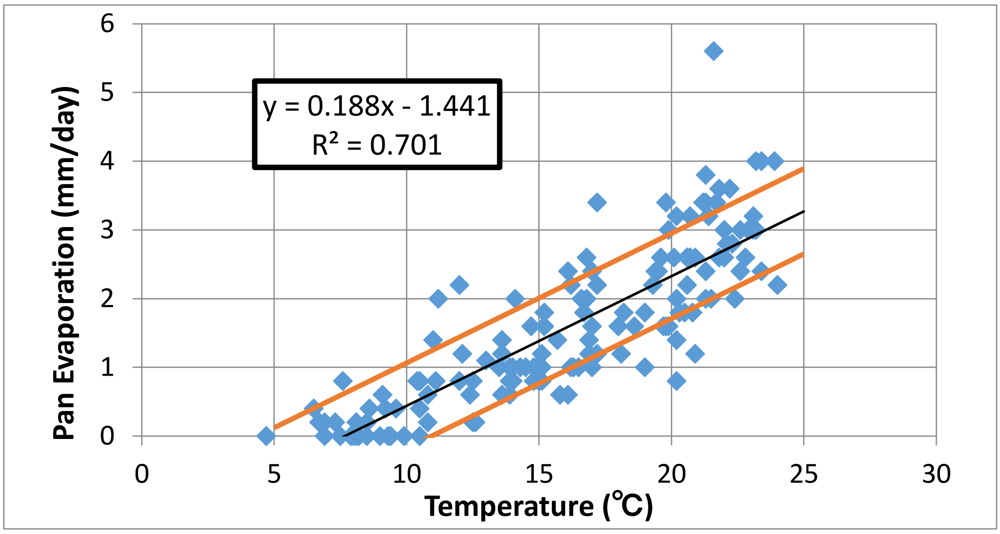


Fig. 3-10 Relationship between three years monthly average 5 days temperature and pan evaporation

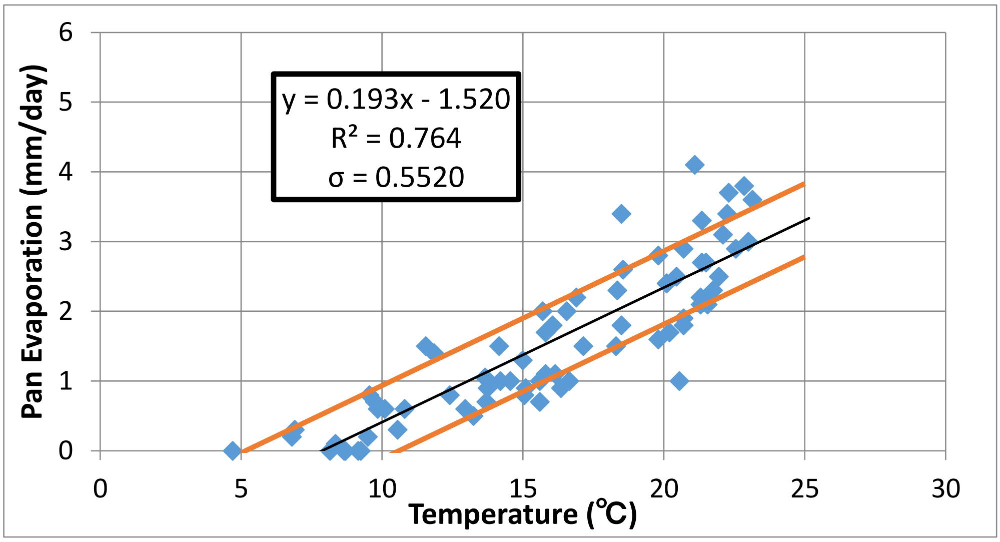


Fig. 3-11 Relationship between three years monthly average 10 days temperature and pan evaporation

Table 3-3 Three years monthly average air temp. Relative humidity, and Sunshine hour (2010-2012)

Month	Tempereture (^{O}C)	Relative humidity (%)	Sun Shine hour (h)
Jan	-2	42.2	5.7
Feb	-2.8	51.9	4.5
Mar	6.6	42.3	6.9
Apr	11.6	43.3	7.3
May	15.7	38.6	9.2
Jun	19	31.8	10.4
Jul	21.8	31.5	9.8
Aug	21.3	37.5	8.7
Sep	17.9	37.1	8.6
Oct	12	36.3	7.8
Nov	6.6	37.7	6.7
Dec	0.7	35.6	6.4

3.4 Conclusion of this chapter

About 80 % of the population of Afghanistan are dependent on agriculture. The agricultural production depends largely on the availability of water which is supplied as direct rainfall or in the form of irrigation. In Afghanistan due to lack of irrigation planning during the cultivation and growing season shortage of water occur often, in that case agriculture productivity is low.

Since Afghanistan is arid to semi- arid country and summer season is hot with no precipitation and relative humidity is low. The use of irrigation water for crop production is higher in this season. Winter season is cold and the most rain and snow fall in this season of the year. Due to the cold weather, no crop farming practice.

According to meteorological properties in Kabul, irrigation practices are required during summer periods from May to October. There is good agreement between the observed air temperature and pan evaporation values. Moreover results suggest that this relationship (Eq. $y = 0.193x - 1.520$) could be applicable as a practical indicator for estimating pan evaporation. This simple approach may help to minimize the amount of irrigation water required for crop cultivation in Kabul. It is important to conduct further research in Kabul and others provinces of Afghanistan and to propose the best practice for estimating crop water requirement in field test.

References of this chapter

Batchelor, C.H. institute of hydrology, wallinford, oxfordshirt OX108BB, England. 231p.

Clark, (1986) Themes for a research program. In Clark. W.c NAD munn, R.E.eds, sustainable development of the biosphere, Cambridge Univ.Press, pp.5-48.

David M. Sumner, Jennifer M., Jacobs,Utility of Penman–Monteith, Priestley–Taylor, reference, Evapotranspiration, and pan evaporation methods to estimate Pasture evapotranspiration,

Davies, J.A. and Allen, C.D. 1973. Equilibrium, potenstial and actual evaporation from cropped surface in southern Ontario. J.appl. Meteorol. 12, pp.649-657..

FAO (1997): As reported in the Afghanistan Agricultural Strategy international water management institute (IWMI)

FAO of the united Nations, Kabul Afghanistan,Rabah. Lekhal, Agro meteorological Services Required Under Emergency Situations:An Example from Afghanistan

FAO of the United Nation database, environment statistic country snapshot: Afghanistan, 2007. pp. 1-2.

Gerson Araujo de Medeiros, Flavio Bussmyeyer Arruda, Emilio Sakai, 2005. Crop coefficient for irrigation beans derived using three reference evaporation methods. Agricultural and forest meteorology 135: pp.135-143.

James Shuttleworth. W. and IAN R. CALDER., 1979. Has the Priestly-Taylor Equation Any Relevance to Forest Evaporation. Institute of Hydrology, Wallingford, Oxon, UK.

John D. Valiantzas.2006. Simplified versions for the Penman Evaporation equation using routine weather data. Division of water resources management, Department of Natural Resources and Agricultural Engineering, Agricultural University of Athens, Greece. Journal of Hydrology 331, pp.690- 702.

Lean,J and Warrilow, D.A.(1989); Simulation of the regional climatic impact of Amazon deforestration.Nature, 413.

Penman,H.L(1963) vegetation and hydrology , Tech Comm.53, Commonwealth Bureau of Soils,Harpenden.

Qureshe, A. S., 2002 water resources management in Afghanistan: the issues and option. -International water management Institute (IWMI).

Chapter 4

Estimating optimum irrigation discharge under furrow irrigation in Afghanistan

4.1. Introduction

4.1.1 Background

The history of irrigated agriculture in Afghanistan goes back to more than 4,500 years ago (ancient settlement near Kandahar). Except for a few areas where rain-fed agriculture can be practiced, agriculture production in most of the country is not possible without irrigation as the rainfall is either meager or unreliable. The allocation of water and land is closely related to customs and traditions of the sedentary population, and maintenance works of irrigation schemes have always been a well-defined activity in the farmers' seasonal calendar (Azizi, 2009).

Afghanistan has always suffered from water shortages, the shortage of water is the result of war inflicted damage to irrigation system (40 % of irrigation structures are damaged), traditional irrigation system and prolong drought.

Agriculture employs 80 % of the Afghan population and sustains more than half its gross domestic product (Gregory et al, 2010). The arable agricultural resource base of Afghanistan is about 8 million ha, which is 12 % of the total land area. There are roughly 3.9 million ha of cultivated land of which 1.3 million ha is rain-fed and 2.6 million ha is irrigated (Asad, 2002). This irrigated area produces almost 85 % of all agricultural productions. In Afghanistan the agricultural lands are irrigated by surface irrigation methods such as furrow, border and basin irrigation. However, application efficiencies and distribution uniformities are very low due to high runoff and deep percolation losses. Therefore, minimizing deep percolation and runoff while meeting irrigation requirements of crops can increase irrigation performance. On the other hand, surface irrigation especially furrow irrigation is one of the oldest methods of irrigation and remains a common techniques for irrigation of furrow crops across the world requirements (Koech et al., 2014). Surface irrigation is the most extensively used way of applying irrigation water in the world, and furrow irrigation one of its main example. Unfortunately these methods often have lower water use efficiency, for these reasons several management techniques have been developed to reduce water losses during the irrigation event. In this case, no research has been done before in Afghanistan, and only a few studies of estimating optimum irrigation discharge under furrow irrigation in other countries of the world.

The objective of this chapter is to introduce a method to estimate optimum irrigation discharge which it can reduce deep percolation for furrow irrigation. In this study, a mathematical model of surface irrigation was used to determine optimum irrigation discharge in the cultivation of tomato and to compare irrigation application efficiency with existing furrow irrigation.

4.2 Material and Methods

4.2.1 Infiltration model

Infiltration is one of the most important soil parameters in the design and evaluation of the surface irrigation methods (Iembelman, 1987). Estimation of soil infiltration is major problem in irrigation studies due to proper selection of the technique used to determine the parameters of the infiltration models, the use of empirical infiltration model, and its dependence on soil moisture, soil characteristics, and surface roughness (Holzapfel et al., 1988; Walker and Busman, 1990). There are a number of infiltration equations available that attempt to explain the process of infiltration (Christiansen, et al., 1966, Watanabe et al., 1996, Esfandairi and Maheshwari, 1997, Jose, 2003). In this study, the volume balance equation during an irrigation event is used as shown in Eq. (1).

The left side of Eq. (1) is the volume of water applied into a furrow. The right side of the equation shows the sum of the infiltrated volume and the volume accumulated in the soil surface along a furrow.

$$q\ t = \int_0^x \Phi\ (\ t\ - \tau) d\zeta + \mu x \quad \ldots\ldots Eq\ldots.(1)$$

Where q is water supply amount per unit time (discharge), Φ (T) = $\alpha_0 T^{\beta_0}$ is cumulative infiltration amount in time T, $\alpha_0 = \alpha/(1+\beta)$, $\beta_0 = 1+\beta$, α and β are intake coefficients, x is water advance distance, t is the time of water applied, τ is arrival time when reach to ζ (advance distance), μ is average cross-sectional area of surface flow. The analytical solution of the above integral equation (Shirai, 1968) can be expressed as:

$$\upsilon = x/t,\ \upsilon_o = q/\mu,\ \zeta = \zeta_o\ t^{1+\beta} \ldots\ldots\ldots\ldots Eq.\ (2)$$

$$\zeta_o = \alpha\Gamma(1+\beta)/\mu, \quad \upsilon/\upsilon_0 = F \quad \ldots\ldots\ldots\ Eq.\ (3)$$

When ζ is small (ζ <1),

$$F = 1 - \frac{\zeta}{\Gamma(3+\beta)} + \frac{\zeta^2}{\Gamma(4+2\beta)} - \cdots = \sum \frac{(-1)^n \zeta^n}{\Gamma(n+2+n\beta)} \ldots\ldots\ldots Eq.\ (4)$$

When ζ is large (ζ >1),

$$F = \frac{1}{\Gamma(1-\beta)}\frac{1}{\zeta} - \frac{1}{\Gamma(-2\beta)}\frac{1}{\zeta^2} + \frac{1}{\Gamma(-1-3\beta)}\frac{1}{\zeta^3} \cdots + \frac{(-1)^n}{\Gamma(1-n-n\beta-\beta)}\frac{1}{\zeta^{n+1}} + \cdots \ldots\ldots Eq.\ (5)$$

Where υ is velocity of water advance (m/s), x is advance distance (m), t is required for water advance to reach distance of x in furrow (s), υ_0 is initial velocity of water advance at inlet furrow and Γ is gama function.

This mathematical model was used in this work to conduct numerical experiments to determine optimum irrigation discharge. This equation was applied to determine intake coefficients and estimate distribution of infiltration amount under furrow irrigation. This calculation procedure is shown in Fig. 4-1. Finally an optimum irrigation discharge for tomato crop was found based on application efficiency under furrow irrigation with different discharge.

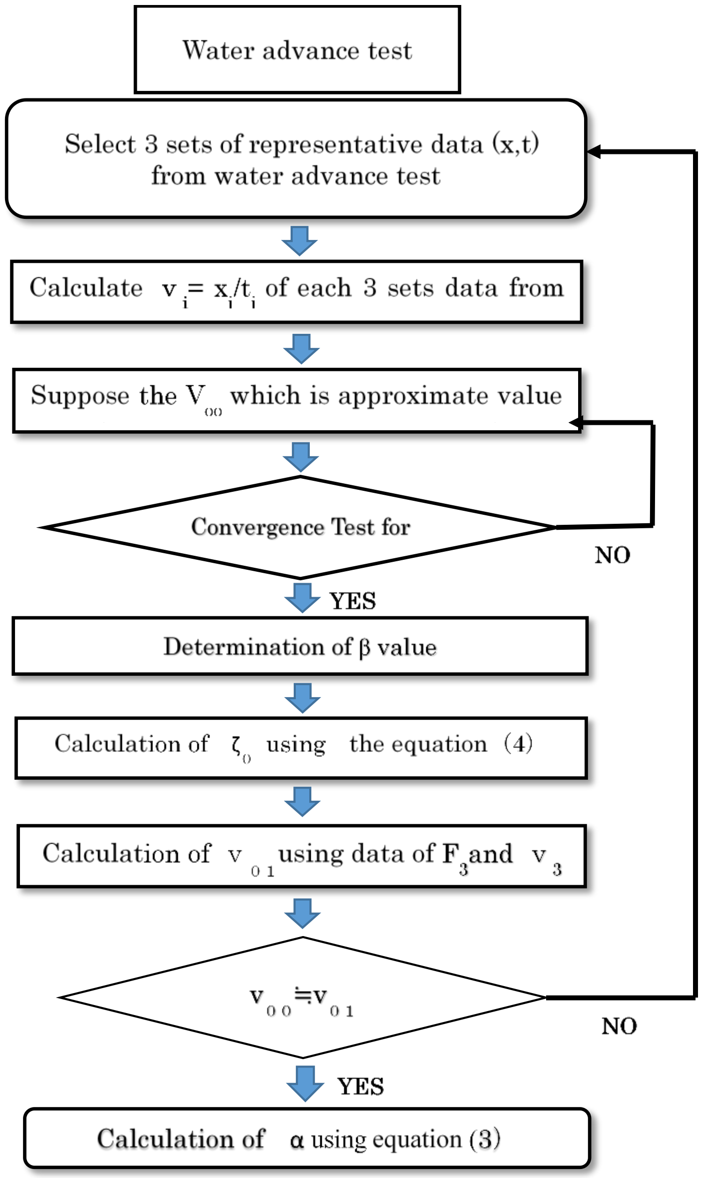


Fig. 4-1 Flow chart of calculating intake coefficients on α and β

4.2.2 Field measurement

Water advance test was conducted at the Badam Bagh Agricultural Expirement station in Kabul where is located in north part of Kabul, the total area of farm is around 80 ha, the area is semi-arid with average annual rainfall of 350 mm. The soil type is clay loam, determined using the textural triangle classification of the International Society of Soil Science. Soil pH is 8. As shown in Fig. 4-2, a furrow was 40 m in long with 0.2 m high bed, 0.7 m in surface width and 0.3 m in depth. Average slope of furrow was approximately flat with 0.02 % along the direction of irrigation, (Fig. 4-3, 4-4, 4-5).

In this upland field, tomato was cultivated under furrow irrigation. Irrigation water was taken from a deep well in this station. When water advance reached at the end of furrow, irrigation water was immediately stopped. The irrigation discharge for tomato crop was 0.00148 m^3/s, usually like this amount of discharge farmer's irrigated agricultural field. Reaching time of water advance was measured at each 5 m distance along furrow in order to calculate intake coefficients (α, β) and cumulative infiltration amount. To measure soil moisture content, soil sample were taken at 0.05 m in depth at each 5 m interval before and after conducting water advance test.

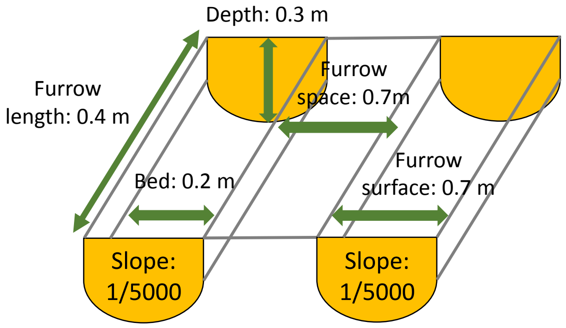


Fig. 4-2 Furrow and Furrow design

Fig. 4-3 Furrow length 40 m and slope 0.02 %

Fig. 4-4 Furrow surface width 0.7 m

Fig. 4-5 Furrow bed width 0.2 m

4.2.3. Calculation of crop water requirement

Crop water requirement is calculated from FAO Crop Wat 8.0 using the following procedure. By adding monthly minimum temperature, maximum temperature, humidity, wind and sun shine hour, which were collected from meteorological station in the research center, the monthly ET_o mm per day is found. As well as by adding the value of Kc 0.60 for initial stage, 1.15 for development up to mid-season and 0.80 for late season, and stage of growing is 30 days initial stage, 40 days development stage , 45 days mid-season stage and 30 days late season stage, total growing stage equal to 145 days. root depth in the initial stage was 0.25 m and mid-season 0.40 m, critical depletion (fraction) was 0.30 in initial stage, 0.40 in mid-season stage and 0.50 in late season stage, yield response fraction was 0.50 in initial stage, 0.60 development stage, 1.10 mid-season stage and 0.80 in late season stage and crop height was 0.60 m in mid-season stage, the harvest date is found, which is 22/08. And then monthly rain data was added, this was collected from rain gauge, the amount is as follows; 30, 44 ,41.5, 21, 50.5, 0.2, 27, 26.5, 7 mm in January, February, March, April, May, June, July, August and September respectively (Fig. 4-6, 4-7), after which, irrigation requirement of tomato for each decade of month is calculated to get the tomato crop water requirement for the first decade of August, which is 42.6 mm (4.26 mm per day). For Irrigation interval of 7 days (Fig. 4-8).

Crop water consumption =irrigation interval × crop water requirement per day. Crop water consumption= 7×4.26 mm= 29.82 mm,

To convert to meters, divide by 1,000, in this case, 29.82/1,000= 0.0298 m. Average furrow width is 0.45 m, in this case Average furrow width ×crop water consumption for 7 days, 0.45× 0.0298= 0.0134 m^2

Necessary amount of water (m^2) is $13.4 x 10^{-3}$.

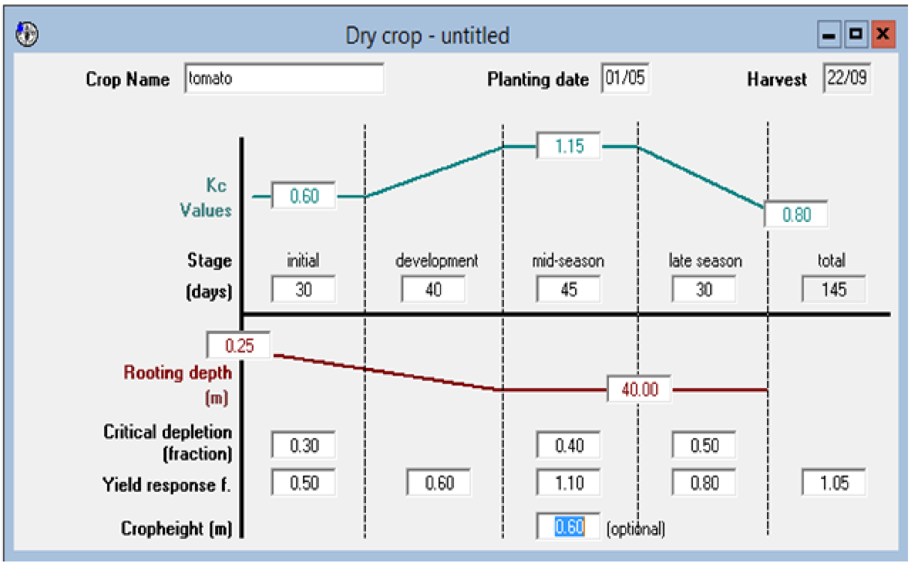
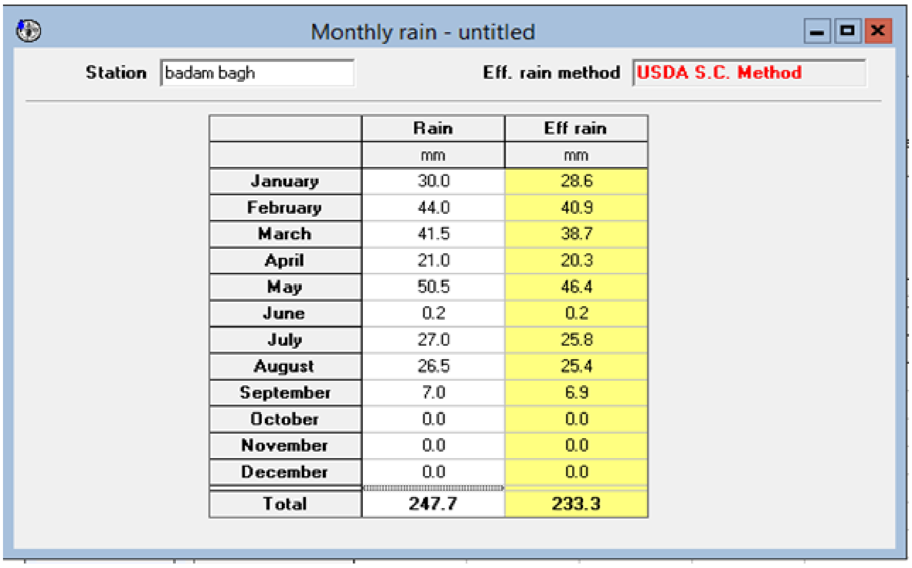


Fig. 4-6 Tomato growth stage and time of harvest in this experimental station

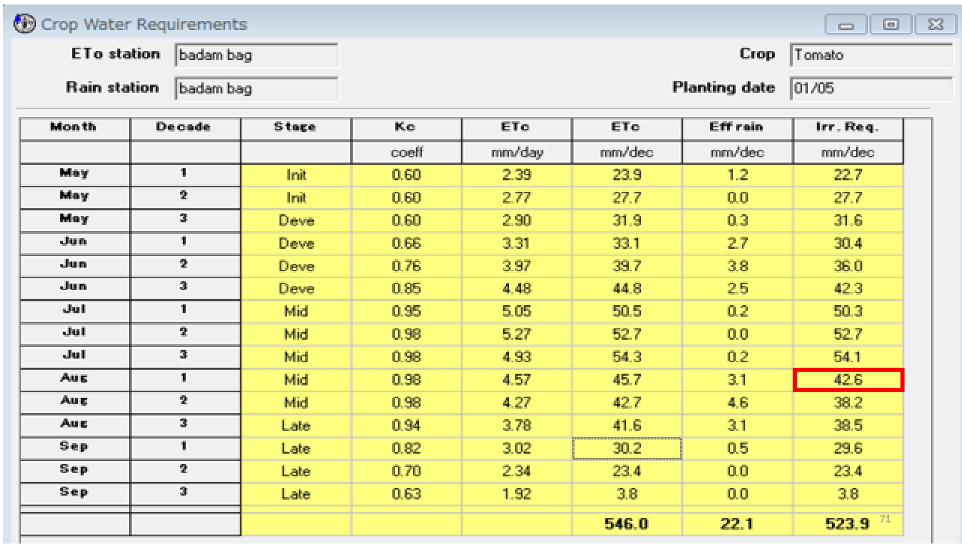


Monthly rain - untitled

Station: badam bagh | Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	30.0	28.6
February	44.0	40.9
March	41.5	38.7
April	21.0	20.3
May	50.5	46.4
June	0.2	0.2
July	27.0	25.8
August	26.5	25.4
September	7.0	6.9
October	0.0	0.0
November	0.0	0.0
December	0.0	0.0
Total	247.7	233.3

Fig. 4-7 Monthly rainfall in this experimental station



Crop Water Requirements

ETo station: badam bag | Crop: Tomato

Rain station: badam bag | Planting date: 01/05

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.60	2.39	23.9	1.2	22.7
May	2	Init	0.60	2.77	27.7	0.0	27.7
May	3	Deve	0.60	2.90	31.9	0.3	31.6
Jun	1	Deve	0.66	3.31	33.1	2.7	30.4
Jun	2	Deve	0.76	3.97	39.7	3.8	36.0
Jun	3	Deve	0.85	4.48	44.8	2.5	42.3
Jul	1	Mid	0.95	5.05	50.5	0.2	50.3
Jul	2	Mid	0.98	5.27	52.7	0.0	52.7
Jul	3	Mid	0.98	4.93	54.3	0.2	54.1
Aug	1	Mid	0.98	4.57	45.7	3.1	42.6
Aug	2	Mid	0.98	4.27	42.7	4.6	38.2
Aug	3	Late	0.94	3.78	41.6	3.1	38.5
Sep	1	Late	0.82	3.02	30.2	0.5	29.6
Sep	2	Late	0.70	2.34	23.4	0.0	23.4
Sep	3	Late	0.63	1.92	3.8	0.0	3.8
					546.0	22.1	523.9

Fig. 4-8 Calculation of crop water requirement by FAO Cropwat

4.3. Results and discussion

4.3.1 Water advance test and intake coefficient

The actual farmer's irrigation water discharge was 0.00148 m^3/s, the three representatives data were x_1 t_1, x_2 t_2, and x_3 t_3, and the velocity advance test(v_1, v_2, v_3) were 0.0603, 0.0730 and 0.1 m/sec respectively (Table 4-1). The intake coefficients of α and β were $4x10^{-4}$, -0.4988, respectively. The average sectional area of the surface stream (μ) was $9.6786x10^{-3}$. The result of water advance test with actual farmer's irrigation water discharge was shown in Table 4-2 which the target area was irrigated in 627 seconds.

Table 4-1 Mathematical analysis of the three representatives' data and intake coefficient

Date:	2014/08/06	q (discharge) : 0.00148 m^3/sec		Place : Afghanistan		Slope : 1/5000		
x1	T1	v1	X2	T2	v2	x3	T3	V3
35	580	0.0603	20	274	0.0730	10	100	0.1

Table 4-2 Result of water advance test with q= 0.00148 m^3/s

Advance distance (m)	water advance time(s)
0	0
5	40
10	100
15	174
20	274
25	378
30	486
35	580
40	627

4.3.2 Cumulative infiltration water amount

When water advance reached the end of the furrow, irrigation was immediately stopped. At this period total amount of irrigation water (qt) was 9.338×10^{-1} m^3. Amount of water infiltrated into soil layer (S_1) was calculated using Simpson rule. The infiltrated amount of water was 5.430×10^{-1} m^3 and amount of remaining surface water in 40 meters length of furrow (μx) was 3.991×10^{-1} m^3. After remaining surface water amount (S_2) was infiltrated into the soil layer. Total amount of irrigation discharge (qt) was 9.338×10^{-1} m^3. The amount of infiltrated (S_1+S_2) was 9.335×10^{-1} m^3. The relationship between total water supply (qt) and total infiltration amount (S_1+S_2) is as follows:

$$qt = 9.338 \times 10^{-1}\ m^3 \fallingdotseq S_1+S_2 = 9.335 \times 10^{-1}\ m^3$$

It shows that two values are approximately equal. Table 4-3 shows water infiltration amount by Simpson's rule. Cumulative infiltration amount of water was calculated at each 5m distance (Table 4-4)

4.3.3 Application efficiency of actual Irrigation water

Percent of application efficiency calculated by the following formula:

Application efficiency % = amount of water stored in the effective soil layer-÷total water supply

$$=0.0134 \times 40 \div q\ t \times 100 = 0.537 \div 0.9335 \times 100 = 57.4\ \%$$

Application efficiency value of furrow irrigation managed by local farmer was 57.4 % as shown in Fig. 4-9. In order to determine the maximum value of irrigation application efficiency, we calculated the distribution of infiltration amount with different irrigation discharge such as 0.0011, 0.002, and 0.003 m^3/s in order to compare application efficiency to conventional irrigation discharge (0.00148 m^3/s). Crop water requirement for tomato was 4.2 mm/day on August 2014 using FAO CROPWAT program 8.0. Growing period of tomato was in mid-season. Irrigation interval was 7 days which is same as farmers' vegetable crop irrigation interval. Crop water requirement for a furrow was 0.0134 m^2.

Table 4-3 Water infiltration amount by Simpson's rule

Simpson's rule	S1	μL	qt	S1+μL	Simpson's rule	S1+S2	ΔT
0.194453407	0.54295	0.39915	0.933829	0.9421	0.214589436	0.93355	589
0.170203403					0.232009998		
0.125708727					0.239445387		
0.052585808					0.247505263		

Table 4-4 Result of water advance test and calculation of cumulative infiltration amounts, q= 0.00148 m^3/s

Advance distance (m)	Infiltration time (s)	Cumulative infiltration
0	627	0.0201626
5	587	0.0195072
10	527	0.0184808
15	453	0.0171309
20	353	0.0151175
25	249	0.0126911
30	141	0.0095432
35	47	0.0055021
40	0	0

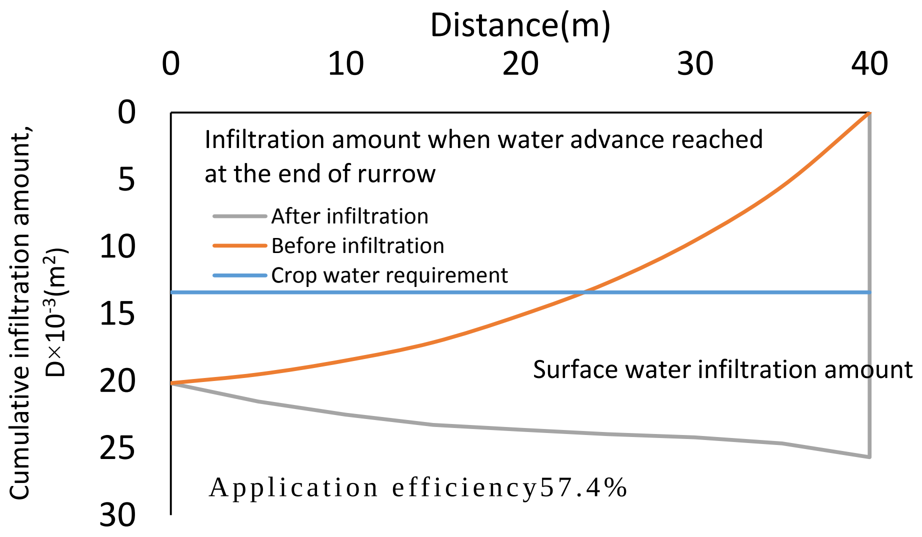


Fig. 4-9 Actual infiltration amount, q= 0.00148 m^3/s

4.3.4 Simulation water advance test and intake coefficient

(1) q= 0.0011 m^3/sec

In order to determine the maximum value of irrigation application efficiency, we are calculated the distribution of infiltration amount using 0.0011 m^3/s which is lower than actual irrigation discharge, we selected three representatives data of x_1 t_1, x_2 t_2, and x_3 t_3, the velocity advance test were 0.04902, 0.06578 and 0.084 m/sec respectively (Table 4-5). The intake coefficients of α and β were $4x10^{-4}$, -0.5023, respectively. The average sectional area of the surface stream (μ) was $7.3304x10^{-3}$. The result of water advance test with estimating irrigation water discharge is as shown in Table 4-6, where the target area was irrigated in 899 seconds.

Table 4-5 Mathematical analysis three representatives' data and intake coefficient

Date: 2014/08/06 q : 0.0011m^3/sec Place: Afghanistan Slope: 1/5000

x 1	T1	v 1	X2	T2	v 2	x 3	T3	v 3
35	714	0.0490	20	304	0.0658	10	119	0.0840

Table 4-6 Result of water advance test with q= 0.0011 m^3/s

Advance distance (m)	water advance time(s)
0	0
5	49
10	119
15	204
20	304
25	421
30	556
35	714
40	899

By using irrigation water discharge of 0.0011 m^3/s, the total amount of irrigation water at the end of the furrow (qt) was 9.89×10^{-1} m^3. Amount of water infiltrated into soil layer (S_1) was calculated using Simpson's rule and found to be 7.073×10^{-1} m^3 and the amount of remaining on the surface of the 40 meters length of furrow (μx) was 2.932×10^{-1} m^3. After time (ΔT) which is 660 sec the remaining surface water amount (S_2) was infiltrated into the soil layer. Total amount of irrigation discharge (qt) was 9.89×10^{-1} m^3. The amount of infiltrated ($S_1+ S_2$) which is equal to 9.9×10^{-1} m^3. The relationship between total water supply (qt) and total infiltration amount (S_1+S_2) is as follows

$$qt = 9.338 \times 10^{-1}\ m^3 \fallingdotseq S_1+S_2 = 9.9 \times10^{-1}\ m^3$$

It shows that two values are approximately equal as shown in Table 4-7. Cumulative infiltration amount of water were calculated at each 5 m distance (Table 4-8).

Application efficiency of Irrigation water

Percent of application efficiency calculated by the following formula:

Application efficiency % = amount of water stored in the effective soil layer- ÷total water supply

$$=0.0134 \times40 \div qt \times 100 = 0.537 \div 0.9891 \times 100 = 54.2\%$$

Application efficiency value of furrow irrigation with estimating irrigation water discharge 0.0011 m^3/s was 54.2 % as shown in Fig. 4-10.

Table 4-7 Water infiltration amount by Simpson's rule

Simpson's rule	S	μL	qt	S+μL	Simpson's rule	S1+S2	ΔT
0.207006441	0.64148	0.29322	0.989	0.9347	0.248043901	1.04699	660
0.188076944					0.262761663		
0.156886097					0.269304398		
0.089514671					0.266878707		

Table 4-8 Calculation result of cumulative infiltration amount, q= 0.0011 m^3/s

Advance distance (m)	Infiltration time(s)	Cumulative infiltration amount(m^2)
0	899	0.0241541
5	850	0.023485
10	780	0.0224947
15	695	0.0212305
20	595	0.01964
25	478	0.0175985
30	343	0.0149013
35	185	0.0109351
40	0	0

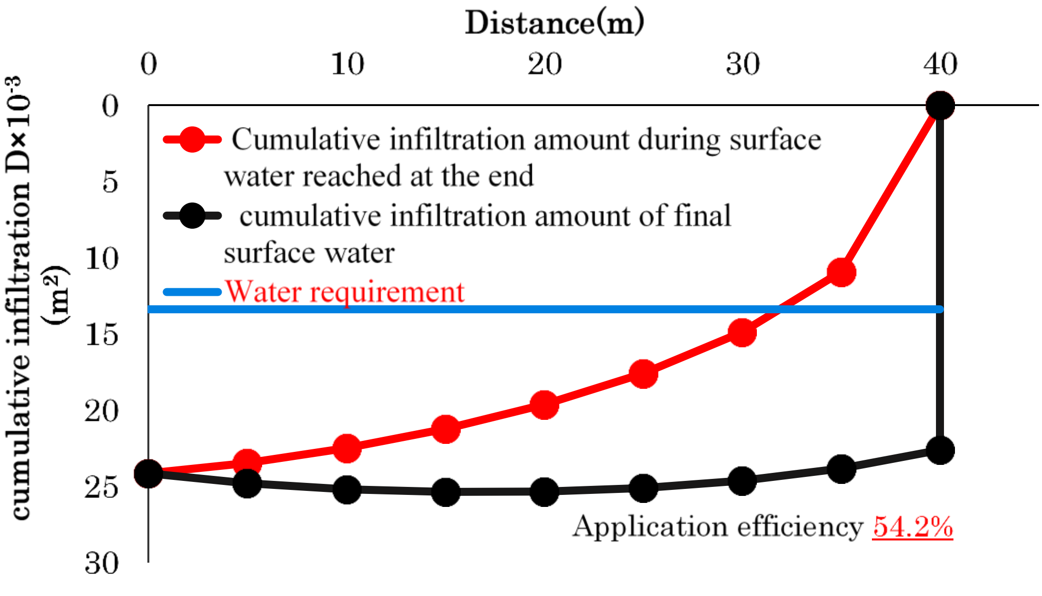


Fig. 4-10 Simulation infiltration amounts, q= 0.0011 m^3/s

Water advance test and intake coefficient

(2)q= 0.002 m^3/sec

To find the maximum value of irrigation application efficiency, we are calculated the distribution of infiltration amount using 0.002 m^3/s which is higher than actual irrigation discharge, we selected three representatives data of x_1 t_1, x_2 t_2, and x_3 t_3, the velocity advance test were 0.0954, 0.1149 and 0.1370 m/s respectively Table 4-9. The intake coefficients of α and β were $4x10^{-4}$, -0.4979, respectively. The average sectional area of the surface stream (μ) was $9.6786x10^{-3}$. The result of water advance test with estimating irrigation water discharge is shown in Table 4-10 where the target area was irrigated in 442 seconds.

Table 4-9 Mathematical analysis three representatives' data and intake coefficient

Date :	2014/08/06	q (discharge) : 0.002m^3/sec		Place : Afghanistan		Slope : 1/5000		
x1	T1	v1	X2	T2	v2	x3	T3	V3
35	367	0.0954	20	174	0.1149	10	73	0.1370

Table 4-10 Result of water advance test with q= 0.002 m^3/s

Advance distance (m)	water advance time(s)
0	0
5	33
10	73
15	121
20	174
25	233
30	297
35	367
40	442

By use of irrigation water discharge of 0.002 m^3/s the water that reached the end of the furrow (qt) was $8.84x10^{-1}$ m^3. Amount of water infiltrated into soil layer (S_1) was calculated using Simpson's rule and found to be $4.843x10^{-1}$ m^3 and remaining water on the surface in the 40 m length of furrow (μx) was $3.871x10^{-1}$ m^3. After time (ΔT) 567 sec, the remaining surface water amount was infiltrated (S_2) into the soil layer. Total amount of irrigation discharge (qt) was $8.84x10^{-1}$ m^3. The amount of infiltrated water (S_1+S_2) was $8.85x10^{-1}$ m^3. The relationship between total water supply (qt) and total infiltration amount (S_1+S_2) is as follows, qt= $8.84x10^{-1}$ m^3 ≒ S_1+S_2 = $8.85x10^{-1}$ m^3. It shows that two values are approximately equal as shown in Table 4-11.

Cumulative infiltration amount of water were calculated at each 5 m distance (Table 4-12). Application efficiency of estimating Irrigation water discharge 0.002 m^3/sec.

Application efficiency % = amount of water stored in the effective soil layer- ÷ total water supply= 0.0134 x 40÷ qt x 100= 0.537 ÷ 0.8852 x 100= 60.5 %

Application efficiency value of furrow irrigation with estimating irrigation water discharge 0.002 m^3/s was 60.5 % as shown in Fig. 4-11.

Table 4-11 Water infiltration amount by Simpson's rule

Simpson's rule	S	μL	qt	S+μL	Simpson's rule	S1+S2	ΔT
0.16298333	0.48571	0.38715	0.884	0.8728	0.18564658	0.87268	567
0.144232171					0.21115099		
0.115878359					0.230492156		
0.062616381					0.245393772		

Table 4-12 Calculation result of cumulative infiltration amount, q= 0.002 m³/s

Advance distance (m)	Infiltration time(s)	Cumulative infiltration amount(m^2)
0	442	0.016921
5	409	0.016276
10	369	0.015457
15	321	0.014414
20	268	0.013168
25	209	0.011625
30	145	0.009678
35	75	0.006955
40	0	0

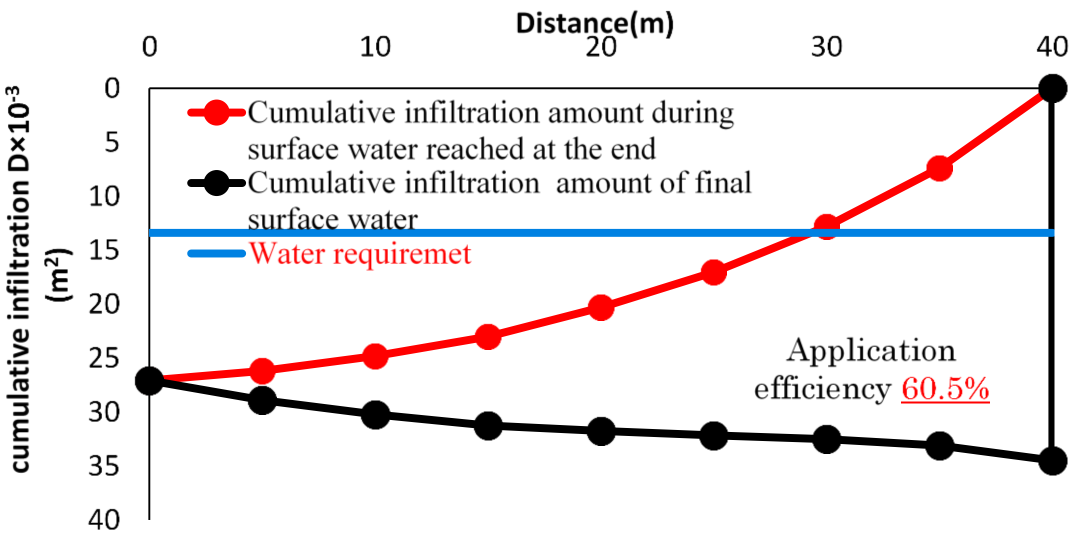


Fig. 4-11 Simulation infiltration amounts, q= 0.002 m³/s

(3)q= 0.003 m^3/sec

In order to determine the maximum value of irrigation application efficiency, we are calculated the distribution of infiltration amount using 0.003 m^3/s which is higher than actual irrigation discharge, also three representatives data of x_1 t_1, x_2 t_2, and x_3 t_3, were selected, the velocity advance test were 0.1357, 0.1550 and 0.1754 m/sec respectively (Table 4-13) The intake coefficients of α and β were $4x10^{-4}$, -0.4952, respectively. The average sectional area of the surface stream (μ) was $1.2312x10^{-3}$. The result of water advance test with estimating irrigation water discharge is as shown in Table 5-14. The target area was irrigated in 306 seconds.

Table 4-13 Mathematical analysis three representatives' data and intake coefficient

Date :	2014/08/06	q (discharge) : 0.003m^3/sec		Place : Afghanistan		Slope : 1/5000		
x1	T1	v1	X2	T2	v2	x3	T3	V3
35	258	0.1357	20	129	0.1550	10	57	0.1754

Table 4-14 Result of water advance test with q= 0.003 m^3/s

Advance distance (m)	water advance time(s)
0	0
5	26
10	57
15	91
20	129
25	169
30	212
35	258
40	306

By using irrigation water discharge of 0.003 m^3/s the, amount of irrigation water (qt) that reached the end of the furrow was 9.18 x 10 $^{-1}$ m^3. Amount of water infiltrated into soil layer (S_1) was calculated using Simpson's rule and found to be 4.127x 10^{-1} m^3 and amount of water remaining on the surface of 40 m length furrow (µx) was 4.925 x10^{-1} m^3. After the remaining surface water amount (S_2) was infiltrated into the soil layer. Total amount of irrigation discharge (qt) was 9.18 x 10^{-1} m^3. The amount of infiltrated water (S_1+ S_2) was 9.05 x 10^{-1} m^3. The relationship between total water supply (qt) and total infiltration amount (S_1+S_2) is as follows qt= 9.18 x 10^{-1} (m^3)≒ S_1+S_2= 9.05 x 10^{-1} (m^3). It shows that two values are approximately equal as shown in Table 4-15.

Cumulative infiltration amount of water were calculated at each 5 m distance (Table 4-16).

Application efficiency of Irrigation water

Percent of application efficiency calculated by the following formula:

Application efficiency % = amount of water stored in the effective soil layer- ÷total water supply

=0.0134 ×40÷ q t ×100 = 0.537 ÷ 0.9052 × 100 = 59.2%

Application efficiency value of furrow irrigation with estimating irrigation water discharge 0.003 m^3/s was 59.2 % as shown in Fig. 4-12, and Table 4-17 show application efficiency of actual and simulation water discharge.

Table 4-15 Water infiltration amount by Simpson's rule

Simpson's rule	S	μL	qt	S+μL	Simpson's rule	S1+S2	ΔT
0.141045002	0.41277	0.4925	0.918	0.90525	0.172605177	0.90525	633
0.123018134						0.21336	
0.097254527						0.24596	
0.051451307						0.27333	

Table 4-16 Calculation result of cumulative infiltration amounts, q= 0.003 m^3/s

Advance distance (m)	Infiltration time(s)	Cumulative infiltration amount(m^2)
0	306	0.0141
5	280	0.0135
10	249	0.0127
15	215	0.0118
20	177	0.0107
25	137	0.0094
30	94	0.0078
35	48	0.0056
40	0	0

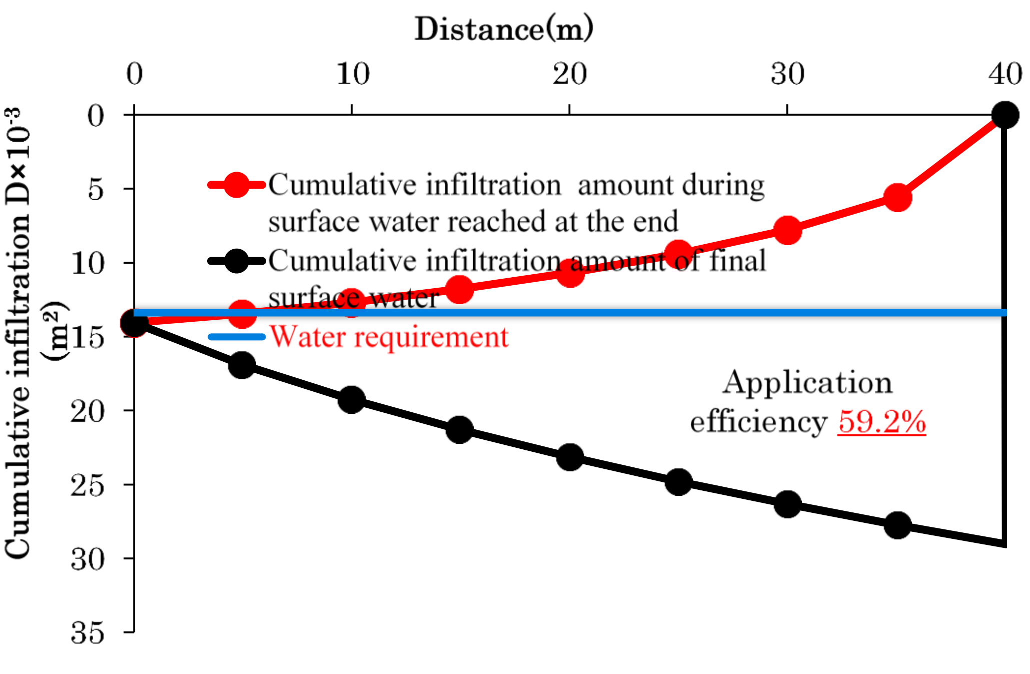


Fig. 4-12 Simulation infiltration amounts, q= 0.003 m^3/s

Table 4-17 Application efficiency of actual and different water discharge

Discharge (m^3 /s)	Application efficiency (%)
1.10×10^{-3}	54.2
1.48×10^{-3}(actual water discharge)	57.4
2.00×10^{-3}	60.5
3.00×10^{-3}	59.2

Verification of water saving

It shows that the conventional irrigation water amount in one furrow with length of 40 m is equal to 0.934 m^3. According to results of estimating the optimum irrigation water discharge in furrow with same furrow size, it is equal to 0.883 m^3. Difference of total amount of irrigation water between conventional irrigation method managed by farmer and optimum irrigation water by simulation is equal to 0.051 m^3. This values are little amount of water for one furrow. However, it is supposed to calculate irrigation water amount for one hectare land with under 40m in length under furrow irrigation. If we finally consider irrigating tomato field in one hectare land which has 100 furrow lines with length of 40 m and under water discharge 0.002 m^3/s. it could be saved 5.1 m^3 per hectare of irrigation water amount compared to existing irrigation condition in each irrigation scheduling (Fig. 4-13).

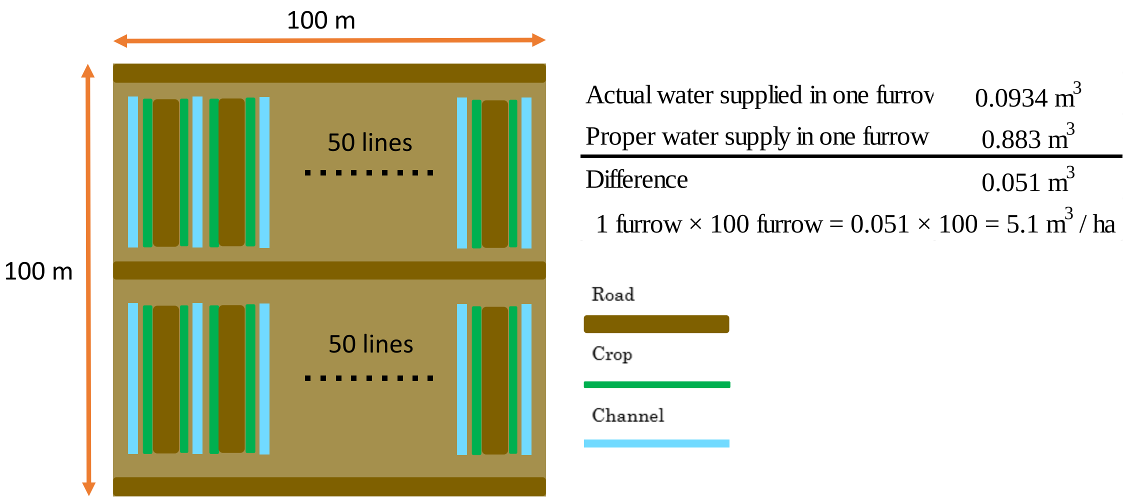


Fig. 4-13 Agriculture field layout

4.4 Conclusions

Water management under arid and semi-arid zone in irrigated agriculture includes multiple faces, one of them is a modified water discharge in furrow irrigation system in Afghanistan to reduce runoff losses and deep percolation. The use of measured water flows proved vital for application efficiency. In this study actual water discharge was 0.001489 m^3/s which are used by local farmers in their land after irrigation, and infiltration of water in the furrow of agriculture field is calculated as well as application efficiency of actual water discharge is determined. The application efficiency was found to be 57.4 %. By estimation of 0.0011 m^3/s, 0.002 m^3/s, and 0.003 m^3/s water discharge application efficiency improved a different percentage. Especially irrigation discharge of 0.002 m^3/s had the highest application efficiency value, water discharge application efficiency were 60.5 %. This water advance approach can be applicable to estimate optimum irrigation discharge for furrow irrigation. This is 3.1 % higher than actual water discharge. Based on the data obtained it was estimated to save 5.1 m^3/ha of water in one irrigation scheduling time. Under the irrigation with 100 lines with 40 m long furrow. This method can be applicable in estimation of optimum irrigation discharge for furrow irrigation. For more details it is important to conduct further research in other crops to propose the best practice for reducing amount of irrigation water for furrow irrigation.

References of this chapter

Asad Sarwar 2002. *Water resource management in Afghanistan,* International water management institute (IWMI), Working paper 49.

Azizi, Dr. Pir Mohammad, 2009, Special lecture on water resources in Afghanistan, Ministry of Irrigation , Water Resources and Environment, Kabul, Afghanistan.

Carter D L 1993. Furrow irrigation erosion lowers soil productivity. Journal of Irrigation and Drainage Engineering, 119, pp.964-974.

Christiansen,J. E., Bishop, A. A., Kiefer, F. W., Fok, Y. S., 1966. Evaluation of intake rate constants as related to advance of water in surface irrigation. Trans, ASAE 9 (5), pp.671-674.

Don Tiffin, ADAS, .John King, ADAS, Stephen Perkins, ADAS 2003. Irrigation best practice a water management toolkit for field crop growers. Department for environment food and rural affairs, Grandfield University and Natural England.

Esfandiari.M, Maheshwari.B.L, 1997. Application of the optimization method for estimating infiltration characteristics in furrow irrigation and its comparison with other methods. Agricultural water management 34, pp.169-185.

Esfandiari.M, Maheshwari.B.L, 2001. Field Evaluation of furrow irrigation models. Agricultural Engineering 79(4), pp.459-479.

Jose Antonio Rodriguez Alvarez 2003. Estimation of advance and infiltration equation in furrow irrigation for untested discharges. Agriculture water management 60, pp.227-239.

Holzapfel.E.A, Jara.J, Zuniga.C,Marino. M.A, 2004. Infiltration parameters for furrow irrigation. Agriculture water management 68, pp.19-32.

Holzapfel, E., Marino, M.A., Chavez, J, 1984. Comparison and selection of furrow irrigation models. Agricultural Water Management. 9, pp.105–125.

Holzapfel, E., Marino, M.A., Valenzuela, A., D´ıaz, F., 1988. Comparison of infiltration measuring methods for surface irrigation. Journal of Irrigation and Drainage. Engineering. ASCE 114, pp.130–141.

Koech .R.K, Smith.R.J, Gillies.M.H, 2014. Evaluation the performance of a real –time optimization system for furrow irrigation, agriculture water management 142, pp.77-87.

Karmeli, D., Salazar, L., Walker,W., 1978. Assessing the spatial variability of irrigation water application. Office of Research and Development US Environmental Protection Agency, Oklahoma, USA.

Keshawarz, Saleh M. 2002. Rapid assessment of water sector, Afghanistan, United States Agency for International Development (USAID).

Merriam, J, L., Keller, J., 1978. Farm irrigation system evaluation: A Guide for Management, 3rd. ed. Utah State University, Logan, Utah, 285p.

Meek,B.D., DeTAR.W.R., Rolph.D., Rechel.R.E., CARTER.L.M., 1990. Infiltration rate as affected by an alfalfa and no-till cotton cropping system, soil science society of America journal volume54, pp.505-508.

Raghuwanshi.N.S.and Wallender.W.W, 1998. Optimal Furrow Irrigation Scheduling under Heterogeneous conditions, Agricultural system, Vol.58, No.1, pp.39-55.

Shirai K. 1968. An analysis on surface irrigation (II), Journal of Agricultural Science, Mie University, Vol.37, pp.55-66.

Strelkoff, T., 1985. BRDRFLW. A Mathematical Model of Border Irrigation. USDA, ARS, p. 100.

Watanabe F., Shirai K., Takahashi S. and Sasaki T. 1996. Determination of coefficients of intake rate using water advance velocity, International conference on agricultural engineering, Madrid, Proceeding 96C-049, pp.623-624.

Zimbelman D. D. 1987. Planning, operation, rehabilitation, and automation of irrigation water delivery systems. Proceeding of a symposium ASCE.

Chapter 5

Effect of mulching with film of different colors on soil temperature and yield of tomato

5.1 Introduction

5.1.1 Background

Afghanistan is a semi-arid land lock country and it is located in central Asia. Covering area of about 652,225 km^2 (Naseri). Afghanistan stretches between 29^o 35'and 38^o 40' latitude to 60^o 31' and 74^o 55' of the longitude. With a total of 55.29 km of border, the longest being 2,640 km bordering Pakistan to the south and stretching through southeast to the eastern part of Afghanistan. It is also bordered to the west by Iran (930 km) and to the north by central Asia states of Tajikistan (1,206 km), Turkmenistan (744 km) and Uzbekistan (137 km). Afghanistan is northeast border is on its eastern frontier with china (76 km) (Fig. 5-1). The eastern part of Afghanistan is a region of swift – flowing, river, green and fertile valleys. Highlands's deserts make the south and south west. Mostly rugged mountain. Afghanistan is characterized by a continental climate, although the presence of mountains causes many local variations. The typical climate varies from arid in the south and southwest to semi–arid in most other parts of the country (Olaf Thieme., 2006 and asad sarwar Qureshi 2002). The highest point in Afghanistan is now Shaq which attains altitude of 7,492m and the lowest point is Amu Darya with 258 m asl, the annual distribution of precipitation in the more than half of the area receives 100 mm to 300 mm per annum. The remaining 50 % of the country (having altitude of more 2,000m asl) receives 300 mm to 800 mm of precipitation. About 50 % of the precipitation occurs in winter (January to march), much of which falls in the form of snow. A further 30 % falls in spring (April to June) and remaining 20 % during summer and autumn. In Fig.5-2 and 5-3 is shown agro climate of two provinces with different altitude. The daily (20-30 °C) and the seasonal (35-40 °C) variation of temperatures all over the country lead to different lengths of growing seasons, and require a careful selection of the most suitable crop for an area. Annual evapotranspiration rate are relatively low in the Hindu kush (1,000-1,300 mm) because of severe long winters. They vary between 1,300 mm and 1,500 mm in the northern plains and reach up to 1,800 mm in the southern and southwestern plains. However, summer evapotranspiration rates are high showing a daily peak of 6-8 mm in July and August (Fig. 5-4) as recorded in most places.

The agriculture production depends on the availability of water, either as direct rainfall or in the form of irrigation. 1997 FAO survey indicates that an area of 92,000 ha of vegetables were planted in 1976.during this period vegetable area had remained more or less constant at 90,000 ha. the major vegetable crops in Afghanistan include melon 38.0 %, watermelon 18.0 %, onion 12.0 %, potato 12.0 % , tomato 7.4 % (6,660 ha), with these five species representing 87. 4% of the total area under vegetable cultivation (Fig. 5-5). In Afghanistan Tomato (Lycopersicon *esculentum L.*) is one of the important vegetable crops extensively grown during the spring and summer seasons in many regions. The average yield of tomatoes are

10,710 kg/ha (ICARDA, 2003). However, tomato cultivation has many issues due to low temperature in early spring and water deficit in summer, on the other hand, heavy infestation by summer weed is a great problem, since chemical control in fresh market fruits faced with limitations in the above mentioned case tomato yield is very low. To obtain good yield plastic mulch can be used. Plastic mulch application is effective in increasing soil temperature, conserving soil moisture and weed control. Mulch surface color can influence the plant microclimate sufficiently and to affect early yield of fresh market tomato. Color of mulch also affected both the plant light environment and soil temperatures. Plastic mulches affect plant microclimate by modifying the soil energy balance and by restricting soil water evaporation. Modification of these microclimate factors influence soil temperature, which affects plant growth and yield. Increased root-zone temperature (RTZ) is one of the main benefits associated with use of plastic mulches (Wien and Minotti, 1993) significant research during the last 30 years indicates that black mulch is recommended during the spring to warm the soil (Hatt et al., 1995, Lomant, 1993). In the summer and fall, aluminum or white colored mulches are preferred because the mulches heat the soil less than black mulch (Hatt Graham et al., 1995). In addition to soil warming, plastic mulch also modify the light environment around the plant the light reflected from the mulch may affect plant growth and morphogenesis (Decoteau et al., 1989). However, the influence of mulch color on plant responses has been difficult to reconcile. The effect of mulch color on tomato plant growth and yield vary according to the geographic location and season (Csizinszky et al., 1995), suggesting that plants grown on colored mulches respond to factors in addition to the light reflected from the mulch.

The main objectives of this study are to measure the influence of mulch surface color on reflected light and determine the effects of various mulch surface colors on yield of fresh-market tomatoes planted in the spring.

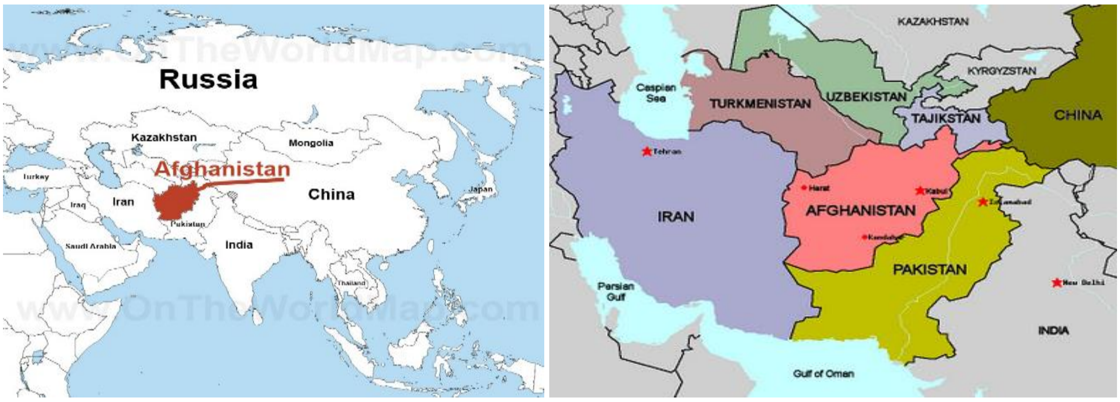


Fig. 5-1 Location and map of Afghanistan

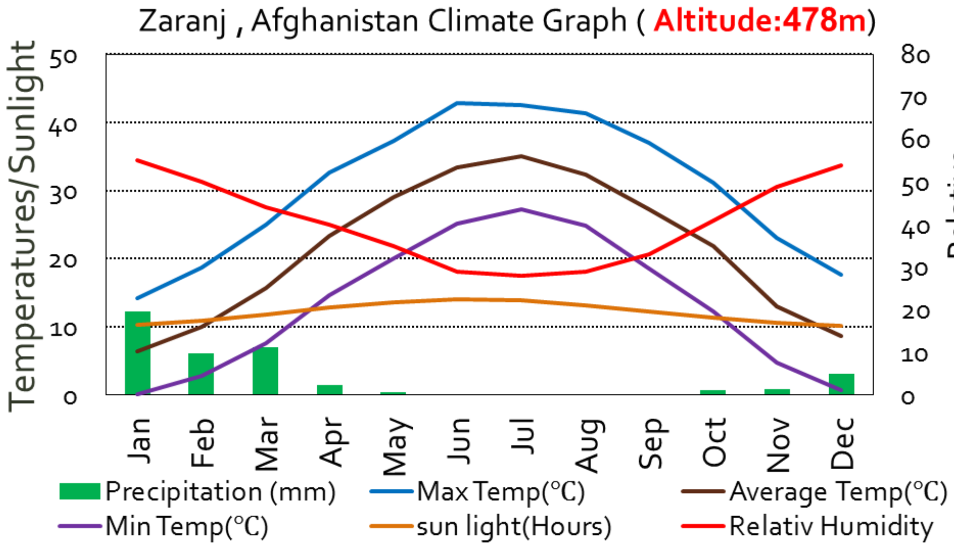


Fig. 5-2 Climate of Zaranj province, Afghanistan

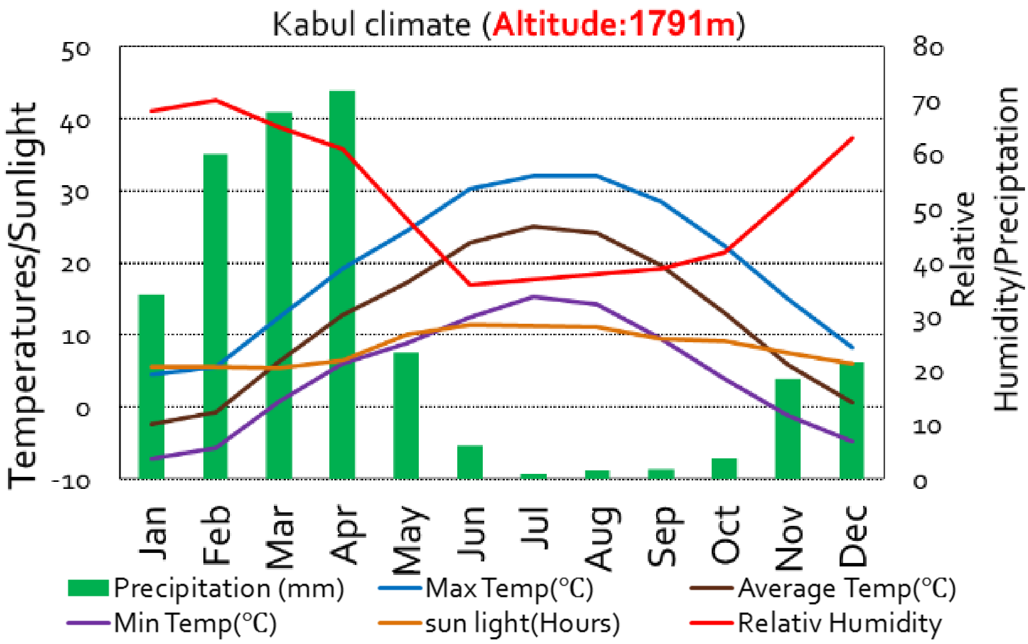


Fig. 5-3 Climate of Kabul province, Afghanistan

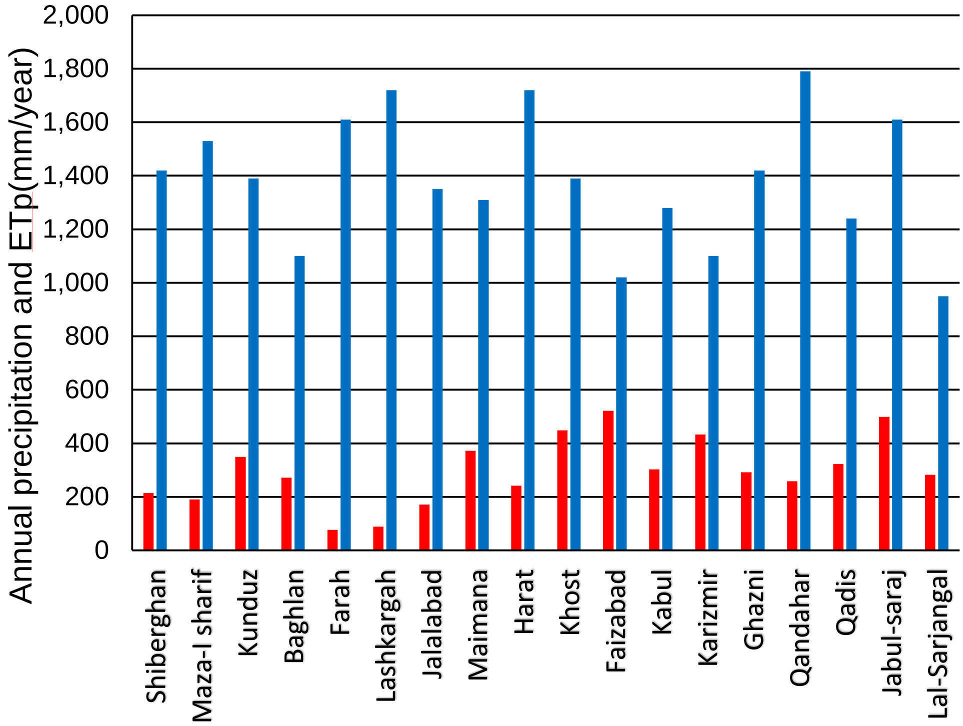


Fig. 5-4 Annual precipitation and evapotranspiration at different location of Afghanistan

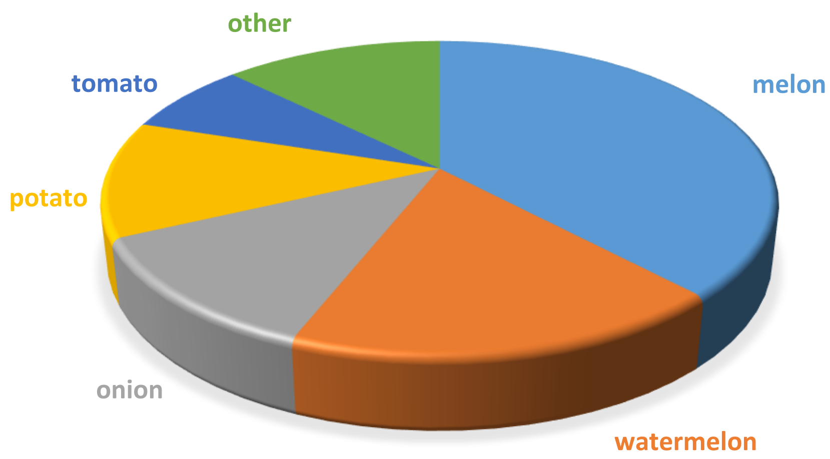


Fig. 5-5 Vegetable growing percentage in Afghanistan

5.2 Materials and Methods

The experiment was conducted during the period of May to October 2009, 2010 and 2011 for three years at the Qargha research station of Kabul- Afghanistan (latitude 34° 54 N, longitude E 69° 8 E, elevation 1,834 m). Soil textural of the experimental field was sandy loam using the textural triangle classification of the international society of soil science. Soil pH was 8. The experiment design was a randomized complete block with three replications. Three mulching treatments (black, red and white) along with a control (bar soil) experiment layout map is shown in Fig. 5-6. The experiment plot consisted of 27 m-long, 0.7 m-wide, on 0.15 m high raised beds, Intra-row spacing was 0.5 m, Fig. 5-7. Before laying the mulches, fertilizer was applied at the beginning of each fertilizer at average N, P and K rate 80, 80 and 125 kg/ha respectively then disked into the top 0.15 m of soil Fig. 5-8 after which laying the colors plastic mulch to each treatment. Trickle irrigation tubing were applied in all the plots under mulches during the same process, also in the beginning trickle irrigation tube wore connected to valve, for close and open the irrigation water Fig. 5-9. The polyethylene mulch covered beds of 0.7 m wide and 0.15 m high in the field by hand and holes (diameter 0.15 m) on plastic mulch were made for transplanting the plants. Each mulch plot was had 45 holes spaced at 0.6 m apart. Plants were started in a greenhouse around six weeks and transplanted to the surface of soil in the center of a bed on the middle of May in 2009, 2010 and

2011 Fig. 5-10. Water resource was deep well, water was availed to the farm by pumping to reservoir (tank), which was located around three meter higher above soil surface, the capacity of the tank was 2,000 litters Fig. 5-11. Otherwise filter was use to prevent blockage of emitters, and also in each one and half months added two liters of sulfuric acid 96 % in water tank and mixed in two thousand liter water tank and irrigation experiment started. Soil temperatures were measured to a 0.7 m depth from surface in all beds during growing season. For all treatments using soil thermometer one time (9 a.m.) every day. To ascertain the temperature of ground field for a week at a depth of 0.5 m temperature data loggers were installed on august 3 to 10 in all treatments, and each recorded for 10 minutes also to know the exact impact on the soil temperature was studied in 24 hours. Reflected light from each surface color mulch was determined using a pyranometer. Upwardly reflected light was measured at a point 0.2 m above the much surface. Fruit were harvested weekly where yield recorded at each harvest and tomato size classified by USDA measurement, Fig. 5-12. Data were analyzed statistically.

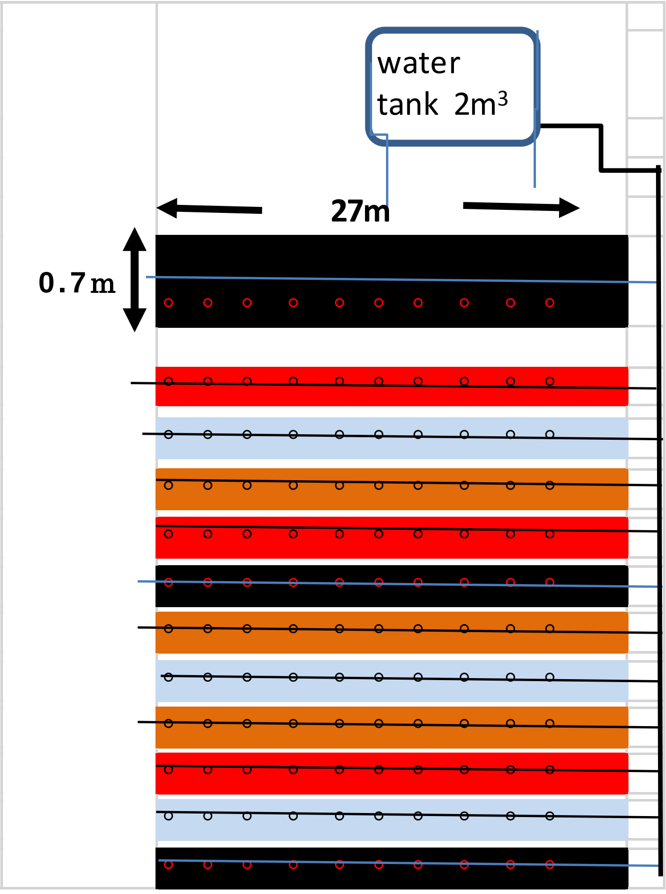


Fig. 5-6 Layout map of experimental field

Fig. 5-7 Preparation of treatment, length 27m and wide 0.7m

Fig. 5-8 Applying chemical fertilizer in the soil

Fig. 5-9 Trickle irrigation tubing were applied, length 27m

Fig. 5-10 Layering plastic mulch, hold and transplanted tomato plant

Fig. 5-11 water tank with filter connected to pipe

Fig. 5-12 Tomato size measure

5.3 Results and discussion

Average air temperature in May reached to 14 °C, and in June and July it rose. The agrometeorological data was recorded every day, and average monthly data was as shown in Table 5-1.From the table 5-2, we find that reflected light of the polyethylene mulch influenced soil temperature and air temperature. The white mulch surface reflected more total photosynthetic light than red and black plastic mulch, the light reflected from the mulch may affect plant growth and morphogenesis.

The soil temperature registered in bare soil were always lower than that of mulch treatment, and the soil temperature under the different mulches was affected by the type of material employed. In the selected measuring dates during the crop cycle, soil temperatures were higher in black polyethylene and followed by red and white. Soil temperature 0.7 m below the black mulch surface averaged almost 1.2 °C higher than the soil temperature below the white mulch surface, the red mulch treatment was cooler than black and coolest under white at 9:30 to 10:00 am every day (Fig. 5-13, 5-14, 5-15). Average daily soil temperatures were 23.3, 22.9, 22.2 °C for black, red and white mulch plot, respectively. Plastic mulch increased soil temperature 2.4 to 4.2 °C as compared to control plot (bare soil) in 2009, 2010 and 2011. The study was extended to clarify and know exact impact of plastic on the soil temperature and studied for a week on August (Fig. 5-16, 5-17). Average daily soil temperature were 31, 30.6, 28.1 and

26.9 °C for black, red, white and bare soil respectively. These increase resulted in higher, clear and dark materials than in the reflective colors such as white or silver aluminum (Csizinzky et al., 1997; Rangarajan and ingall, 2001). In the later, the temperatures can even be lower than in bare soil (Liakatas et al., 1986; Lamont, 1996). The results obtained in this experiment support the previous studies; thus, the soil temperature in bare soil was always lower than under mulches, and the maximum soil temperatures were always attained under the black polyethylene film, followed by the red mulch and white, because these last materials reflect back most of the incoming solar radiation (Ham et al., 1993).

Plant response- mulch color affected photosynthetic partitioning and growth characteristics, but not biomass accumulation in the shoots, plants grown over the white mulch surface had shorter stems and more lateral growth (branching). Red mulch increased early tomato yields, (Coffey et al., 1999, Csizinszky et al., 1995). Increased early and total yield (Kasperbauer and Hunt, 1998: Taber et al 1999). Root zone temperature is important in plant growth and development because it affects physiological processes in roots such as uptake of water and mineral nutrients (Coopr, 1973, Dodd et al., 2000, Tindall et al., 1990). Root zone temperature may also be critical for plant survival, because root have a lower optimum temperature and are less adapted to extreme fluctuations than shoots (Paulsen, 1994) studies at constant root zone temperature indicate that the optimum root zone temperature for mineral nutrient uptake and growth in tomato is between 26 and 34°C (Cooper, 1973, Grosselin and Trudel, 1983, Tindall et al., 1990).

Average daily irrigation water amount in May was 98.9, 100.8, 60.8 mm, in June 106.5, 110.3, 108.4 mm, in July 148.3, 150.2, 152.1 mm, in August 178.7, 161.6, 161.6 mm , and in September 83.7, 85.6, 98.9 mm in 2009, 2010 and 2011 respectively (Fig. 5-18, 5-19, 5-20), Average daily irrigation water amount was 5 mm/day (Fig. 5.21) irrigation and mulch treatment increased the soil moisture content from 0 to 0.12 m depth above the control (Adetunji. A., 1990).tomato extra-large size were 35.4, 28.5, 21.5 and 14.6 % under white, red, black plastic and control respectively, and large size were 30.6, 26.6, 26.3, and 16.5 % under white black red plastic and control respectively. Classification of tomato size shows that the largest fruit produced on the white, black and red mulch, which, was significantly larger than fruit from bare soil or control. Under the white plastic mulch tomato size was larger than under black, red plastic mulch and control (Fig. 5-22). The yield for three years are as shown in Fig. 5-23, 5-24, 5-25. The average yields for this period were 39, 37, 35 and 25 t/ha for white, black, red mulch and control, all colored plastic mulch respectively significantly higher than of control (Fig. 5-26), there was no significant difference in the average fruit weight among mulch treatments. However, Decoteau et al. (1986) obtained the greatest number of fruits on plants in the silver treatments, while the largest fruit were measured in the white mulch treatments. Application of plastic mulches increased the yields compared to non-mulched plots. Higher yields in mulch treatment might be due to its effects on soil temperature, soil moisture and weed suppression. The highest total yield although produced on white mulch, there was no significant difference statistically among plastic mulches. White, black and red plastic mulch resulted in 56, 48 and 40 % respectively higher in tomato yield compared to bare soil or control, due to light reflected from the mulch surface. However, there was no significant difference between this mulch, black, red and white plastic. Among the different colored plastic mulch plots, the yield of white plastic mulch plot was greater than other colors plot. The increase of yield in mulched plot may associate with conservation of soil moisture and time of cultivation. Results of tomato yields were significant. Because plants were transplanted in the end of spring season and grown in summer season so that there was no difference in the yield response of tomatoes to color mulch plots.

Table 5-1 Three years average monthly air temperature, Relative humidity, Sunshine, Rainfall and actual ET of Qargha research station.

Months and years	Tempereture (ºc)	Relative humidity (%)	Sun Shine hour (h)	Wind speed (m/s)	Rainfall (mm)	Actual pan evaporatoion(mm)
Jan-2009	1.2	42.7	5.7	2.5	1.0	
Feb-2009	0.2	54.0	0.2	7.6	1.6	
Mar-2009	10.3	41.3	7.5	9.6	1.3	0.6
Apr-2009	13.3	44.1	0.3	13.7	0.7	0.7
May-2009	14.8	44.2	0.4	13.1	1.6	1.0
Jun-2009	18.1	36.2	0.4	0.3	0.1	2.1
Jul-2009	21.5	36.6	0.4	0.1	0.9	2.8
Aug-2009	20.8	44.3	0.3	3.3	0.9	2.1
Sep-2009	17.5	35.4	0.4	7.4	0.2	1.5
Oct-2009	12.9	31.5	0.3	5.3		0.7
Nov-2009	6.7	30.2	0.4	2.1		
Dec-2009	1.3	28.9	0.3	2.6		
Jan-2010	-0.8	35.7	0.2	2.5	0.0	
Feb-2010	-0.6	51.6	0.2	1.9	3.4	
Mar-2010	6.3	40.5	0.3	1.7	0.8	
Apr-2010	10.6	40.2	0.3	2.7	1.6	0.4
May-2010	17.9	32.3	0.4	2.9	0.3	2.0
Jun-2010	20.8	27.2	0.5	3.7	0.0	3.5
Jul-2010	22.7	28.5	0.4	13.6		3.4
Aug-2010	21.5	37.5	0.4	3.4	0.5	2.3
Sep-2010	18.5	36.7	0.4		0.3	1.4
Oct-2010	11.4	43.3	0.3		1.3	0.7
Nov-2010	7.3	46.9	0.2	11.3	1.1	0.4
Dec-2010	0.6	32.9	1.0	8.7		
Jan-2011	-6.3	48.2	5.3	12.8	1.1	
Feb-2011	-7.9	50.2	5.3	12.7	2.0	
Mar-2011	3.1	45.0	5.7	15.4	1.5	
Apr-2011	10.9	45.7	6.7	15.7	1.7	0.9
May-2011	14.3	39.3	8.9	15.2	1.2	1.3
Jun-2011	18.0	31.9	9.4	18.2	0.6	2.0
Jul-2011	21.2	29.3	9.7	18.4		2.6
Aug-2011	21.4	30.6	9.7	14.6	0.3	3.0
Sep-2011	17.7	39.2	7.9	11.9	0.4	1.7
Oct-2011	11.7	34.2	7.9	9.9	0.0	0.9
Nov-2011	5.7	36.2	6.4	8.6	0.4	0.2
Dec-2011	0.2	45.2	5.5	9.9	1.6	

Table 5-2 Mulch reflected light ratio

Mulch color	Reflected light % of direct sunlight
Black	6.7
Red	35.5
White	48.3

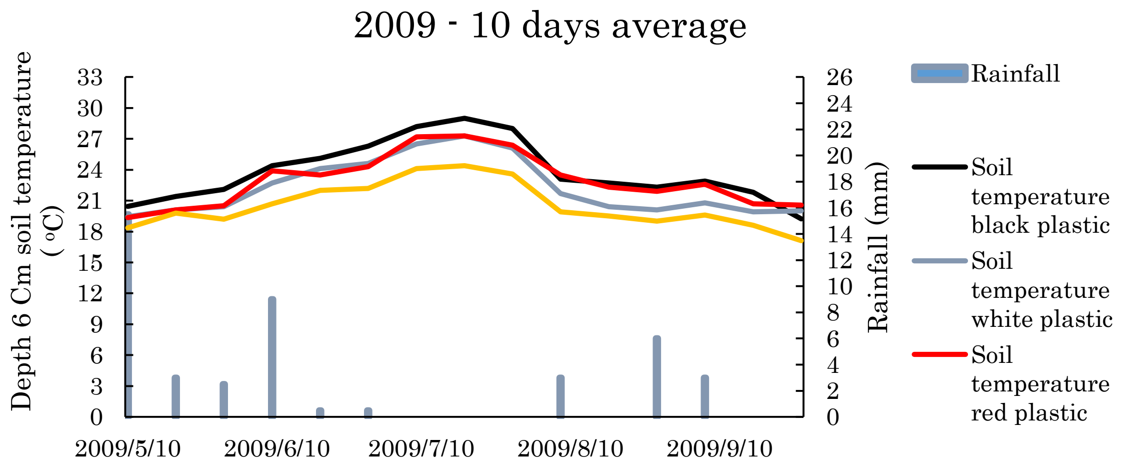


Fig. 5-13 Soil temperature and precipitation -2009

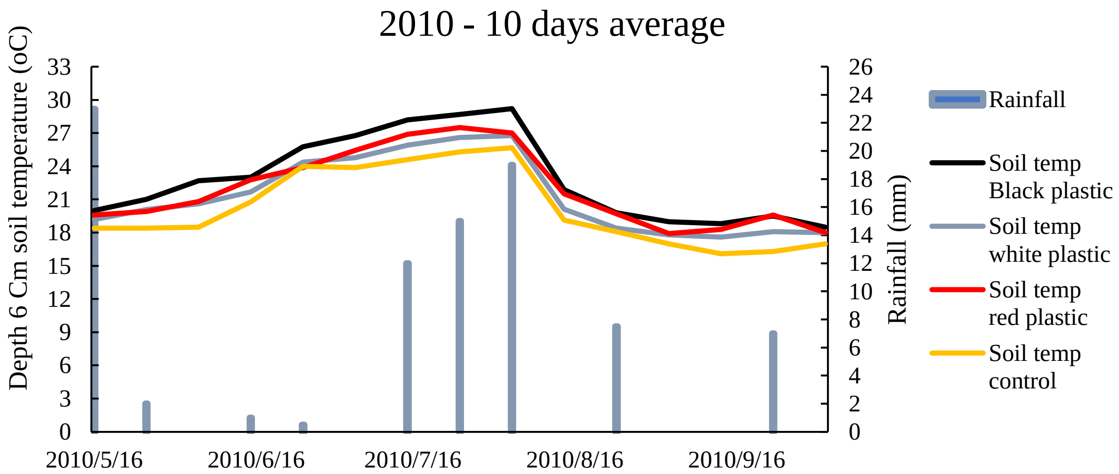


Fig. 5-14 Soil temperature and precipitation -2010

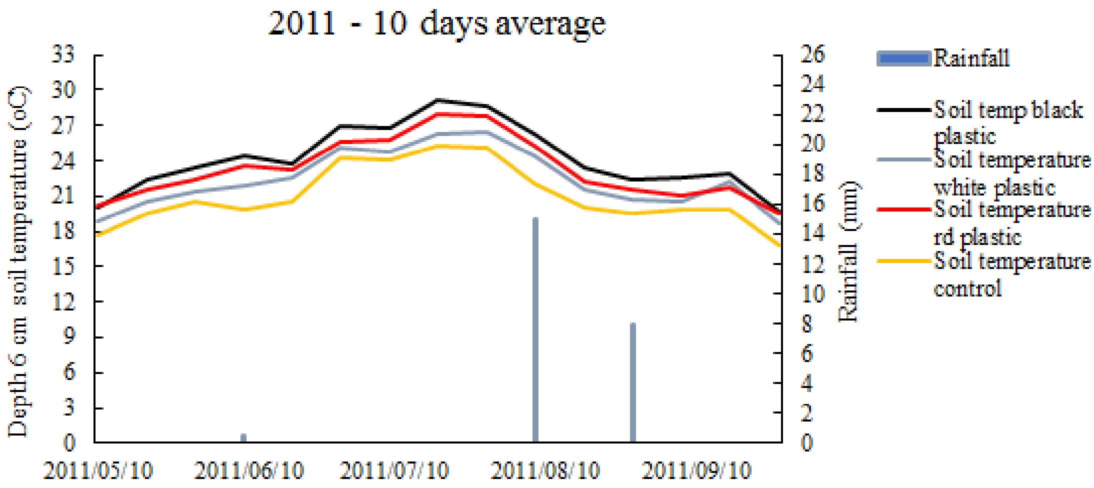


Fig. 5-15 Average soil temp. Under colors plastic and bare soil

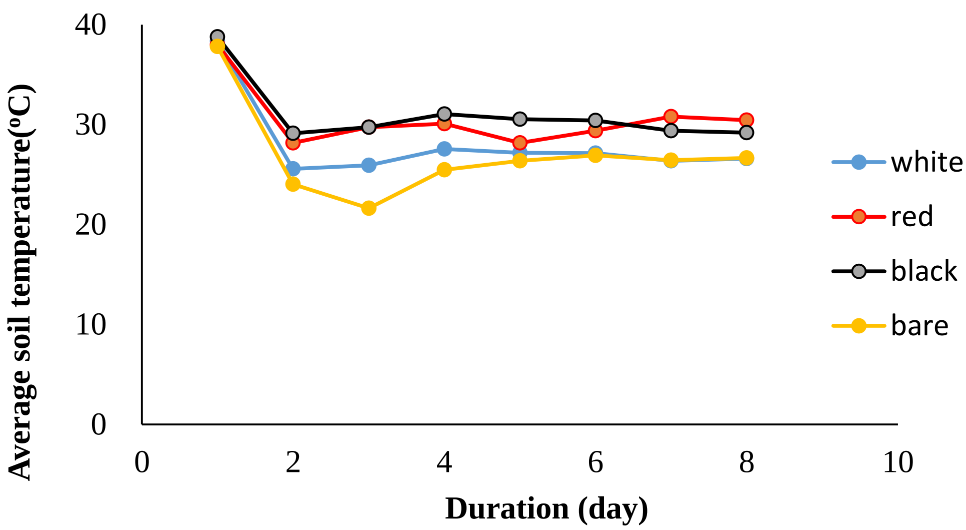


Fig. 5-16 Average soil temp. Under colors plastic and bare soil

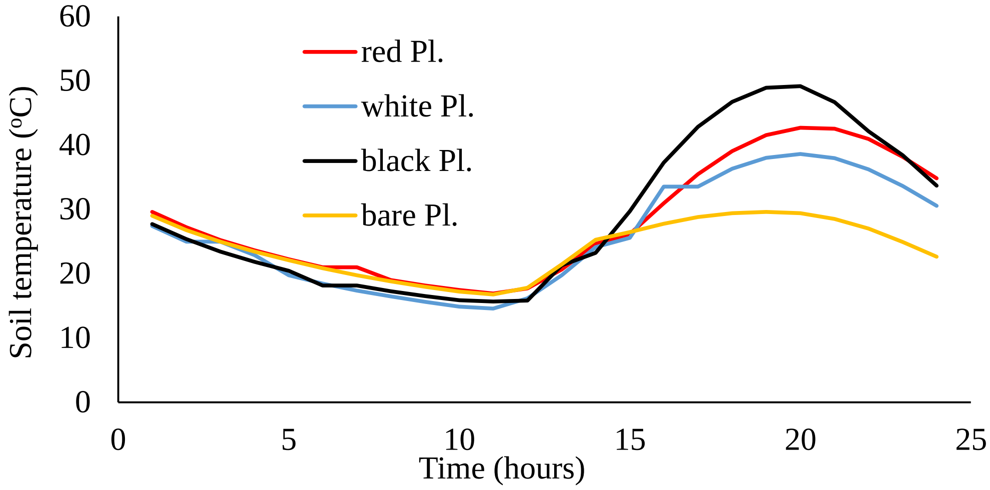


Fig. 5-17 Soil temperature under colors plastic and bare soil in 24 hours (August 4. 2014)

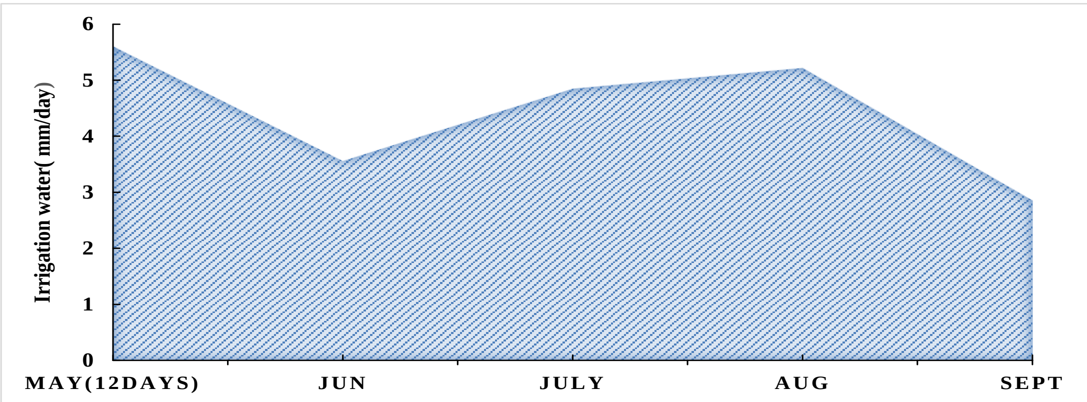


Fig. 5-18 Daily irrigation water in 2009, total irrigation amount 616 mm

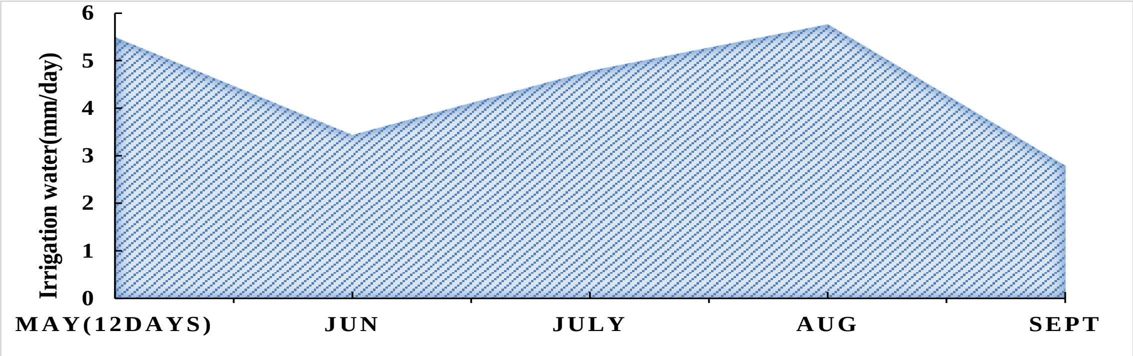


Fig. 5-19 Daily irrigation water in 2010, total irrigation amount 608 mm

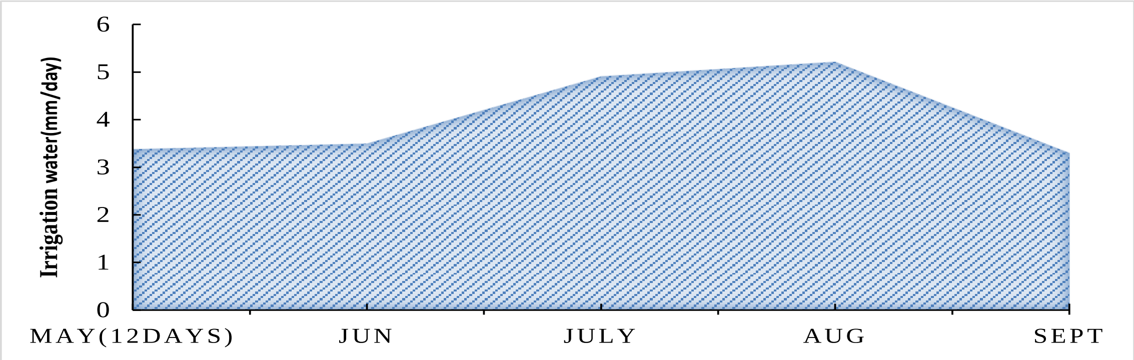


Fig. 5-20 Daily irrigation water in 2011, total irrigation amount 582 mm

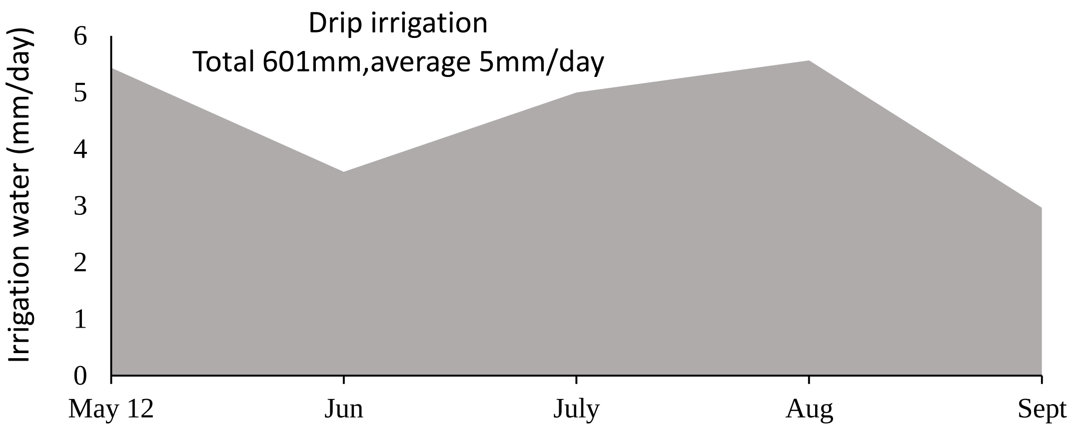
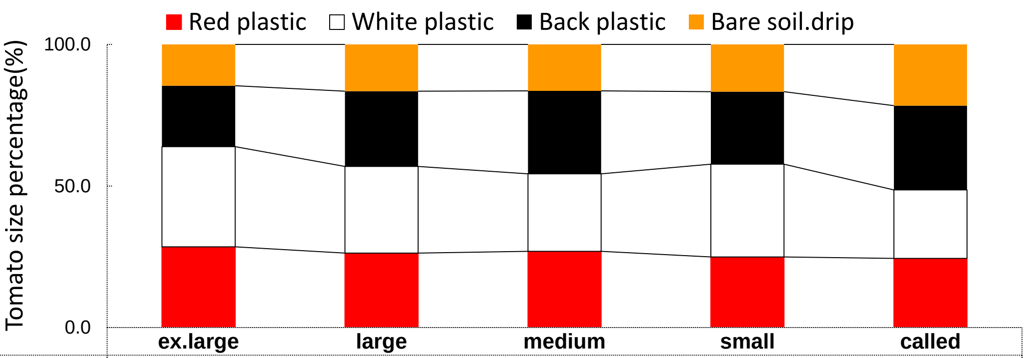


Fig. 5-21 Average 3 years daily irrigation water amount



	ex.large	large	medium	small	called
Bare soil.drip	14.6	16.5	16.4	16.7	21.6
Back plastic	21.5	26.6	29.3	25.6	29.8
White plastic	35.4	30.6	27.4	32.8	24.2
Red plastic	28.5	26.3	26.9	24.9	24.4

Fig. 5-22 Tomato size percentage under white, red, black plastic and control

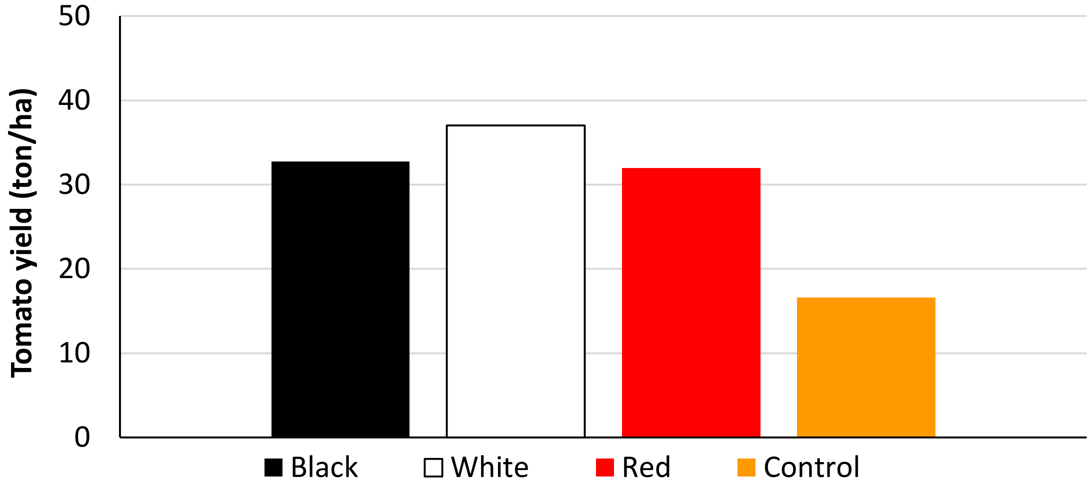


Fig. 5-23 Treatments tomato yield 2009

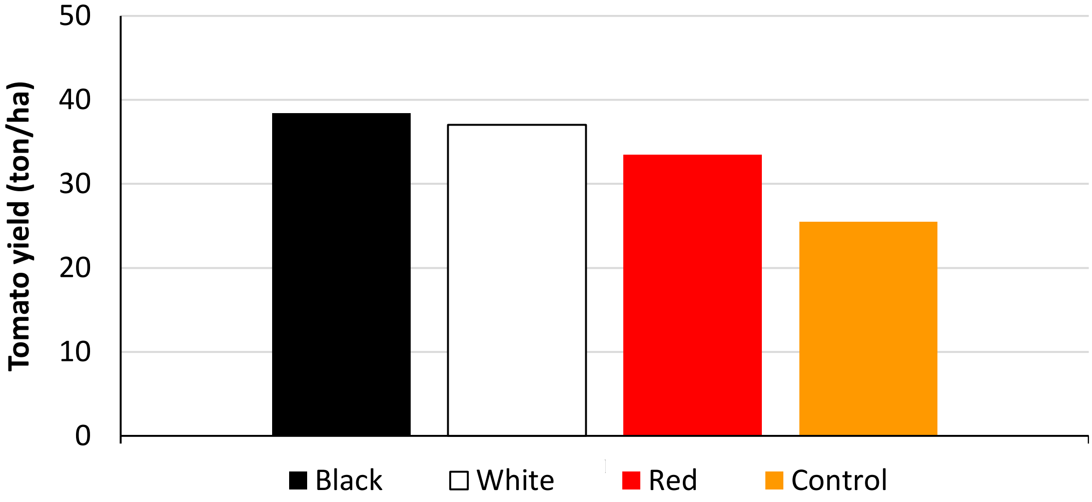


Fig. 5-24 Treatments tomato yield 2010

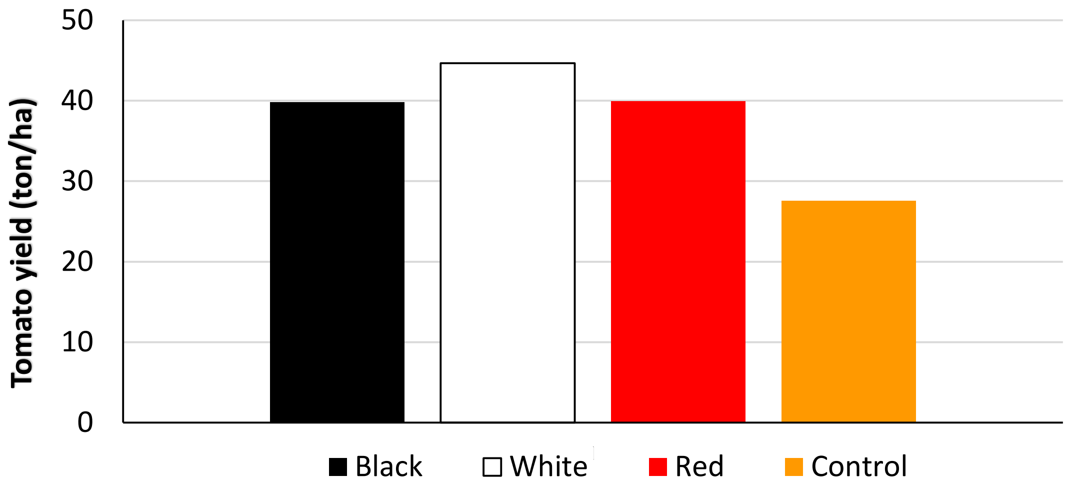


Fig. 5-25 Treatments tomato yield 2011

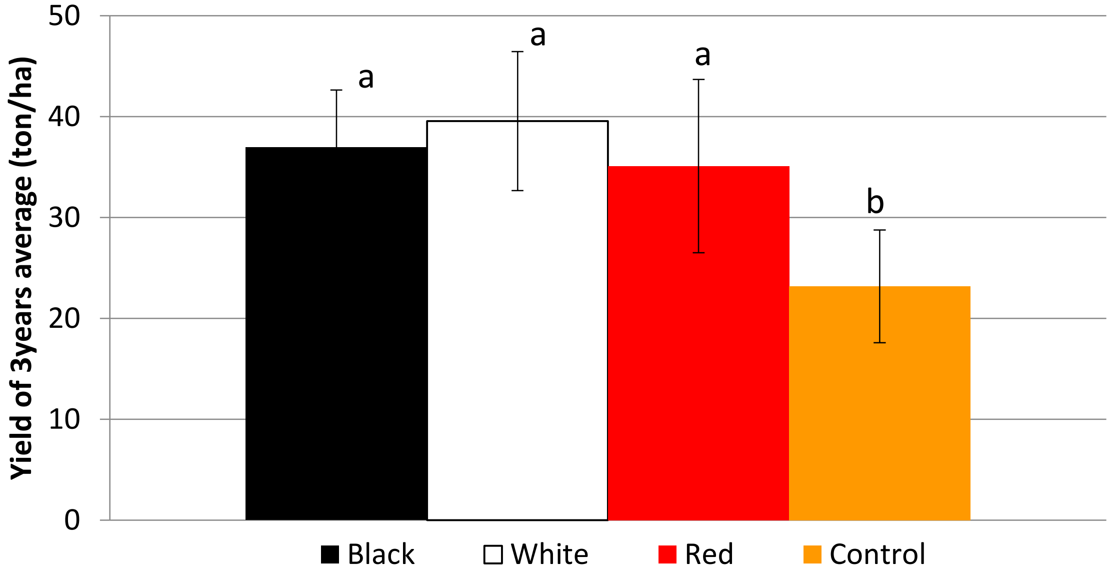


Fig. 5-26 3 years average tomato yield

5.4 Conclusion of this chapter

These studies have demonstrated the benefits of white, black and red plastic mulching on tomato yield. Mulching resulted in 40 to 56 % increase in yield as compared to control treatment. Tomato with the largest size were under white plastic mulch, compared to black, red plastic mulch and control. Upwardly reflected light off plastic mulch influenced the light environment in the seedling establishment zone.

The result of this study showed the effect of colored plastic mulch treatment decreased evaporation of soil. It also increases the soil temperature, which helps in establishing the early planting of tomato plants in cold areas. Soil temperatures were warm under the black mulch plot and coolest under the white mulch plot. mulch has been shown to influence flowering of tomato, plants tomato grown over the white mulch plot had more foliage than those grown over the red and black mulch plot .the beneficial effects of one mulch color as compared to another are related to its effects on spectral distribution of upwardly reflected light as well as on soil temperature and by extension contributing on energy balance. The best mulch color for a crop may vary with season and geographic area. In this study, plants grown on plastic mulch plots could produce more number of branches and leaves than in bare soil plot.

Refrences of this chapter

Asad Sarwar Qureshi, 2002. Water resources management in Afghanistan. International water management institute. Pakistan country Series No.14, working paper 49

Adetunji. A., 1990. Effect of mulch and irrigation on growth and yield of lettuce in semi- arid region.Biotronics 19, pp.93-98.

Olaf Thieme (with contributions by J.M. Suttie) FAO-2006.Country pasture /forage resource profile Afghanistan FAO, vial delle terme di Caracala, 00153 Rome,Italy.

William James Lamont,Jr. 2005.Plastics:Modifying the microclimate for the production of vegetable crops. Hort Technology., 15:477-481.

Zhang,T.Q., C.S. Tan, and J. Warner. Fresh market sweet corn production with clear and wavelength selective soil mulch films. Plant Sci. 2007, 87 (3), pp.559–564.

Dennis R. Decoteau and Michael J. Kasperbauer and Patrick G. Hunt. 1989. Mulch Surface color Affects yield of fresh market Tomatoes. J.Amer. Soc. Hort. Sci. 114(2), pp.216-219.

Decoteau.D.R. Kasperbauer, M.J., Daniels, D.D., Hunt, P.G. 1988. Plastic Mulch color effects on reflected light and tomato plant growth. scientia Horticulture, 34:169-175.

Naseri.Country report on the state of plant genetic resources for food and agriculture Afhanistan.

Csizinzky.A.A, Schuster.D.J. 1995. Color mulches influence yield and insect pest populations in tomatoes.Hort.Sci.120 (5), pp.778-784.

Decoteau et al., 1989.mulch surface color affects yield of fresh market tomatoes.Hort.Sci.114 (2), pp.216-219.

Hatt Graham et. al.1995..Development of a polyethylene mulch system that changes color in the field.Hort Science 30(2), pp.265-269.

Wien.H.C, Minotti.P.L.1993. Polyethlene mulch stimulates aerly root growth and nutrient uptake of transplanted tomatoes.Hor.Sci.118 (2), pp.207-211.

ICARDA January 2003, Aleppo, Syria. Need assessment on horticulture in Afghanistan. Future harvest construction to rebuild agriculture in Afghanistan.

Csizinzsky A.A., Schuster D.J., Krin J.B., 1997. Evaluation of colour mulches and soil spray for yield and for the control of silverleaf whitefly, Bemisia argentifolii (Bellows and perring) on tomatoes. Crop Prot 16, pp.475-481.

Rangarajan A., Ingall B., 2001. Mulch colour affects radicchio quality and yield. HortSci 36, pp.1240-1243.

Liakatas A., Clark J.A., Monteith J.L., 1996. Measurements of the heat balance under plastic mulches. Part 1. Radiation balance and soil heat flux. Agr forest meteorol 36, pp.227- 239.

Lamont W.J., 1996. What are the components of a plasticulture vegetable system? Hort Tech 6(3), pp.150-154.

Ham J.M., Huitenberg G.J., Lamont W.J., 1993. Optical properties of plastic mulches affect the field temperature rgime. J amer Soc Hort Sci 118, pp.188- 193.

Cooper, A.J. 1973. Root temperature and plant growth- A review. Commonwealth Agro. Bureaux, Slough, U.K.

Gosselin, A. and Trudel M.J. 1993. Intraction between air and root temperatures on greenhouse tomato; 1. Growth, development, and yield. J. Amer.Soc. Hort.Sci. 108, pp.901-905.

Tindall, J.A., Mills, h.a., and Radcliffe. D.E., 1990. The effect of root zone temperature on nutrient uptake of tomato. J.Plant Nutr. 13, pp.939-956.

Coffey, D.L., Buschermohle, M.J., Wills, J.B., Burns. R.T., Yoder, R.E., Honea, G.S AND Summerlin. 1999. Soil temperature and moisture conditions and performance of tomatoes grown on colored plastic mulches. Natl. Agr. Plastic Congr. Proc. 28, p.54.

Csizinszky, A.A., Schuster.D.J and Kring. J. b., 1995. Colormulches influence yield and insect pest population in tomatoes. J. Amer. Soc.Hort. Sci. 120, pp.778-784.

Decoteau, D.R., Kasperbauer, M.J., and Hunt, P.G., 1989. Mulch surface color affects yield of fresh- market tomatoes. J. Amer. Soc. Hort. Sci. 114, pp.216-219.

Kasperbauer, M.J. and Hunt. P.G., 1998. For –red light affects photosynthate allocation and yield of tomato over red mulch. Crop Sci. 38, pp.970-974.

Kasperbauer, Hunt, P.G., M.J, and Matheny. T.A.1989. soybean seedling growth responses to light reflected from different colored soil surface. Crop Sci. 29, pp.130-133.

Taber, H., Lawson, V, and Smith,B. 1999. Colored plastic mulches affect early tomato yield. Natl. Agr. Plastics Congr. Proc. 28, p.61.

Chapter 6

Conclusion and recommendations

Overall conclusions and recommendations of this dissertation

Agriculture is one of the most important sectors of agricultural production in the world. Especially in countries, where most of the population engaged in this sector. Such Afghanistan, that more than 80 % population of the country is directly or indirectly engaged in agriculture, and all of their income is dependent on agriculture. Unfortunately, the level of agricultural production in the country is very low. Even sometimes they did not gain expenditures. Afghan people are suffering from food shortages. This is a very big problem in the country. To solve these problems it is necessary to full investigate it. One of the major problems in Afghanistan is shortage of irrigation water. Especially downstream area. Due to insecurity in recent decades the farmers have ignored all the rules, especially by powerful people, and this problems is furthered. Afghan farmers do not have information about Irrigation Plan. Due to lack of knowledge in this regard, their decision mainly depends on visual plant stress indicators and the availability of water in the canal system. Farmers do not have any adequate method of deciding about the timing of irrigation. The two important criteria mainly used for deciding the timing of irrigation are dry appearances of the soil surface and remembrance of the time of last irrigation, the overall irrigation application efficiency is very low and also crop productivity levels even from regional standards.

Afghanistan has specific position, with high slop, high elevation and flat plains. Also with different agro ecological zone and a very varied geography. The winter minimum temperature can be as low -20 °C and summer maximum temperature is about 50 °C, with high evapotranspiration the evaporation peak up 6-10 mm/day in summer season. Afghanistan is an essentially arid country with more than half of the area receiving 100 mm to 300 mm of precipitation. And remaining mountain area having altitude of more 2,000 m also receive up to 800 mm precipitation mostly precipitation occurs in winter season in the form of snow, in this time there is no agriculture practice.

The main problems is shortage of water. Traditional irrigation system, Lack of knowledge on irrigation scheduling, great losses of water (deep percolation and surface run off), high evaporation from soil surface.

In this research, we attempt to analyze the relationship between actual pan evaporation and meteorological parameters. Also we effort to estimate optimum irrigation discharge to reduce deep percolation and improve application efficiency for furrow irrigation in Afghanistan. In the same way, we tried to analyze the effect of mulch colors and drip irrigation system on tomato plant growth and yield.

The objectives of this studies are to improve irrigation water use efficiency through estimating Pan Evaporation, estimating optimum irrigation discharge under furrow irrigation and mulching system for conserving irrigation water. In this study, the best assessment was based on improving agriculture irrigation water use efficiency in Afghanistan, compared to current farmer's irrigation water use efficiency.

The following conclusion were drawn from the finding of this studies:

For estimating evaporation, we compared estimated evaporation using Penman method and observed evaporation with class A-pan, there was a large differences in the relationship between the estimated evaporation and the observed. We tried to estimate evaporation with other meteorological parameters. We estimated relative humidity, wind speed with pan evaporation, there were a large disagreement, we tried to estimate sunshine with pan evaporation, and they have a good relationship compared to relative humidity and wind speed. Similarly we estimated air temperature and pan evaporation, finally we found that air temperature was a crucial parameter for estimating pan evaporation value.

Also water advance test was conducted at the Badam Bagh agricultural research station in Kabul, Afghanistan. The result of water advance test with actual farmer's irrigation water discharge was 0.00148 m^3/s and application water use efficiency was 57. 4 %. In order to determine the maximum value of irrigation application efficiency, we calculated distribution of infiltration amount with different irrigation discharge such as 0.0011m^3/s less than actual water discharge and 0.002, 0.003 m^3/s more than actual water discharge, in order to compare application efficiency to conventional irrigation discharge. The values of application efficiency were 54.2, 60.5, and 59.2 %, respectively. The maximum water application efficiency was 60.5 % with irrigation discharge 0.002 m^3/s for a furrow, this is 5.1 % higher than actual water discharge. We can save 5.1 % water in each irrigation scheduling time. This method can be applicable to estimate optimum irrigation discharge for furrow irrigation.

For the use of colored plastic mulch, we attempt to study and analyze mulch colors effect on tomato crop yield. Mulch colors like Black, Red and White increased yield as compared to bare soil. It was also noted to increase size and number of tomato fruits. Plastic mulch increase soil temperature, especially under black plastic mulch and coolest under white plastic. Reflected light of plastic mulch influenced the light environment in the seedling establishment zone, otherwise effect of colored plastic mulch treatment decreased evaporation of soil. The best mulch color for a crop may vary with season and geographic area.

Base on the findings and conclusions of the study, the following recommendations were formulated:

- Afghanistan agriculture basic problem is shortage of water and low knowledge by farmers, this should be improved.

- Afghanistan has different agro-climatic conditions and meteorological stations should be installed in every climatic region in the country.
- Responsible Personnel should be trained to observe data and analyses it.
- For irrigation scheduling, evaporation should be estimated as necessary, with air temperature parameters to estimate evaporation in Kabul, and calculate crop water requirement.
- This evaporation estimating method is very important, extension department should extend among the farmers and increase their knowledge, to prevent losses of water.
- At present, farmers irrigation water use application efficiency is very low, capacity building should be done to improve the knowledge of farmers in this issues and use optimum irrigation water to improve on efficiency and crop production.
- Furrow irrigation is one of the popular and traditional surface irrigation system which has high losses of water that leads to low water use efficiency, it is suggest that the mulching be promoted among the farmers, so that the future drip irrigation reduce losses of water and increase water use efficiency.
- Afghanistan has different agro climatic zone and cultivation scheduling, it is suggested that different colors of plastic

mulch for warming soil temperature, soil moisture management and reflection of light be promoted by extension staff.

- To harvested fresh products throughout the year, farmers should use colored plastic mulch everywhere in the country.
- All the above finding which include but not limited to pan evaporation, use of mulching, proper irrigation scheduling and observation of optimum irrigation discharge be extended to the members of agriculture irrigation water user associations, Mirabs and farmers by extension officers.