SOIL AND WATER RESOURCES CONSERVATION AND MANAGEMENT FOR AGRICULTURAL PRODUCTION IN DRY AREAS OF UZBEKISTAN

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

IRRIGATION WATER MANAGEMENT

By

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JUNE, 2005

CANDIDATES DECLARATION

I hereby certify that the work which is being presented in this Dissertation entitled **"SOIL AND WATER RESOURCES CONSERVATION AND MANAGEMENT FOR AGRICULTURAL PRODUCTION IN DRY AREAS OF UZBEKISTAN"** in my partial fulfillment of the requirement for the award of the Degree of Master of Technology in Irrigation Water Management (IWM) submitted in the department of Water Resources Development and Management (WRDM) Indian Institute of Technology Roorkee (IIT Roorkee) is authentic record of my own work carried out during the period from June 2004 to June 2005 under the supervision of Dr. DEEPAK KHARE, Associate Professor deptt. of WRDM IIT Roorkee (UA) India and Prof. RAJ PAL SINGH, Professor deptt. of WRDM IIT Roorkee (UA) India.

I have not submitted the matter in this dissertation for the award of any other degree.

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ACKNOWLEDGEMENT

I take great pleasure in expressing my profound indebtedness and heartfelt gratitude to Dr. Deepak Khare, Associate Professor Deptt. of WRDM IIT Roorkee (UA) India and Prof. Raj Pal Singh, Professor Deptt. of WRDM IIT Roorkee (UA) India for their encouragement and pain taking supervision to complete this Dissertation. I had the privilege to work under their guidance and they have been the inspiration to make the turning point of my carrier and allow me to work in the area I like most.

I am very grateful to Prof. S.K. Tripathi, Professor and Head, Deptt. of WRDM IIT Roorkee (UA) India for kind cooperation and for facilitating this work. I appreciate the support and cooperation from my fellow Trainee Officers.

I would like to thank the Government of Uzbekistan for giving me this chance to study here and also thank the Government of India for funding my study.

I am indebted to Dr. Shavkat Yakubov, Head of Deptt. of Modeling of Hydro-Geological Processes (MHGP), Central Asian Scientific Research Institute for Irrigation (SANIIRI) Tashkent, Uzbekistan, for providing me with relevant data for the study.

No words are enough to express my gratitude to my **PARENTS** and all family members for their love and prayers for my success during the study period. Without their encouragement and moral support, the Dissertation would not be completed successfully.

ADHAM U. TULAGANOV

ABSTRACT

Land and water are the most important natural resources and are regarded as the permanent assets in the service of mankind. Agriculture plays an important role in the economy of Uzbekistan. About 15 million people (60% of total population) depend directly or indirectly on agriculture. Twenty to forty percent of the Gross Domestic Product (GDP) is derived from Agriculture. The available land of the republic is 44.4 mha. of which about 11.8 mha are potentially suitable for irrigation including 4.3 mha of existing irrigation area (MAWR,Uzbekistan, 2000). The other 32.6 mha. is desert pastures, mountains, sandy soils (Uzdaverloiykha, 2000). There is a rainfed arable area of 0.8 mha. Yields in the rainfed area are low but the area makes an important contribution to national grain production. The average annual precipitation in the plains is about 80-100 mm to the east and south parts of the country the amount reaches 890-1000 mm. During vegetation period precipitation is less; therefore all crops must be irrigated so as to fulfill their water requirements. Main irrigated crops are Cotton, Grain and Vegetables. Commonly used irrigation methods are furrow, border and basin.

The crisis of the Aral Sea and its coastal area basin is widely known and do not require detailed description. The Sea has decreased in volume to one-third as much, in water surface area to half of original size and its water salinity has increased fivefold. Excessive emphasis an extension of irrigation system and construction of many medium and small-scale reservoirs have created problems for both the environment and system efficiency during the last 30 years. Particularly, substantial water losses and surplus of irrigation caused by implementation of inappropriate irrigation technologies have led to water logging, soil salinization, and decline of water quality and also have resulted by the aggravation of the Aral Sea status. Currently in Uzbekistan, total agricultural area subjected to salinization is 3.7 mha of which 1.1 mha is the land of medium and highly salinized.

Uzbekistan has a big potential reserve of the area suitable for irrigation, but water resources limit the development of irrigation. Emphases must be given to bring into use the irrigation methods which will assist in solving problems like irrigation waster saving, improvement of production and conservation of soil fertility and its structure. Keeping in view the above background ICARDA has established as integrated research site at Boykozon farm, in the Tashkent Province of northeastern Uzbekistan. The site represents the typical agro-ecological and mixed farming system of the country. Three advanced irrigation techniques are tested on these fields. Encouraging results of water and soil conservation have been obtained form these studies. The techniques includes use of Joyak (Zigzag) furrows for irrigation of winter wheat crop, the use of Portable Polyethylene Chutes (PPCH-50) with adjustable aperture for irrigation of potato crop, and the use of Marginal waters for irrigation.

Results of this study showed that above irrigation techniques have higher water productivity and irrigation efficiency. Soil erosion is decreased from 3.48 t/ha to 0.54 t/ha as compared with traditional irrigation method and Joyak (Zigzag) technique due to reduction in the velocity of water flow in the furrow. In case of PPCH-50 studies it is observed that the water saving up to 50% of traditionally used amount can be obtained for same yield and soil erosion is reduced from 3.1 t/ha to 0.4 t/ha. Thus, these techniques can be used as improved irrigation method with the purpose of conservation and management of water and soil resources in the dry agricultural areas of Uzbekistan.

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LIST OF ABBREVIATIONS

RUz	Republic of Uzbekistan abbreviation
MAWR	Ministry of Agriculture and Water Resources
UzNIIHI	Uzbek Scientific Research Cotton Growing Institute
FAO	Food and Agricultural Organization of the United Nations
ICARDA	International Center for Agricultural Research in the Dry Areas
Hydromet	Institute of Hydro-Meteorology
SANIIRI	Central Asian Scientific Research Institute for Irrigation
FSU	Former Soviet Union
NPAEP	National Plan of Action on Environmental Protection
UNDP	United Nations Development Programme
ICWC	International Coordination Water Commission
FSK	Former State and Collective Farm (kolkhoz and sovkhoz)
I&D	Irrigation and Drainage
O&M	Operation and Maintenance
WUA	Water Users' Association
C&D Network	Collector and Drainage Network
KTR-1-A canal	Main irrigation source
U-1, U-2 & U-3	Water delivery systems in study area
K-2-1-4; K-2-1-5	Name of Collectors constructed as half-open and half-closed
2+52 m; 1+26 m	Picket number
D-23-1; D-25-1	Drain number
SW	Ground water table observation well
W.C.	Water content
WT	Water table
CropWat-4	FAO Software package for calculation of crop water requirement
WaSim	Software package for simulation of daily soil water balance

CHAPTER I

INTRODUCTION

1.1 General

Uzbekistan is located in the central part of Central Asian region between 37° and 45° northern latitude and 56° and 73° eastern longitude. Uzbekistan borders on Kazakhstan in the north, Kyrgyzstan and Tajikistan in the east and, Afghanistan and Turkmenistan in the south, on the crossroads of the historical "Silk Road", which a certain degree has left its imprint on the development of agriculture, industry, trade, and in people's interrelations and mentality. Administratively, the country is divided into 12 provinces and one autonomous Republic of Karakalpakstan located in the far west of the country in the zone of environmental disaster related to drying of the Aral Sea.

Climate is extremely dry and semi-arid. A large part of the country's territory is a steppe zone and sands (Karakum sands). A part of the territory is semi-desert lands, and only a small part is comprised irrigated oases. Owing to the dry climate, agriculture is mainly oriented towards irrigated farming. Arable lands make up only 90% of the total land, while irrigated lands occupy 4.3 mha are seasonal pastures

1.2 Agricultural Structure

The agriculture of Uzbekistan is developing mainly on irrigating systems concentrated in the Basin of Amu-Darya and Syr-Darya Rivers, as well as in the Valley of Zarafshan River. The development of agriculture is constrained by scare water for 90 per cent of areas under crops. In Uzbekistan there are 1.389 collective (kolkhoz) farms, 872 cooperative farms, 21.675 dekhan or family-owned farms and

1.895 private farms. Agriculture accounts for 26 per cent of the country's GDP and employs more than a third of the population. The farms include "shirkat" cooperative farms and "dekhan" family farms. The land is on long-term lease from the state. The "dekhan" farms account for more than 60 percent of agricultural production.

The social structure of agriculture has changed fundamentally. Today the public sector accounts for less than 2 percent of the total. The economic independence of agricultural enterprises has been extended. There have been several other structural changes in agriculture. For example, the cotton monopoly inherited from the former centrally controlled Soviet system and so-called all-union division of labor, have been abolished. During the Soviet period, Uzbekistan was mostly oriented towards the production of cotton for the textile and military industries of the Soviet Union. After independence Uzbekistan reduced cotton production by expanding production of grain, vegetables and other crops, which previously did not satisfy domestic requirements.

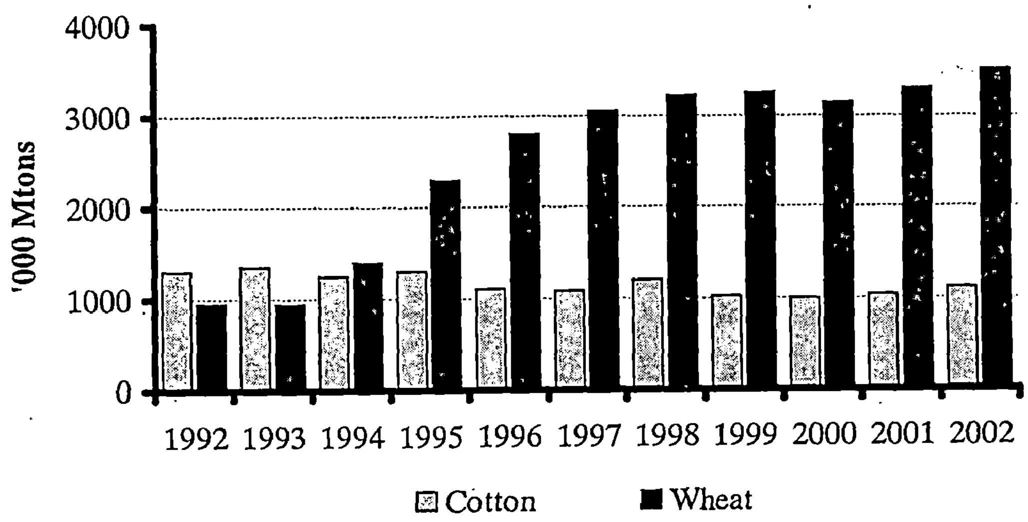


Fig. 1.1 Cotton and Wheat production in 1992-2002

Prior to independence the monoculture of the cotton crop has led to problems of land degradation, especially from salinization and waterlogging. However, cereal production has increased substantially. During the past 3 years alone, the area under cereals, especially wheat, has been extended by more than 300 thousand ha, to reach more than 1 mha in 2001. Cereal production has reached 3.5 Mtons as shown above in Fig. 1.1 and the importation of the food grain has been reduced more than 6 fold.

1.3 The Aral Sea

The Central Asian countries, especially Uzbekistan, are important cotton exporters. The area of irrigated land grew by more than 3.0 mha between 1950 and 1988, mostly in Uzbekistan. In order to support this massive increase in the irrigated area, water withdrawals were made indiscriminately, reducing the river flow until 97% of annual water resources were consumed, leaving only 4 km^3 to flow into the Aral Sea. In some dry years in the 1980s, no water at all flowed into the Aral Sea. One of the reasons for this above-average usage is the heavy salinization of soils in the region, which requires intensive leaching or washing of fields newly under irrigation, and periodic leaching of almost all irrigated land.

Until about 1960, the volume of the Aral Sea was more or less in equilibrium, with evaporation from the surface counterbalanced by inflow from rivers, groundwater and rainfall. Since the mid 1960s, demand for the water resources of the basin has risen dramatically. The irrigated area expanded by over one-fifth between 1960 and 1990, while the consumption of water tripled to meet the increasing needs of agriculture and the population. Water use often exceeded the stream flow of the rivers, as water used for irrigation upstream was reused downstream.

Historically the natural fluctuations of the sea level due to climatic changes in its basins were between 1.5 and 2 meters. Since 1960, the Aral Sea has lost almost 75% of its volume, and has shrunk to 50% of its previous surface area. Its shores have receded dramatically, in some places more than 120 km. Over 33,000 km^2 of former seabed are exposed. The exposed sea bed is coated with agricultural chemical residues and salt, which are carried by strong winds and deposited over a wide radius, affecting crops, natural vegetation, soil quality, water supply, air quality, and people's health.

The excessive use and the dumping of agricultural chemicals have seriously damaged water and soil quality. Huge quantities of agrochemicals were used; herbicides and insecticides to combat pest and diseases which had acquired immunity due to monoculture practices; fertilizers to supplement the nutrient content in exhausted and over-washed soils and defoliation to facilitate the mechanical harvesting of cotton. Central Asian cotton was treated with as much as 50 kg of pesticides and 430 kg of fertilizer nutrients per hectare. On cotton fields in the coastal area of the Karakalpakstan Republic, pesticides were used at a rate ten times the FSU average.

Countries of the Aral Sea basin are committed to following the path of sustainable development and improving the environment conditions of the affected region to the greatest extent possible. Along with international organizations, they have sought and received global support for the initial phase of a far-reaching multi-sectoral program of action to address the ecological and social aspects of the crisis. The Aral Sea Program has four major objectives: 1) to stabilize the environment of the Aral Sea; 2) to rehabilitate the disaster zone around the Sea; 3) to improve the management of international waters of the basin; and 4) to build the capacity of regional institutions to plan and implement these programmes.

1.4 Socio-Economic Statistics

The agriculture of Uzbekistan contributes greatly to the national economy and effects directly on the health of the population in the region. At the same time agriculture is a dominant socio-economic sector in the basin, and an irrigated agriculture, in particular. Some 30 to 60% of the population is employed in this sector. In Uzbekistan the irrigated agriculture is the main foodstuff source, which provides up to 96% of gross agricultural production. At present re-structuring of agriculture is implemented in the interests of national food security and food production increase.

Although, Uzbekistan since 1991 has achieved food security, cotton production drop during the last several years has been a serious concern to the Government. In 1999, the total crops area on the irrigated lands were 3.56 mha, of them 1.36 mha was allocated under grain, including 1.1 mha for wheat. (State Department of Statistics of Minmakroekonomstat, Republic of Uzbekistan: Sowing area of crops in the irrigated area in 1999). The total of grain and leguminous crops has made 2.9 Mtons in the country that has allowed reducing import sharply.

Institutional transformations in agriculture have provided significant growth of production and not only grain realization, but also vegetables, fruit, animal industry products, which was achieved mainly through private sector. The country has favorable premises for sustainable development of agriculture. Deepening of economic reforms and future infrastructure changes of economy will promote transferring from agrarian republic into industrially developed country with intensive development of agriculture.

1.5 Need of Study

At present, the Government supplies water for irrigation farming on charge-free basis. The necessity of introducing the water-pricing system is recognized by the Government, and the development of such system is planned within the framework of the project on cotton-growing modernization. The price for water should be determined for each particular farm or region to compensate for the cost of water transitions. Nevertheless, within a short period, it is expedient from practical and political and points of view to introduce a water-pricing system for all water users. The principle of introducing the water-pricing strategy is a means to improve the water-use efficiency.

Studies are needed that can inform design and planning authorities upgrade traditional practices, consider the totality of irrigation effects on other water users and uses, and incorporate broader developmental goals and strategies for alleviating poverty, social and gender inequities. At the same time, the strive for sustainable development recognizes long-term needs, conservation avoidance of water quality degradation and the building of institutional capabilities for efficient and equitable water resources investments and management. While much progress can and should be made in transferring improved technologies in dry-area agriculture development, from one country to another, such transfer will succeed only if it is accompanied by adaptive research to ascertain the applicability of these improved technologies.

1.6 Objectives and the Scope of Study

Excessive emphasis an extension of irrigation system and construction of many medium and small-scale reservoirs have created problems for both the environment and system efficiency. Particularly, substantial water losses and surplus of irrigation caused by implementation of inappropriate irrigation technologies have led to water logging, soil salinization, and decline of water quality and also have resulted by the aggravation of the Aral Sea status. It is necessary to take into account that introduction of appropriate irrigation methods will assist in solving many social economic problems in particular irrigation water saving, facilitation of the irrigation process, improvement of production technology and conservation of soil fertility and its structure. The present work objectives are:

1) to increase agricultural production through improved on-farm soil and water management including the optimal use of available water resources both, rainfall and irrigation sources.
2) to develop soil and water management practices to sustain the soil resource and enhance water quality.
3) to sustain irrigated cropping systems through appropriate farm-level management of irrigation and drainage, and the safe utilization of marginal water sources for irrigation.
4) to introduce water-saving irrigation and washing technologies ensuring favorable water-salt regimes in irrigated lands and high crop yields.

1.7 Organization of the Thesis

The Study is organized to achieve its objectives in eight chapters. Chapter 1 is an Introduction, where general information about the country, its agricultural structure, and socio-economic statistics are given. It deals with problem definitions as well as the objectives of the study. Chapter 2 is Literature Review. This chapter mainly deals about the strategies of national soil and water conservation of neighboring countries (Kyrgyzstan, Kazakhstan, Tajikistan and Turkmenistan), China and India as well. Development of irrigation and drainage system, water logging and soil salinity and in irrigated areas and, the main strategies against the soil erosion in irrigated lands have been briefed in this chapter. Chapter 3 is a Study Area, where results of research on management of soil and water conservation which have recently been carried out at the site of SANIIRI are given. Also, some advanced water saving irrigation practices (including Zigzag irrigation, irrigation with Portable Polyethylene Chutes (PPCh-50) with adjustable apertures, Self pressurized Drip irrigation system, and irrigation with help of Shielded Polyethylene Films) for optimization of irrigation application, water use efficiency, soil erosion and yield have been dealt in this chapter. Moreover, this chapter contains certain recommendations and suggestions on soil and water conservation and management for agricultural production. Chapter 4 is data acquisition where current data of the population, climatic condition, environment and, land and water resources of the country are given and have been implemented to the study. Chapter 5 deals with development and principles of reconstruction and operation of drainage systems for farms. It also deals actual conditions of irrigation and drainage systems network in irrigated areas. Chapter 6 is estimation of crop water requirements using the FAO CropWat-4 software package. The software was used for calculation of Eto, for main crops of Cotton and Winter Wheat within the study area. Results are given in at the end of the chapter. Chapter 7 is application of daily soil water balance simulation model (WaSim). The model was tested on predictions of soil water balance in crop root zone. Thus, the model is found to be suitable as a tool to design different controlled drainage strategies for different situations. Chapter 8 is results and discussions where analyses of the study are pointed briefly. Chapter 9 summarizes conclusions and recommendations of the study.

CHAPTER II

LITERATURE REVIEW

2.1 Situation of Soil and Water Loss in China

China has an area of 9.6 Mkm^2 with high land in the west and low land in the east. Mountains, hills and plateaus account for 2/3 of the total area. Out of the total area, arable land is around 135 mha or 14%, forestry is around 167 mha or 16.5%, natural grassland is 280 mha or 29%, fresh water body is 18 mha or 2%, land used for construction is 27 mha or 3%. The rest 35% are composed of deserts, glacier and Rocky Mountains which are difficult for agricultural use. China is one of the countries suffering from most serious soil and water loss in the world. Due to its special natural, geographic, social and economic conditions, soil and water loss has become a major environmental problem. Soil and water loss in China has the following characteristics:

1) Wide distribution and large area. According to the results of the second national remote-sensing survey released recently, the total area of soil and water loss in China is 3.56 Mkm^2, accounting for 37% of the total national territory. This includes 1.65 Mkm^2 affected by water and 1.91 Mkm^2 by wind, out of which 260,000 km^2 is affected by both water and wind. It is found that the west part of China suffers the most serious soil and water loss with the largest area of 1.07 Mkm^2, the central part with an area of 490,000 km^2 and the east with an area of 90,000 km^2. The soil and water loss is mainly distributed in the middle and upper reaches of the Seven Main Basins, such as the Yangtze River, Yellow River, and Pearl River etc.
2) Differentiated erosion causes and complicated types. Erosion caused by water, wind, freezing and thawing, and gravity such as landslides and mud-rock flows has different features and is interlinked. The sandy area and grassland in

the dry west suffer from serious wind erosion. The areas with both farming and husbandry in the semi-arid areas of the northwest are affected by the combination of both water and wind erosion.

3) According to statistics, the annual soil erosion in China amounts to 5 billion tons. The total annual soil erosion in the Yangtze River basin is 2.4 billion tons, including 1.56 billion tons from the upstream. Sediment from the Loess Plateau of the Yellow River basin into the river is as much as 1.6 billion tons. The serious soil and water loss has adversely affected the economic and social development, and people's production and life in China to a great extent.

Key projects for soil and water conservation in the 7 main river basins, such as the upper reaches of the Yangtze River, the middle and upper reaches of the Yellow river etc., have been well implemented with great progress. Such projects have produced significant results. The amount of sediment discharged into the Yellow River decreases 300 Mtons per year. The projects not only reduce sediment deposition in rivers, lakes, and reservoirs, but also improved agriculture conditions and ecological environment. In the meantime, attention has been paid to allocate water for ecological use.

The prevention and protection practice was implemented in the "Resource of the Three Rivers" with an area of 300 thousands km^2. There are 894 counties implementing practice of mountain enclosure without cultivation and graze in an area of 520 thousands km^2. In the process to hasten eco-environment rehabilitation, the corresponding construction measures, such as small-watershed of optimal quality and high efficiency, water resource engineering, animal rising by enclosure, ecological immigration, and electric power to replace firewood, are strengthened. From the experiences in the past two years, practice of improving eco-environment by the power of Nature is not only successful in South China with plenty of rainfall, but also feasible in North China with less precipitation.

2.2 Soil Conservation Strategies in India

In India about 81 mha lands are affected by erosion problem out of total geograpfical area of 326.8 mha. In other term "out of net cultivated area of 185.8 mha", 56.7 mha lands are suffering from erosion either due to water or wind. Out of these about 40 mha lands are badly affected and needed immediate control measures. The dominating factors which are responsible for producing the problems of soil erosion in India are the excessive deforestation, overgrazing, faulty agricultural practices and occurrence of flood.

The water and wind are the two main natural agents, causing soil erosion. The consequence of water erosion is pronounced particularly in humid areas, where rainfall is more and intense, while wind erosion is common in arid and semi-arid areas, where rainfall is less and temperature and wind velocity are high. In India, wind erosion is more effective in arid areas of Rajasthan, coastal areas and semi-arid tropics covering the areas of Haryana, Gujarat, U.P and Punjab. Comparatively, water erosion is occurring more higher percentage than the wind erosion. The serious soil problem in the country is mainly in the form of sheet erosion, in which top soil is removed in the form of layer through overland flow from the soil surface.

Furthermore, the gullied land along banks of the rivers like Yamuna, Chambal, Mahi and other rivers in Gujarat have serious water erosion problem. The mountainous regions of Himalaya are in highly deteriorated conditions due to deforestation, mining and adoption of cultivation practices on steep slopes. Like wise in north-eastern part of the country, there is also existing serious soil erosion problem mainly due to shifting cultivation system. The rate of soil erosion in different soils by sheet erosion is estimated as from 4 to 10 tons/ha/year in red soils, from 17 to 43 tons/ha/year in black soils and, from 4 to 14 tons/ha/year in alluvial sols. The rate of soil erosion from gullies is computed as 33 tons/ha/year in ravine regions. Similarly, the range of soil erosion from hill side varies more than 80 tons/ha/year. The annual soil erosion rate in India is estimated to be about 5334 Mtons due to agricultural activities and its associates. And about 1572 Mtons soil as sediment per year are carried away into the sea by the rivers of the country. Likewise about 480 Mtons of soils are deposited into various reservoirs of the country.

For reducing soil erosion in effective manner, the soil conservation schemes are formulated, which must be well designed with most appropriate sequence of events associated with the soil erosion phenomena. The success of any scheme or plan depends very much on how well the nature of erosion problem has been identified and on the suitability of the conservation measures selected to deal the problem and relation to the agricultural or land use system, which is easy to implement by the farmers or other personnel. The aim of soil conservation strategies for cultivated land is to establish and maintain a good ground cover for controlling the soil erosion. The study indicates that, tall tree crops, low-growing crops with big leaves are the least effective in protecting the soil. Similarly, continuous growing of cereals, rubber, oil palm, grape, maize, sugarbeet, etc., produce moderate to serious erosion problem.

2.3 Management of Soil Resources in Kyrgyzstan

The land resources of Kyrgyzstan make up about 17 mha, including 10.6 mha of agricultural land, of which the arable land is about 1.3 mha, including irrigated area of 840,000 ha and a rainfed area of 460,000 ha. (Kyrgyzstan Soil Research Institute, 1990). The soil in the country is represents by 20 types, 80 sub-types, 300 kinds and 3400 varieties.

Due to the mountainous landscape, the soil in this country is subjected to different types of erosion, such as water, wind, irrigation, pasture and mud stream. Eroded soils make up 705.200 ha, including arable lands 523,500 ha, fallow lands 20,900, and hay lands 5,400 ha. (Mamatov A.M. Soils of Mountainous Areas of Central Asia and Southern Kazakhstan. Frunze, Ilim)

Under inappropriate irrigation scheduling and management methods, with a lack of natural or artificial drainage systems, secondary salinization annually converts tens of thousands of hectares into barren soil. The main factor of soil fertility is organic component of soils. In recent years, its losses in the soil have been 20-40% compared with the original organic matter content in the virgin land. To create its positive balance in the soil, it is required to annually apply 5-6 tons of manure per hectare of arable land, and 30 tons per crop rotation. Under monoculture of cereals, cotton, sugarbeet and potatoes soil depletion takes place and the yield is consequently reduced. Now, the status of the soil upper layer in this country is very critical and is a serious concern. Therefore, it is necessary to find a deeper approach to exploring fundamental and applied problems, concerning stabilization and extended reproduction of soil fertility. (Report AB "The Project on Regional Development of Agriculture". Republik of Kyrgyzstan).

2.4 Water and Land Resources Management in Kazakhstan

In Kazakhstan, in average hydrological years, surface water accounts for 101 billion m^3, and in poor hydrological years 51.8 billion m^3. The runoff which is available to be used in an average hydrological year is about 44 billion m^3. The uptake of groundwater comes close to 2.5 billion m^3 and in the next 15-20 years it is expected to exceed this level. In regions with inappropriate water resources management and unfavorable ecological conditions, the main water use is the agrarian sector, consuming about 70-80% of water fro regular irrigation. However, the development and use of irrigated lands are being carried out at a low technological level. Therefore, within an on-farm network, 20-30% of water is being lost, while within the inter-farm network the water losses are about 10-15%. Under such conditions, it is extremely important to evaluate water resources in a proper way in order to consider and to meet water demands within the territory of the country. (Committee of water Resources of the Republic of Kazakhstan. 1996. Annual Operation report for 1995. Almaty)

Irrigated agriculture is very important for crop production. Kazakhstan previously produced 20-30% of crop production (including 100% of rice, sugarbeet and cotton, about one third of vegetables, more than 25% potatoes, etc,) on irrigated land, which occupied a little more than 5% of the total arable lands of 3.3 mha of which 2.3 mha are with regular irrigation.. In the recent past, a high predomination of monocultural production on irrigated lands, for example rice production has brought about significant negative consequences in production and social spheres, as well as in ecology. It is expedient to reduce the production share of these crops to an extent determined by recommended crop rotation structures and to replace them with fodder, vegetable and other crops. (Agriculture of Kazakhstan. Statistics for 1994-1997). During the last few years irrigated lands have been significantly reduced, due to unfavorable land reclamation status of irrigated areas, malfunction of inter-farm and on-farm network, and shortage of water, etc. Besides, after introducing of water-pricing, the owners of land have been forced to switch into rainfed agricultural production, as they are not able to pay for water. Thus, for the period 1991-1995, the reduction made is about 84,000 ha, while in 1996 it was 165,400 ha. (Ospanov B. 1998. Improvement of land relations and its legalization in the Republic of Kazakhstan. The Land relations and organizationof the use of land. International Agriculture Magazine 1: 6-7).

2.5 Problems of Rotational Use of Water and Soil Resources in Tajikistan

In the republic of Tajikistan, there were nine operated reservoirs in 1995, the capacities of which are from 0.028 to 10.5 km^3. The total volume of water in these reservoirs makes up about 12% of the total runoff of Central Asian Rivers, but this index will increase up to 22% after the reservoir is put into operation, with its capacity of 13.3 km^3, which is now under construction. About 600 rivers and temporary watercourses of Amu-Darya and Syr-Darya Basins originate on the territory of Tajikistan as here are the headwaters of Amu-Darya and Zerafshan Rivers, minor middle parts of Syr-Darya River and tributaries of these rivers. The total runoff of the rivers traversing the territory of the republic amounts to 65.1 km^3 per year. Of this volume, in the average year, 51.2 km^3 is formed within the boundaries of Tajikistan, including Amu-Darya Basin (50.5 km^3) and Syr-Darya (0.7 km^3). During the last few years, monitoring for quality of surface water is not being carried out by the hydraulic metering service, because of complicated economical and political conditions in the Republic. Therefore, it makes difficulties for deriving reliable data on quality and quantity of regenerated flows into rivers.

Development of new areas, increase of water supply to the foothill zones and high specific-water supply for irrigation of about 17,000 m^3/ha cause an increasing feed of underground water, enhance the hydro-chemical processes, and result in waterlogging and salinization of lower lands. All these facts lead to overloading of the drainage system and increase the volume of collector-drainage runoff, which makes 30-40% of water abstraction for agricultural needs in the country. In order to explore integrated use of water and land resources in the Republic, it is necessary, first of all, to define the main goals of development, to consider a system of the auxiliary objectives and its interrelations, and to identify their properties.

2.6 Management of Water and Land Resources in Turkmenistan

In general, in Turkmenistan, only about 3% of its total area of 448,100 km^2 is considered suitable for development, while for stable irrigation it is not more than 2 mha. Agriculture of Turkmenistan was previously based mainly on artificial irrigation dictated by the features of nature-climatic conditions of the region. Within the territory of the northern Turkmenistan, there was a developed system of irrigation canals and water intake dams. There were more than 300 small-sized irrigation systems in this region and the general extent of irrigation canals had reached 10,000 km. Thus, in the territory of Turkmenistan, by the 20^{th} century had a rather developed system of native agriculture with artificial irrigation on the area of about 200-250 thousand ha. At present, the water resources of the country which are used by economic sectors include surface runoff of Amu-Darya, Tezden, Atrek Rivers and other small-sized watercourses, underground water, as well as minor quantities of collector drainage water of acceptable quality. The surface water resources account for 97.5 - 98.2% of all available water resources in the water-resources balance. The Amu-Darya is the most important surface water resource, as it is annual runoff distribution meets the demand of irrigated agriculture. (Report-yearbook about land reclaiming status of irrigated lands in Turkmenistan. 1998)

The area of irrigated lands in Turkmenistan during the last year3s fluctuated within a range of 1.7 to 1.8 mha. In the general scheme of used land, the share of Cotton and Wheat is about 60% of total irrigated area. The production areas under each of these crops make up 500-600 thousand ha. With consideration of water supply method, the irrigated lands are classified as follows: 52% are irrigated by gravity, and 48% by means of machine water-lifting. The majority of irrigation canals pass through ground bed (its share in the total extent of canals is about 92%). The water intake for the farm irrigation and other purposes is conducted in accordance with the water supply schedules, handed out based on "Crops Irrigation Scheduling in Turkmen SSR" (Ashkhabad, 1990) for Turkmenistan region. At present, the bedding depth of underground water withing the irrigated area is as follows: up to 1 m, 1%; from 1 m to 2 m 39%; more than 2m, 60%. It is necessary to note that the determining factor for the land use iis not a table of underground water bedding, but its salinity content.

Regarding the issues to improve water and soil resources management, first of all, it is necessary to accomplish an institutional reorganization of water resources management system, to improve the techniques, and re-equip the water facilities complex with consideration of updated regulatory-legal basis. These are the necessary conditions for further development of irrigated agricultural potential, of which the constraints are water resources scarcity and financial investments. (Hydro-ecological and land reclaiming expedition of the Ministry of Land Reclamation and Water Economy of Turkmenistan. 1998. Ashkhabad)

2.7 Soil and Water Resources Management in Uzbekistan

The agriculture of Uzbekistan is developing mainly on irrigating systems consecrated in the basin of Amu-Darya and Syr-Darya Rivers, as well as in the Valley of Zarafshan River. The development of agriculture is constrained by scarce water resources. Syr-Darya and Amu-Darya Rivers are the sources of irrigation water for 90% of areas under crops. The intensive large-scale development of irrigated lands and establishment of new cotton-growing State farms have taken place during the period 1960-1980. Within this time there have been developed more than 500 thousand ha of new lands, and hundreds of new cotton-growing farms were established in Golognaya, Dzhizak, Karshy, Surkhan-Sherabad steppes and the lower course of Amy-Darya River. (Ministry of Agriculture and Water Resources of Uzbekistan and World Bank, Irrigation and Drainage Sector Strategy Study, vol. 1-3. Draft, November 2000)

The problem of soil resources conservation and improvement of soil fertility is one of the key issues to increase the agricultural production efficiency. Change of cropping structure, introduction of crop rotation practices (cotton-cereals), and decrease of areas planted under alfalfa are dictating the necessity for adoption of new production technologies. It is necessary to reduce soil tillage to prevent both the negative changes in soil structure and avoid and soil compacting in the case of heavy machine use. (Fawzi Karajeh, John Ryan, Christoph Studer ed, 2002. On-farm Soil and Water Management in Central Asia. Proceedings of an International Workshop, 17-19 May 1999, ICARDA/SANIIRI, International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria).

2.8 Irrigation and Drainage Development

To the beginning of the last century, the total irrigated area in present territory of Uzbekistan has reached 1.2 mha, and by the end of the century has increased up to 4.28 mha or 3.6 times and makes 82% of the cultivated area. Impetuous growth of the irrigated lands was marked in second half of the last century, when the large-scale program of cotton irrigation and development of Hungry and Djizzak Steppes in the central part began to be implemented. Karshi - in the south of the country and other so-called virgin lands in a zone of Amu-Bukhara pumping canal, Central Fergana, Surkhan-Sherabad valleys and others. Simultaneously land development began for rice sowing in delta of Amu-Darya in Karakalpakstan.

At present, the irrigated lands give over 96% of gross agricultural output of Uzbekistan. About 44% of total irrigated area of the country is concentrated in Syr-Darya river basin and up to 56% in Amu-Darya river basin. Uzbekistan has a big potential reserve of the area suitable for irrigation, but water resources limit development of irrigation. Basically, all irrigation is controlled using surface water. Drainage flow as return water in a natural condition and in part at water users participation enter into waterways and mixing up with a natural flow form major part of available water resources. It is practically impossibly to specify these to account the areas irrigated using the flows. (MAWR of Republic of Uzbekistan, Mission of the World Bank to Uzbekistan: Strategic Study of Irrigation and Drainage Sector, Volume 1 and 2). Practically, in Uzbekistan, the irrigation is of surface type, including about 69.9% of furrow irrigation, 26.0% strip and 4.0% of basin irrigation. Sprinkling and Drip irrigation practically used on experimental fields only 2.1%.

Meanwhile, research experiments have demonstrated that present crop yields could have been produced with half amount of applied irrigation water. Hence, to produce 5-6 tons of wheat per hectare it is enough to apply 2.000–2.500 m^3 of irrigation water. Presently they apply 4.500-5.000 m^3 of water per hectare, while the average crop productivity for the country is only about three tons per hectare. The same situation occurs in cotton growing. According to the trail experiments, to produce 4.0-4.5 tons of cotton per hectare it is enough to apply 3.000-3.500 m^3 of water. However, the actual water consumption makes 7.000–8.000 m^3, while the crop production is less than three tons per hectare.

Because of complex natural and climatic conditions in many regions of the Country, it is impossible to develop agriculture without reclamation. In 2000, total irrigated area in Uzbekistan was 4.3 mha and out of this 2.9 mha area was provided by drainage. At present, the only way to improve salinized lands is to wash soils away and use artificial drainage.

The maintenance of open collector net capacity at required level is the main condition, encoring drainage in lands with horizontal drainage systems. At present, the repair and rehabilitation works on horizontal drainage systems are planned without taking into account land reclamation condition indices, actual reclamation regimes, indices of drain and collector net reliability, natural and economical, and meteorological conditions.

All above-mentioned facts are a consequence of using inappropriate irrigation practices. Thus, research activities of the Cotton-Growing-Institute proved that during the vegetation period, under furrow irrigation of cotton, 50-60 tons of soil, 1000 kg of organic matter, 100-130 kg of nitrogen, and 140-150 kg of phosphorus fertility, as well as washing away organic matter and mineral fertilizers, has a negative impact on the ecological status of the environment.

2.9 Water Saving and Conservation

In Tashkent province of Uzbekistan, on typical gray soil, seedbed preparation with a rotary cultivator 10-12 cm deep with sub-soiling at 45 cm as compared to plowing provided higher yield of winter wheat planted after cotton in a dry year, but reduced the crop yield in wet year. Broadcasting of wheat seeds under shallow cultivation into standing cotton caused grain yield reduction in dry year but increased the yield in wet year, saving 28 liter of diesel on each hectare. This data show that this practice may become a very important soil and water resources conserving technique. In the short and medium term, a substantial amount of water can be saved by:

- Improving the planning of irrigated lands;
- Improving the water supply system through the development of operational water delivery schemes, enhancing quotas and limits of water consumption, and improving the control over water use; and
- Providing an appropriate maintenance and small preventive repair of canals and water delivery systems and the cleaning-up of drainage and irrigation networks.

In addition to this, reductions in agricultural water use have to be achieved by changing the incentive structure for better practices for water users and water suppliers and institutional restructuring, complemented by the reconstruction and improvement of irrigation and drainage systems. The main recommended activities include as follows: i) Greater reliance on water charges, local funds and private sector involvement to finance the rehabilitation and modernization of the irrigation infrastructure; ii) Involving farmers in the operation and management of irrigation systems and increasing the incentives for them to improve the cost recovery mechanism; iii) Strengthening the legal and institutional basis, in particular for the fee-based use of water; and iv) Increasing public awareness about the need for large-scale common action on water saving and water conservation, and participation of all stakeholders in water resources management

In the short and medium term, special attention should be paid to institutional changes targeted at increasing the incentives for Water Suppliers (irrigation agencies at the local level) and Water Users (farmers and farmers' organizations) to use water more efficiently. In the area of water resources management, the National Environmental Action Plan (NEAP) recommends a program of actions as follows: i) Water saving and water conservation; and ii) The introduction of the integrated management of water and land resources in order to prevent further water and soil salinization and to improve water quality.

2.10 Improving Agricultural Land Use

A consistent reforming of the agricultural sector will be able to provide the necessary ground for resolving environmental problems caused by inappropriate agricultural land and water use practices. As world experience shows, a shift from monocultural agricultural production towards more diversified crop production (for example, more expansive planting of Lucerne, Wheat) is necessary to improve both the agricultural sector performance and the environment in rural areas. The increasing role of economic incentives, the liberalization of prices and markets, the creation of a flexible and responsive market system, and the establishment of a secure land tenure system will provide the necessary conditions for changes in crop production, while the use of new technologies will increase the efficient use of land and water in agricultural production. The most urgent initiatives in this area include:

- Establishing a system of well-defined and protected property rights on land use;
- Development of rural infrastructure;
- Improving the legislation (developing new and revising existing regulations, implementing reinforcement mechanisms);
- Phasing-out state orders on cotton and grain production; and
- Phasing-out subsidies for fertilizers and equipment and the transition to fee-based water use.

The water and land resources of Uzbekistan are the major natural factors of the sustained social and economic development of the Republic. Being on the verge of depletion, they are still used inefficiently and in a wasteful manner. These facts effect negatively on the natural and economic resources of the Republic. Improvement of agricultural output in the Republic is only possible based on the rational use of existing water resources, and the achieving of greater productivity on land. In developing the agricultural sector, any decisions should anticipate possible environmental risks.

Attention should be paid to increasing land productivity. This is an important determinant of agricultural growth in Uzbekistan, since the yield in the country is significantly lower than in other developed countries with similar climate conditions. In order to increase agricultural yields, it is necessary to: 1) raise the seed quality; 2) increase the use of fertilizers and pesticides (which has sharply decreased in the last decade); iii) implement sufficient cultivation practices and timely harvesting; and vi) improve the farming culture in general.

2.11 Environmental Impact on Land Use

Cotton monoculture together with misbalance of NPK to be applied into the soil, deterioration of irrigation regime and drainage have resulted in degradation of separate cultivation areas, especially in risk zone of irrigated agriculture down to partial retire of irrigated area from agricultural production. Over-use of nitrogen fertilizers, especially ammonium nitrate to compensate depleted soil fertility and shortage of P and K in the soil led to nitrate contamination of water sources. Under present conditions, the great attention is devoted to application of mixed fertilizers, and nutrients control in the soil. In connection with elimination of cotton monoculture and extension of small grains area some conditions for are being created to rehabilitate soil structure, reduce drain flow mineralization entering into water sources, and decrease this flow nitrate pollution and to improve NPK balance. It is noted the growth tendency in crop yields under relative reduction of mineral fertilizers to be applied.

2.12 Waterlogging

Intensive rise of ground water level in irrigated area is a consequence of high seepage losses from canals and irrigation fields and inadequacy of drainage and disposing systems. Continuous domination of cotton monoculture and increase of the rice area, with high inputs of irrigating water, also facilitated strengthening of soil degradation. Irrigation by flooding practiced leads to water logging of soils and to an accumulation of salt in the soils. Ground water lies far above the soil depth of 2 m, which leads to the transport of water-soluble salts into the root zone of the plants and to the soil surface via evaporation and capillary effects. (ZEF, Bonn, 2001. Project Proposal., Economic and Ecological Restructuring of Land and Water Use in the Region Khorezm, Uzbekistan). This problem soils is widely spread in zones of difficult natural outflow (Karakalpakstan, Khorezm, Bukhara, Ferghana and Syrdarya Oblast). Total area with a critical level of underground water is shown in Table 2.1.

Table 2.1 Distribution of Water Logging Area, 1999 ('000 ha)

Month	Surveyed area	Less 1 m	1.0-1.5 m	1.5-2.0 m
April	4221,12	81,65	428,38	844,20
July	4080,76	162,05	347,52	774,29
October	4211,13	67,41	395,53	872,12

Source: Soil Institute, 2001.

According to the data of Soil Science Institute, about 77.2% of irrigated area of Khorezm region has ground water level from 0-1.0 to 1-2.0 m. Land area with mineralization 5-10 g/l and 10-15 g/l composes accordingly 17.3% and 10.0% of total irrigated area. In Djizak region, its various ranches of 1.0-2.2 m and average depth according 1.29-2.03 m. Ground water mineralization are chloridesulphate and sulphate from 2.2 to 17.8 g/l (Soil Institute, 2001). Existing practices of irrigation and leaching do not provide an adequate desalination of irrigated salt affected soils and gypsiferous soils in Hunger and Djizzak steppes.

2.13 Future Development

Considering all above-mentioned issues, a program of improving the irrigation methods in the Republic of Uzbekistan has started. There are trails to be conducted for application of drip and sprinkler irrigation. It is well understood that the adoption of more appropriate irrigation technologies initially requires substantial investments. Therefore, the process of introduction of such methods as drip and sprinkler irrigation is going on slowly. However, it is necessary to take into account that introduction of appropriate irrigation methods will assist in solving many social-economic problems, in particular irrigation water saving, facilitation of the irrigation process, improvement of production technology, and conservation of soil fertility and its structure. One of the main social and economical objectives of introducing appropriate irrigation methods is to ensure 5 km^3 of irrigation water to be saved.

Further agricultural growth can be achieved in Uzbekistan only through the more efficient use of already fully utilized water resources and an increase in land productivity. In moving towards greater agricultural intensification, environmental repercussions both negative and positive should be taken into account, while developing policies and making decisions on agricultural sector development.

2.14 Soil Salinity

Water mismanagement and unsustainable land use cause development of soil degradation and deterioration in its quality. Most part of the irrigated area is subject to several types of degradation, which influence causes decrease of agricultural production approximately up to 30-42 % per year. The most extensive major category of problem soils is the human-induced (secondary) salinization of the old and new irrigated areas. Occurrence of the secondary salinization on irrigated area in Uzbekistan is given in Table 2.2. It occurs elsewhere within Uzbekistan with considerable difference in genesis of salinity. For example, the soil salinity in the new irrigated area of Hunger and Djizzak steppes, and Karshi steppe is mostly connected with the residual-natural salinization. Secondary salinisation of soils is occurred mostly in Karakalpakstan, Syrdarya, Khorezm and Navoi, as well as in Ferghana, Kashkadarya and Bukhara Oblasts.

The main causes of the secondary salinisation in the irrigated area are water mismanagement and poor drainage, and water quality deterioration. Infrastructure of the irrigation and drainage is operated more than 30 years without modernization and rehabilitation. Because of the operational difficulties, many existing drainage systems are malfunctioning or losing its carrying capacity, and approximately 50% of the vertical drainage is not operated at all. The extreme water overuse for irrigation on a background of poor drainage brings about the rise of ground water table and under flooding.

Table 2.2 Occurrence of the Secondary Salinization on Irrigated Area in Uzbekistan

Region	Irrigated Area ('000 ha)	Salinization Degree, %			Total Saline Area	
		Light	Moderate	High	('000) ha	(%)
Ferghana	356.9	29.1	8.7	8.3	103.8	53
Syrdarya	293.7	54.3	25.2	7.2	254.9	99.1
Djizak	300.5	46.7	37.5	1.0	256.0	82.9
Tashkent	390.9	2.0	0.4	0.0	9.2	2.5
Samarkand	373.2	2.2	1.2	0.2	13.6	6.8
Bukhara	273.6	58.2	27.0	10.1	260.5	38.9
Navaiy	127.7	53.5	28.7	4.9	111.2	86.6
Syrkhandarya	328.2	25.4	16.5	1.8	143.5	43.6
Kashkadarya	500.9	32.4	10.7	3.0	232.5	46.7
Khorezm	275.3	46.8	41.1	12.1	275.3	100
Karakalpakistan	500	50.7	33.7	9.8	471.6	94.3
Total	**4275.2**	**30.8**	**18.3**	**4.5**	**2111.6**	**50.3**

Source: Uzgiprozem, 1999

2.15 Soil Erosion

Wind erosion is observed on the area over 2.0 mha of the irrigated land. Its development is promoted greatly by natural factors. Nature of economic development and land use strengthen this development. The greatest damage causes ploughing up and processing of slopes without observance of anti-erosion agro-technical methods, and over-pasturing of the cattle. Harmful winds are characteristic for the western and central part of Ferghana valley, southeast part of Hungry steppe, Surkhan-Sherabad valley, Karshi steppe and Bukhara oasis. Sowing area in Surkhandarya frequently suffers from a hot wind "Garmsil" which is accompanied by dusty storms.

Water erosion affects more than 4 mha or about 20% non-irrigated areas, and in separate oblasts, Surkhandarya, Samarkand, Kashkadarya on 50% to 60%. Erosion is wide spread on foothill slopes and adirs. Especially dangerous of the erosion is developed under steep slopes with poor vegetative cover and intensive stock farming. Irrigation erosion is observed on irrigated area and it is occurred on 262.1 thousand ha. It is the consequence of wrong furrow irrigation or by flooding on poor land leveling. It arises at application using great rates and on considerable slopes when speed of water exceeds speed of soil absorption. Besides the specified types of erosion in separate territories, the combination of water and wind erosion is observed. The area of the land subject to mixed erosion makes about 1.4 mha. Basically, these are Kashkadarya and Surkhandarya Oblasts.

Mudflows are formed as a result of snow melting in the mountains, intensive rainfalls which fall in treeless and heavy eroded basins where the significant amount of melkozem and debris material have been accumulated. The area, subjected to influence of mudflows and avalanches makes 4.7 thousand ha (Ferghana valley, Tashkent, Syrdarya, Kashkadarya and Surkhandarya Oblasts. On average estimates, the total area occupied by ravines makes about 35 thousand ha. Distribution of Wind and Water Erosion in Uzbekistan is shown in Table 2.3

Table 2.3 Distribution of Wind and Water Erosion in Uzbekistan (area in '000 ha)

Irrigated			**Rainfed**			**Pastures**		
Slight	Mean	High	Slight	Mean	High	Slight	Mean	High
				Wind erosion				
1459,0	519,0	134,0	215,1	26,7	1,6	1108,3	10521,2	5663,7
				Water Erosion				
200,4	52,8	8,9	314,2	209,0	177,2	1106,2	1262,9	947,2

The drying of the Aral Sea has created so-called desert «Aralkum». This solid salt marsh emits tremendous masses of salt and finely dispersed dust that is transported by a powerful air running from west to east (UNEP, 2000). The average yearly fallout of salt in the Aral Sea basin is estimated between 150 and 230 Mtons. These aerosols comprise sulphate, chlorides and even heavy metals.

2.16 Fertility Degraded Soils

At present, content of the humus in the soil, which is basis of its fertility, has decreased by 30-40%. Soils with the very low humus content (0.4 to 1.0 %) occupy about 40% of total irrigated area, and low productivity soils cover 0.5 mha. Continuation of these processes lead to further loss of organic matter and, thus, soil fertility. It is serious threat for sustainable development of irrigated agriculture of Uzbekistan. The main causes of fertility degradation are the monoculture of cotton that caused loss of humus, exhaustion of the soil and its physical and chemical qualities. Cotton monoculture enquired a large-scale application of chemical fertilizers, pesticides and insecticides. Huge chemical doses (from 20 to 90 kg of pesticides and 300-500 kg of mineral fertilizers per one hectare) and the highly intensive agricultural practices resulted in soil fertility loss.

Progressive contamination of soils has been observed in many farms. Its sources were large rates mineral fertilizers and pesticides, industrial waste discharge, and motor car exhausts; all of which create access for harmful substance to the soil, ground, underground and river waters, to plants and nutrition products. The heavy metal accumulation in soil brought about along by fertilizers and industrial waste, is an issue of concern. Soil actively absorbs motorcar exhaust gases. The radioactive elements from industrial enterprises may also have access to soil trough the air. In this issue of soil environment conservation, soil specialists should explore in detail of the upper soil layer, for its content of nitrates, pesticides, heavy metals, radioactive elements, and fluorine compounds, develop measures to prevent soil contamination by chemical substances and decreased their negative influence.

2.17 Water Use and Water Use Efficiency (WUE)

A general definition of crop Water Use Efficiency can be described as:

$$WUE = \frac{Crop\ Production}{WaterUsedForTheProduction} \quad \ldots\ldots \text{ ("Crop per Drop")}$$

One classical definition of WUE (by Power, 1983) used for many years is:

$$WUE = \frac{Y}{ET}$$

Where,

WUE – Water Use Efficiency;

Y – Quantity of the plant product (either biomass or marketable product) produced on a given surface area in a given time period;

ET– Water used for evapotranspiration from the same surface in the same period

However, many parameters additionally contributing to the efficiency of water use in crop production are not reflected in this definition, particularly with regard to rainfall capture, the efficient use of irrigation water, or the extent of different types of water loss. It is clear that scale at which we consider WUE determines largely the definition of WUE to be used; the parameters to be included in the definition of WUE differ a lot, depending on whether we are interested in WUE at the leaf, plant, field, and farm or basin level.

Water use and water use efficiency of both irrigated and dry land crops are measured with weighing lysimeters and with soil water balance methods using measurements of soil profile water content. Accurate soil water content measurement systems are determined/developed. Water use is predicted with well-established but limited models, and more experimental methods, including those providing spatially varying predictions (maps). Effects on water use and WUE of irrigated methods, timing and depth, tillage, and plant density, row spacing, and other management methods are investigated using sprinkler, surface and micro irrigation. Crop coefficients that are compatible with the new FAO 56 guidelines for computing crop water requirements are determined for alfalfa, corn, cotton, sorghum, soybean, wheat, and several turf varieties using both newly measured data and our previous thirteen years of data.

2.18 Factors Effecting Water Use Efficiency

Crop production is a very complex process. Many factors and variables influence this process, many of which remain to be known. According to current knowledge, factors affecting WUE can be broadly categorized in four groups as follows:

1) ***Climate:*** The two most important factors in this category are water (rainfall) and temperature. These are working in two opposing directions. In dry areas, an increase in air temperature is usually associated with an increase in vapor pressure deficit. Consequently, these are increase of evaporation and water loss from plant and soil (Turner, 1997). The more humid the atmosphere, the greater the WUE is, all other things being equal. Dry land farming is a rainfed crop production system in which water is the major factor limiting production. Ideally, as much as possible of the available water should be used for transpiration with minimum losses to evaporation, "Drainage", and "Runoff". WUE is very sensitive to changes in soil water is low increases crop yield, but simultaneously increases crop ET as well (Jensen et al. 1990 and Carefoot and Major, 1994)
2) ***Soil:*** Soil is the basic resource in agriculture. Sustainability of agricultural production depends heavily on its proper management (Trout et al., 1990). Because soil acts as a reservoir for storing water and nutrients necessary for plant growth, soil depth and type are probably the most two important factors, especially in rainfed areas. The effect of soil management on water use efficiency cannot be considered independently of other factors, particularly water and crop factors. Soil fertility is among the important factors influencing crop production. It has been well established that yield increases with the

increase in the rate of fertilization until to a certain limit depending on the level of water availability to the crop (Harris et al. 1991; Rayan nad Matar, 1992; Jones et al., 1993; and Pala et al., 1996) Beyond this limit, increasing the rate of fertilization will not increase the yield unless the water availability to the crop increased. In dry area agriculture, soil surface management is of utmost importance because these aims work collectively to efficiently capture, store and beneficially use the limited amount of rainfall water.

3) ***Crops:*** Among the crop factors and crop-related practices that influence yield and WUE are: Crop variety and species, tillage, planting date and phenology of crop in relation to the length and characteristics of the growing season, planting density, water and nutrient availability, rooting system, canopy morphology, weed control, disease, insects, crop rotation and cropping system (Harris, 1994; Jones and Singh, 1995; Pala, 1996). One of the primary ways to increase crop production is to select and adapt plant species that are suitable for the given environment. For dry areas, drought-tolerant plants are usually recommended. However, plants with high drought resistant are not usually efficient users of water. Further, plants having a drought avoidance strategy have greater survival value than tolerance because they can continue growth and development, while tolerant plants can only survive (Tipton, 1998). Thus, cultivars with a short growing season practically escape drought. However, a cultivar with a short growing season may yield less than longer-cycle cultivars during years with a long humid season.

4) ***Management:*** Variability of production and income is a major feature of dryland farming. Managers must be ready to adjust practices and farming plans for whether conditions. Drought periods within and across years is the major problem, along with some occasional severe frost and heat events. Farmers often have to cope with wide price changes that may severally affect their income and attitudes. Successful farm management must crop with uncertainties of whether disruption, machinery breakdown, input shortages, and labor vagaries (Hoffman et al., 1990; Jones, 1993). Among essential management factors and/or decisions that have a direct impact on farm productivity and

income (Perrier and Salkini, 1991) are related to the proper selection of: i) Crop varieties most adapted to the local environment; ii) sowing date and seeding rate; iii) crop rotation (with or without livestock) and tillage; iv) type, amount and timing of fertilizer application; v) weed control (timing and techniques); vi) pest and disease control; and vii) crop harvesting.

2.19 Water Harvesting and Supplemental Irrigation (SI) for Improved Water Use Efficiency (WUE) in Dry Areas

While irrigation may be most obvious response to drought, increasing the area under irrigation will be increasingly costly and to be efficient, it needs more sophisticated system. There is now increasing interest in a low-cost and simple technical alternative "Water Harvesting". Water harvesting involves the collection of natural or induced rainfall runoff and storing it for productive purposes. Rainwater harvesting techniques for agriculture were extensively practiced in past throughout much of North America, Latin America, Middle East, North Africa, China and India (UNEP, 1983; Manassah and Briskey, 1981).

Water harvesting links rain fed agriculture, soil and water conservation and irrigated agriculture. However, under water harvesting, there is generally no control over irrigation timing. Runoff can only be harvested when it rains. Nevertheless, water harvesting has great potential to increase and stabilizing agricultural production (Prinz, 1994). The goals of water harvesting are: i) supplying drinking water for man and animals, and water for other domestic purposes; ii) making land productive (grazing, marginal and arable); iii) increasing yield in drought-prone areas; iv) minimizing desertification of tree cultivation; and vi) generating new jobs, improving farmers standard of living and preventing migration to urban areas

Water harvesting can be defined as the process of concentrating rainfall through runoff from a larger catchment area to be used in a smaller target area. The process may occur naturally or artificially. The collected runoff water is either immediately used to irrigate an adjacent agricultural field or stored in some type of on-farm storage facility for later use such as, water supply source for animals and humans or for supplemental irrigation of crops. Water harvesting is generally feasible in areas with an average annual rainfall of at least 100 mm in winter rain areas and 250 mm in summer rain areas. It is a technique that may support a flourishing agriculture in dry areas, where the rainfall is low and /or erratic in distribution (Oweis and Taimeh, 1996; Carmona and Velasco, 1990; Oswal, 1994, Krishna et al., 1987)

Supplemental Irrigation defined as the addition of limited amount of water to the crop during times when rainfall fails to provide essential moisture for plant growth, in order to improve and stabilize yield, the additional water along being insufficient to produce a crop (Oweis, 1996; Arar, 1992). The concept of (SI) in rain fed areas having limited water resources has three bases as follows: 1) water applied to rain fed crops which normally produce without irrigation; 2) since, rainfall is the principal source of moisture for rain fed crops, SI are applied only when rainfall is inadequate; and 3) the amount and timing of SI are not meant to provide moisture stress-free conditions over the growing season, rather to provide minimum water during the critical stages of crop growth to ensure optimal instead of maximum yield.

Therefore, supplemental irrigation is a limited type of irrigation, intended to optimize crop yield per unit of applied water rather than per unit of cultivated area. SI aims to increase total farm yield and WUE by maximizing the area that benefits from the water available (Caliandro and Boari, 1992). For greater effectiveness, SI should be given at those critical growth stages at which water deficits can severely affected yield. Thus, in order to maximize WUE, it is important to know the sensitivity to water stress of the growth stages of each crop species. Potentially, SI may have three major effects: 1) yield improvement; 2) stabilization of production from year to year (increasing reability); and 3) providing conditions, suitable for economic use of higher technology inputs, such as high-yielding varieties, fertilizers and herbicides.

CHAPTER III

STUDY AREA "BOYKOZON" BENCHMARK SITE IN THE TASHKENT PROVINCE OF NORTH-EASTERN UZBEKISTAN

3.1 Introduction

In 1998, International Center for Agricultural Research in the Dry Areas (ICARDA) established an integrated research site at Boykozon farm in the Tashkent Province of northeastern Uzbekistan. The map of the site is given in Fig. 3.1. The site represents the typical agro-ecologies and mixed farming systems of the steeply sloping hill terrain of Central Asia. It was selected as a suitable place to conduct the integrated research needed to address the common problems of low agricultural productivity and degradation of the natural resource base.

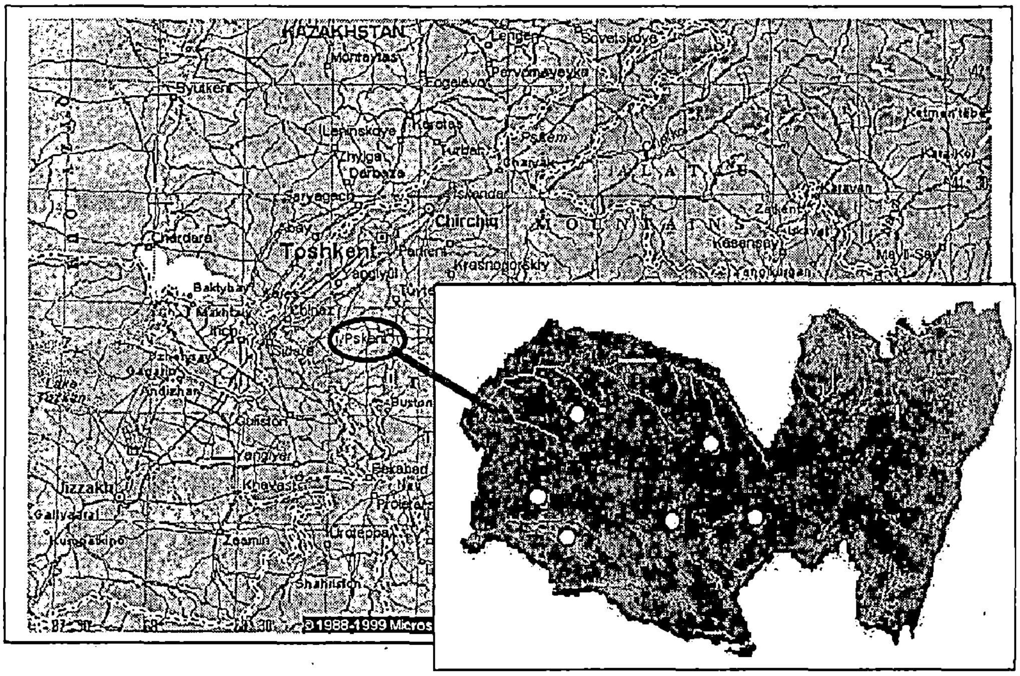


Fig. 3.1 Map of Boykozon farm in the Tashkent Province of North-Eastern Uzbekistan

Boykozon farm covers about 8,000 ha, including 6,000 ha of rangelands. It contains wheat, vegetables, fodder crops, fruit trees and grapes. There are 1,300 people working on the farm. Steep slopping land that causes soil erosion and other serious problems in soil and water management are the major constraints to sustainable agriculture development in the farm. The climate of Boykozon shows the extremes of weather, typical of continental locations. In winter, temperature frequently falls below freezing, while in summer it reaches nearly forty degrees centigrade (40^0 C).

The main emphasis is given to water and irrigation management through testing and improvement of irrigation technologies to increase water use efficiency and reduce soil erosion, which is a major problem on sloping lands. The soils are mainly moderate to heavy loam, with low to medium nutrient contents. Winter wheat, vegetables, and grapes are the main crops and, beet, alfalfa, and fodder grains are grown. Irrigation water is provided from the Parkent main canal, which comes from the Chirchik River. Two problems characteristics of Uzbekistan's irrigated areas prevail at this site:

- Low productivity from the water available and loss of soil by erosion due to runoff from irrigated fields; and
- Considerable amount of water flows off the fields during irrigation, taking away large amounts of soil and nutrients.

The result shows crop yield is declining, in addition to the negative environmental impact. Annual soil erosion of the country averages 51 t/ha, while that of irrigation efficiency is less than 60%.

3.2 Advanced Irrigation Technology for Optimization of Irrigation Application, Water Use Efficiency, Soil Erosion and Yield

After tests of Joyak (Zigzag) irrigation method using various types of furrows, it was found that the most efficient and optimal productivity observed on zigzag furrows having 2.8-3.0 m. width. The width of furrows depends upon on the degree of relief.

However, the experimental result shows that to minimize the difficulty of regulation of water flows and overall work the width of the furrow should not be less than 2.0 m, are illustrated in Figs. 3.2 and 3.3. For strongly intersected slopes, zigzag with 2.0 m width and similarly 2.5-3.0 m width for nearly parallel or parallel horizontal slopes. Spacing between the furrows of 0.7-1.4 m across the slope increases irrigation efficiency along the zigzag from 0.78 up to 0.87 against efficiency of control (traditional) irrigation method of 0.7-0.75. The economy of irrigation water makes 400-878 m^3/ha for the whole cropping season. As infiltration rate increases in zigzags furrows of 2.0 m permeability will be 0.0011-0.0039 m/hr. Similarly in zigzags furrows of 2.5 m and 3.0 m permeability will be 0.0018-0.0045 m/hr and 0.0028-0.0048 m/hr respectively.

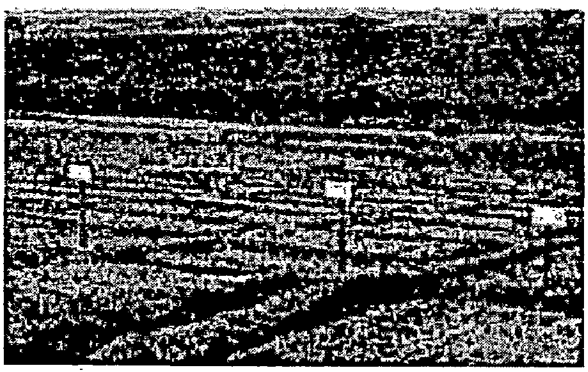


Fig. 3.2 A view of Zigzag furrows

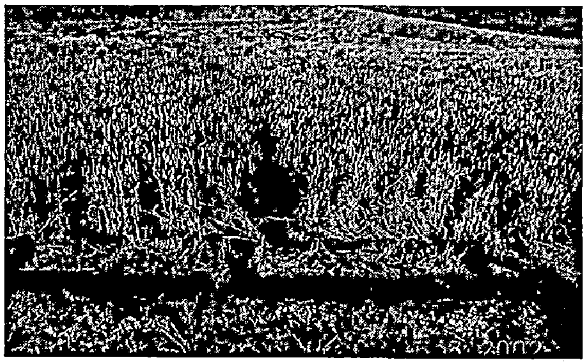


Fig. 3.3 Winter wheat irrigated by Zigzag irrigation

Soil erosion will also decrease from 0-0.52 ton/ha in a year in comparison with 3.48 ton/ha for the control of in a year due to the reduction in velocity of flow along the furrows from 0.22-0.23 m/sec (control) to 0.12-0.14 m/sec. The excess water at the end of furrow is 2.0-2.35 times less when compared to the control. The water productivity increased from 211.3 -253.2 m^3/ha (control) to 103.3-184.3 m^3/ha. Inter-irrigation periods were shorter than that of for control irrigation which required over 4-5 days. Labor productivity varies from 0.83 ha/day for control to 1.78-2.86 ha/day. Atmospheric precipitations were effectively used in zigzag furrows. All specific parameters of Winter Wheat irrigation are given in Table 3.1.

Conclusively, research of Joyak (Zigzag) irrigation of Winter Wheat indicated that high water-saving efficiency as well as protection of soil from erosion can be achieved. However, zigzag irrigation technology has its own limitations: during the period of harvesting, intersected furrows are made are leveled so as avoid difficulty for the movement of tractor "combiner". And hence, it is necessary to develop mechanisms for cutting zigzag furrows.

Table 3.1 Results of research of improvement of irrigation technology of winter wheat in 2001-2002

Parameters		**Control irrigation**	**Zigzag irrigation**			
			2.0 m	**2.5 m**	**2.8 m**	**3.0 m**
No of irrigation		3	3	3	3	3
Total (m^3/ha)	Gross	3510	3510	3510	3510	3510
	Net	2500	2600	2500	2500	2400
Irrigation efficiency, (%)		0.71	0.78	0.80	0.81	0.82
Precipitation (m^3/ha)		3446	3446	3446	3446	3446
Soil erosion (t/ha/year)		3.48	0.52	-	-	-
Soil moisture regime		70	70	70	70	70
Production, (quintal/ha)		32.4	37.2	41.1	46.5	45.4
Net irrigation consumption (m^3/quintal)		77.2	64.8	59.6	51.6	52.4
Slope				0.08 - 0.11		
Length of furrow, (m)		66	160	184	194	207

Source: SANIIRI, 2002

3.3 Experiments on Portable Polyethylene Chutes (PPCH-50) with adjustable apertures for Irrigation of Potato and Wheat Crop

Uniformity of water distribution on irrigated sloping areas is usually poor. Application of improved irrigation technologies using portable chutes has provided a uniform water jet to each furrow. Irrigation water has been most rationally used on irrigation of potato with the help of PPCh-50. Water productivity has also doubled under growing of summer-sown potatoes from 1.6 to 3.4 kg/m^3. In Fig 3.4, we can see observed water productivity under spring and summer sown potatoes using the PPCh-50 and traditional irrigation practice

After testing of PPCh-50 on various slope steepness, the particular characteristics and parameters which were received in comparison with traditional irrigation method are given in Table 3.2. For the application of PPCh-50, technical and operational parameters are necessary for its guidance.

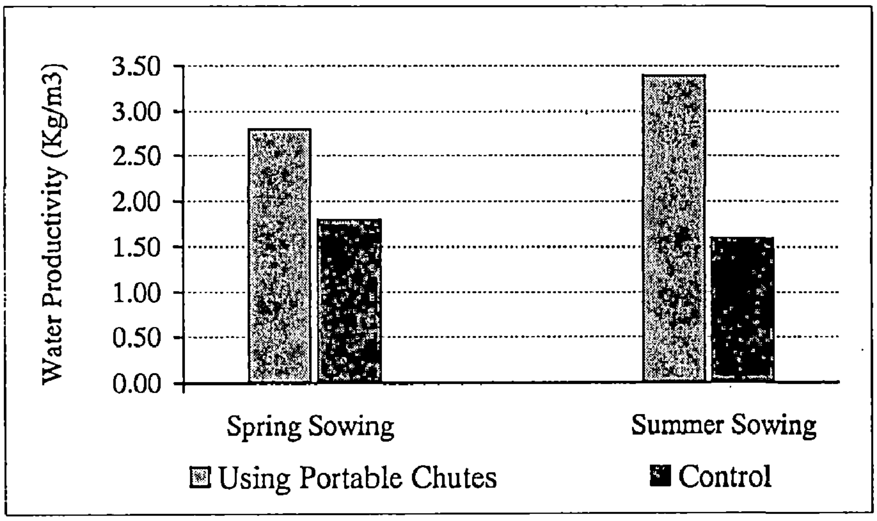


Fig. 3.4 Water productivity under growing of summer sown Potatoes

In case the furrows are lengthy, two or more complete sets of PPCh-50 are necessary. The first one is installed at the beginning of furrows, and the second one is about 60-100 m dawn the slope. A water-distributor is installed at intake point so that, water will flow into the first set of PPCh-50 with the rest flowing into the second set of PPCh-50 through polyethylene hoses. From research, at the Boykazon farm in Parkent district of the Tashkent region of Uzbekistan, the key parameters, sizes, and operational parameters of PPCh-50 were received and are given in Table 3.3.

Locally manufactured portable polyethylene chutes were installed at the heads of the field furrows to replace inefficient ditches normally used to supply water in Figs. 35 and Fig. 3.6. The chutes eliminated seepage and ensured uniform distribution of water among the furrows, in addition to providing full control over the timing and amount of water applied to each furrow. This technology was also used on the wheat fields. As a result, the amount of irrigation water needed to produce the same yield was reduced by about 50%. In addition, due to less runoff, soil erosion was substantially reduced.

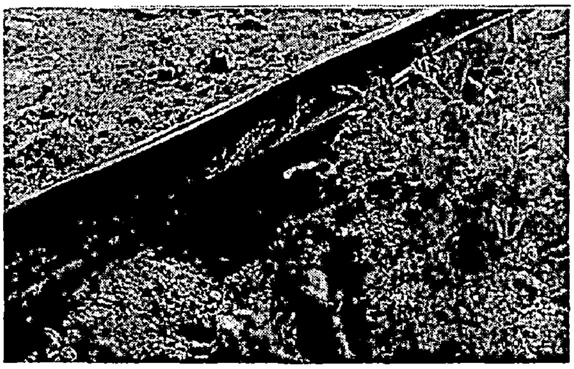


Fig. 3.5 Potato irrigated by PPCh-50

Fig. 3.6 Wheat irrigated by PPCh-50

Table 3.2 Results of research of improvement of irrigation technology of an early potato with the help of PPCh-50 in 2001

Parameters		Control Irrigation	Irrigation by PPCh-50
No of irrigation		10	10
Total (m3/ha)	Gross	11653	9930
	Net	8369	7928
Irrigation efficiency		0.72	0.80
Precipitation m^3/ha		-	-
Soil erosion t/ha		3.1	0.4
Soil moisture regime		75-80	75-80
Production, quintal/ha		31.2	32.4
Net irrigation consumption, m^3/quintal		268.2	244.7
Slope		0.074	
Length of furrow, m		67	67
Area, ha		0.3	0.3
Water discharge, l/s		0.15-0.17	0.08

Source: SANIIRI, 2001

Table 3.3 Main Operational Parameters of PPCh-50

.	Parameters	Measurements	Operational Parameters
1	Mark	-	PPCh-50
2	Scheme of irrigation	-	Contour, Furrow, and Cross-section
3	Max. Discharge	(l/s)	Up to 16
4	Discharge of water-releaser	(l/s)	0-0.1
5	Length of capture	(m)	50
6	Length of inter-row	(m)	0.7/0.35
7	Length of chute per piece	(m)	1.5
8	Set of chutes	Pieces	36
9	Number of water-releasers	-	72
10	Type of water-releaser	-	Adjustable
11	Size of water-releaser	(mm)	15. 50
12	Area irrigated from one position	(ha)	0.5
13	Factor of reliability of technological process	(%)	0.98
14	Factor of land use	(%)	0.99
15	Weight of a complete set	(Kg)	48
16	Warranty period of service	Years	5
17	Cost of a complete set (at serial release)	US $	50

Source: SANIIRI, 2001

3.4 Development of Self-pressurized Drip Irrigation System for Young Vineyards and Vegetables on abrupt biases

When there is an increase in deficiency of water resources, the drip irrigation system is necessary for cultivation of vineyards and vegetables in a foothill zone. The drawbacks to wide application of drip irrigation are high expenses for electric power and a long time of recovery of outlay of the capital expenses enclosed in system. Usually, a vineyard requires 4-5 year of fructification. For young vineyards in flat land areas in the first years the vegetable-cropping practice is to be followed using furrow irrigation. In drip irrigation, spaces between furrows remain dry. Therefore, intermediate cultivation is impossible. Due to this fact, most farmers are very reluctant to use drip irrigation system for vineyards on sloppy areas. Effective utilizing of bias areas within Uzbekistan is expected to be 214,240 ha. For cultivation of vineyards and intermediate crops, new design of drip irrigation system has been developed at SANIIRI, due to the pressure creates by sloppy land. The system is referred to as self-pressurized drip irrigation system.

At the Boykozon farm, as in many other locations, vineyards are grown widely spaced on steep slopes. A drip irrigation system was installed to provide irrigation water to vegetables such as tomatoes, peppers, melons, and cucumbers grown between the vine rows shown in Figs. 2.7, 2.8, 2.9, and 2.10. These enterprises earned additional profit of about US$ 800/ha besides having a positive impact on soil conservation. The vines also benefited from intercropping through improved soil moisture and application of fertilizers to vegetables.

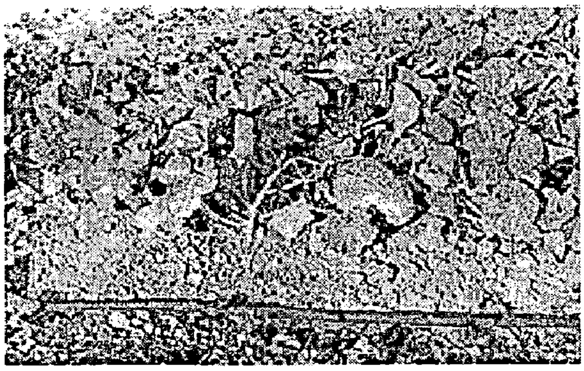


Fig. 3.7
Melon irrigated by Drip Irrigation

Fig. 3.8
Cucumbers irrigated by Drip Irrigation

In 2001, advanced drip irrigation technology tested at Boykozon site was found to be efficient for production of young vineyards, vegetables and melons grown in the inter-row spacing. Using this technology, farmers can benefit from reduced irrigation rate (from 660 to 220 m^3/ha) and secure profit from vegetables and melon during the first three unproductive years of vineyard establishment. Supervision of irrigation of vineyards and productivity of intermediate crops are given in Table 3.4.

Fig. 3.9
Young vines irrigated by Drip Irrigation

Fig. 3.10
Combined vineyards with vegetables irrigated by Drip Irrigation

Table 3.4 Regime of irrigation and productivity of intermediate crops

Crops	Field moisture capacity before irrigation, (%)	Number of irrigation (times)	Time of single irrigation (hr)	The period between irrigation (days)	Discharge of emitters (l/s)	Irrigation norm (m3/ha)	Relative norm (m3/ha)		Irrigation water economy, %	Production, (quintal/ha)
							Drip irrigation	Control irrigation		
Grapes	70	20	16	7	2.8	43	860	2800	69.3	-
Tomatoes	75	9	7	10	2,7	109	981	5300	81.5	360
Cucumbers	75	10	7	8	2,6	103	1030	6000	83.0	328
Green chilly	75	10	10	9	1.9	107	1070	5700	81.3	200
Watermelons	70	9	7	10	2.9	58	522	4300	87.9	675

Source: SANIIRI, 2001

Various research experiments have shown economy of irrigation water by drip irrigation. For young vineyards, water economy of 69.3% has been achieved, while, for vegetables, it ranges from 81 to 83% and is about 87.9% for watermelons. Based on these experiments, numbers of research indications have been drawn:

1. The new designed self-pressurized drip irrigation system, which has been constructed and installed on an experimental field, is in normal condition and functions well during the irrigation period. It provides the necessary quantity of irrigation water for young vineyards, vegetables grown in inter-row spacing.
2. Preliminary technical and economic calculations show that sowing the vegetables and the inter-row crops between vineyards irrigated by the same allows recovery of overall cost of the whole system within a short period. A profit in the first year after land development plus 3-4 years after vineyards start fructification ensures all expenses for construction of drip irrigation system can be recovered.
3. Economy of irrigation water achieved is 69% for young vineyards and 81 to-87% for vegetables and inter-row crops in comparison with control irrigation.
4. Positive results are achieved on pepper crop, which consumes the minimal of water per unit of crop.
5. For tomatoes and pepper crops, it is necessary to define the optimum scheme of sowing in inter-row young vineyards where a drip irrigation system exists.

3.5 Caring out Field Experience on Use of Drainage Water for Irrigation

Drainage outflow from irrigated land causes pollution of fresh water sources. Simple facilities to divert drainage run-off for irrigation of maize, potato and apple trees were designed and installed. In the territory of "Boykazon" farm 273 ha of land has been chosen for experimental research on use of marginal waters near the collector . . -1 is shown in Fig. 3.11. Irrigation-waste water in collector . . -1 from the point of view of its use for irrigation is more fertile than in irrigation canal and is given in Table 3.5.

For studying use of irrigation-waste waters, three experimental fields have been chosen in 2001 as below:

1. Maize cultivated field along the collector BC-1, 0.6 ha, Fig. 3.12.
2. Potato cultivated field along the collector BC-1, 0.6 ha, Fig. 3.13.
3. Apple garden in inter-rows with Lucerne 0.6 ha, Fig. 3.14.

Within the theme of ICARDA, a new convenient technology for lifting and delivering wastewaters from the collector BC-1 to those farmers along the collector which is illustrated in Figs. 3.15 and 3.16 has developed. These interventions demonstrate that the goals of increasing production and protecting the natural resource base are not incompatible in the short term. They require small initial cash outlays and some extra labor, but produce an attractive return on these investments. They will be suitable wherever there is a large nearby urban market for vegetables.

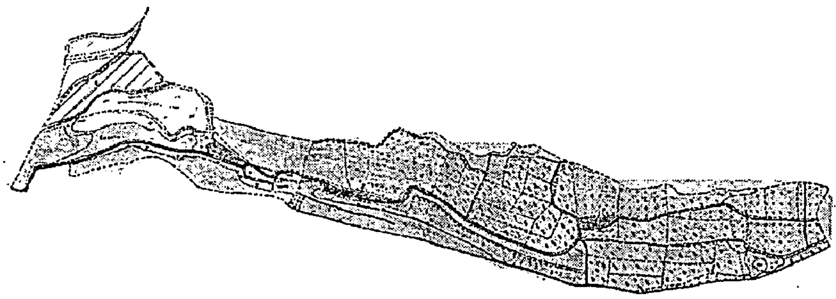


Fig. 3.11 Scheme of fields on use of drainage waters

Table 3.5 Results of the chemical analysis of irrigation water and wastewater, 2001

Place of sampling	Date of sampling	Nitrogen (mg/l)	Phos-phates (mg/l)	Humus (%)	Dry rest, (g/l)	Muddy (mg/l)
Channel irrigation water	29.06	0,025	0,15	2,04	120	0.85
	16.08	2,65	0	2,8	111	0,01
	6.09	0,01	0	0,84	68	0
The end of Spillway BC-1	29.06	0,05	0,72	2,04	197	1759
	21.07	2,9	0,66	2,3	156	0,195
	16.08	2,9	0,55	2,8	127	8
	13.09	0,21	0,27	2,07	72	2,8

Source: SANIIRI, 2001

Fig. 3.12
Maize irrigated with wastewater

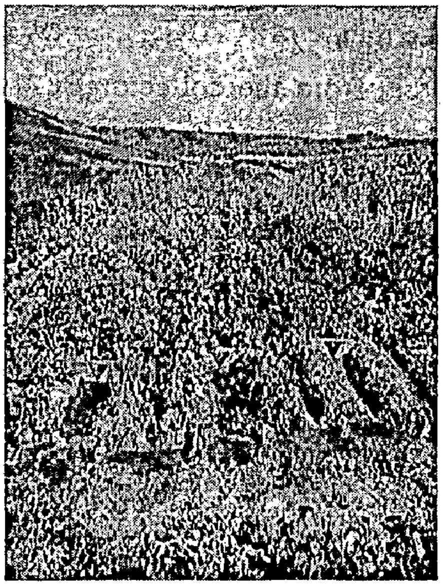


Fig. 3.13
Potato irrigated with wastewater

Fig. 3.14 Apple trees irrigated with wastewater

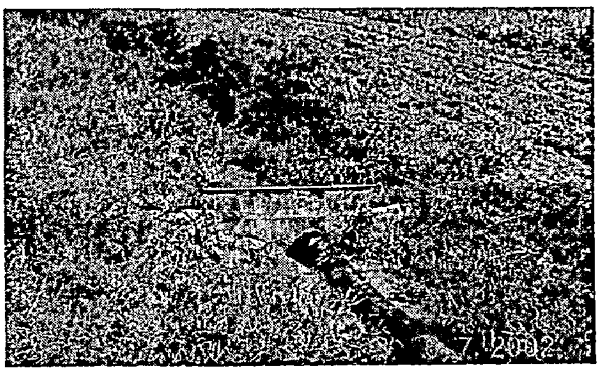


Fig. 3.15 Drainage water intake point

Fig. 3.16 Drainage water outlet point

Reuse of wastewater on the irrigated areas with the raised biases showed that it effectively increased soil fertility, facilitated irrigating inconveniently and earlier non-irrigable areas with smaller expenses of work. It also enables more production and reduced water removal from irrigated territory.

3.6 Experiment of Goffered Hoses for Irrigation of Corn for a silo

Research was carried out from July to September 2000, when Goffered hoses were used on very abrupt biases up to 0.02. The corn for silo showed the same tendency, as winter wheat. On a bias of 0.08-0.14, the coefficient of irrigation efficiency increases from 0.79 at the use of the primary discharge in usual conditions of irrigation to 0.87 by selecting discharge through furrows and lengths of furrow i.e. installation of position of hoses for irrigation having a length of 35-50 m against 50 m as usual irrigation. Experiments of using Goffered hoses have shown their efficiency on irrigation of winter wheat and corn for silo shown in Fig. 3.17. However, it is necessary for Goffered hoses to be installed with adjustable apertures to control water discharge.

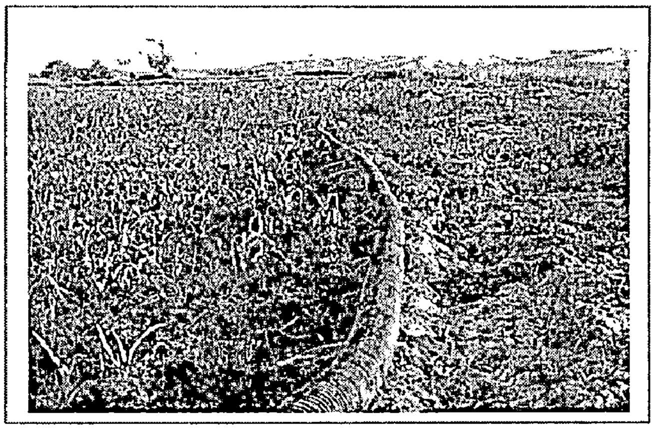


Fig. 3.17 Corn for a Silo Irrigated using the Goffered Hoses

The maneuverability of installation of Goffered hoses allows operatively estimating the field moisturizing process by a character of slopes: its convexity, concavity, and convex-concavity and contrary lengthways on a steepness of a slope. Therefore, during irrigation period the labor productivity reaches up to 2.1 ha/day/person, against control irrigation of 0.78 ha/day/person. Results of research of improvement of Goffred irrigation technology are given in Table 3.6. Thus, discharge of hoses installed across the slope with a bias of 0.02 on 1 ha of land in a width of 100 m can distribute a furrow discharge of 0.05 l/s which will again divided into two halves each of 50 m, to have a total of 36 l/s.

Table 3.6 Results of irrigation of Corn for silo with the help of Goffered hoses in 2000

Parameters		**Irrigation down the slope**	**Goffered hoses**
No of irrigation		5	5
Total irrigation norms m3/ha	Gross	7109	4285
	Net	5635	3735
Irrigation efficiency		0.79	0.87
Precipitation, m3/ha		-	-
Soil erosion, t/ha		2.7	1.3
Soil moisture regime		70	70
Production, quintal/ha		227	308
Net irrigation consumption, m3		24.9	12.1
Slope		0.08-0.04	
Length of furrow, m		75	75
Area, ha		0.28	0.28
Water discharge, l/s		0.08	0.06

Source: SANIIRI, 2000

3.7 Improvement of Irrigation Technology for Production of Stock-beet with the help of Shielded Polyethylene Films

In August 2002, on experimental field of stock beet crop with a slope of 0.06 and with a length of furrows of 95 m, in connection with late sowing and, because of long damp spring, three irrigations were provided as we can see in Fig. 3.18. Noticeable advantages of shielded furrows irrigation to stock beet crops are the best thermo-physical properties of ground, the best microbiological regime of ground, absence of condensation of ground by wheels of ploughing tractor, full elimination of irrigational erosion and promote formation of higher yield of a stock beet. Therefore, in 2000 the yield of beet by shielded furrow irrigation was 118 t/ha, compared with traditional irrigation (irrigation down the slope) of 104 t/ha. The increase in yield appeared to be equal to 14 t/ha. In 2001, the yield of beet on an experimental variant irrigation was 97.8 t/ha compared with traditional irrigation of 87.5 t/ha. The increase in yield was received at a rate of 9.8 t/ha.

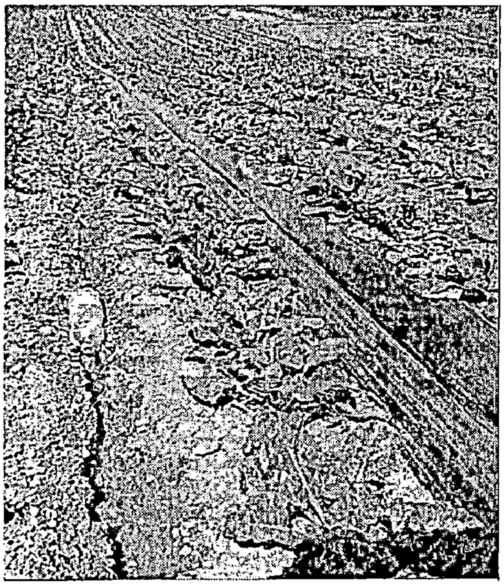


Fig. 3.18 Irrigation technology with the help of Shielded Polyethylene Films

Irrigation of crops by shielded polyethylene film on furrows promotes preservation of fertility of ground. This technology eliminates soil erosion from the irrigated land in inherent and inevitable conditions of "Boykazon" farm. Research on irrigation of stock beet on standard furrows indicated that 27 kg/ha of nitrogen, 7 kg/ha of phosphorus and 3.5 kg/ha calcium washes away from the field together with surface runoff during all vegetative period. As a significant part of ground surface is covered by polyethylene films, evaporation from the soil surface has been prevented. Since this technology keeps soil moisture, which could have been lost due to evaporation, it proved to have high irrigation efficiency particularly for crops such as stock beet.

In 2002, this irrigation technology was tested on a cotton field and maize field at the Central Experimental Base of Institute of Cotton, where salt concentration is high (new zone of Hungry steppe in Dzhizak province) and are shown in Figs. 2.19 and 2.20. Supervision over growth and development of irrigation practice in 2002 showed that on all skilled sites, irrigation by shielded furrows, outstripping growth of plants was observed. Especially, cotton shows sympathetic results. In the Central Experimental Base of institute of cotton, plants having 10 cm higher than traditional practice, with lots of boxes and, with many branches and flowers were obtained.

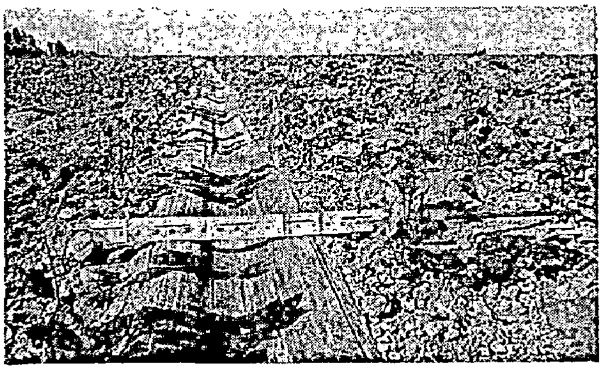


Fig. 3.19 Cotton irrigated with Shielded polyethylene films

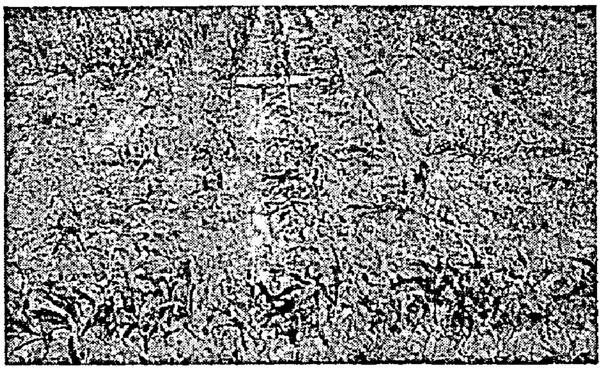


Fig. 3.20 Maize irrigated with Shielded polyethylene films

However, it is necessary to develop mechanisms for stacking of film to the field at the beginning of vegetative period as well removal of them at the end of the season. In addition to this, it is important to establish the color and thickness of films which are most suitable for different crops. It is important to improve technology of water distribution and design of polyethylene films as well.

CHAPTER IV

DATA ACQUISITION

4.1 Population

Uzbekistan is Central Asia's most populous country. Its near about 26 million people (July 2003 est.), concentrated in the south and east of the country, are close to half the region's total population. The predominant ethnicity is Uzbek. Other ethnic group includes Russian 6.0%, Tajik 5%, Kazakh 4%, Tatar 2.0% and other 8% and is shown in Fig. 4.1. In the beginning of 2000, the population of the country was 24.5 million people, which was twice the size of the population 25 years ago.

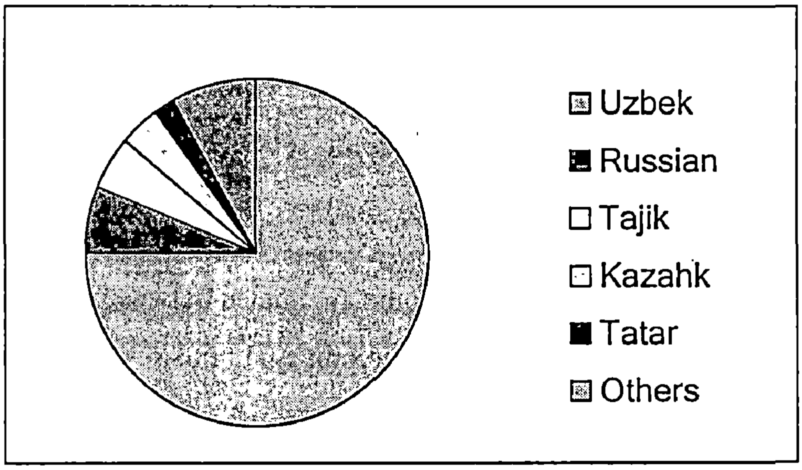


Fig. 4.1 Ethnic structure of Population

Demographers project that the population, currently growing at about 2.5 percent per year, will increase by 500,000 to 600,000 annually between the mid-1990s and the year 2010. Thus, by the year 2010 at least 30 million people will live in Uzbekistan. High growth rates are expected to give rise to increasingly sharp population pressures that will exceed those experienced by most other former Soviet republics. The most densely populated provinces of the country are Andijan, Ferghana, Tashkent, Namangan, and Khorazm, and populations continue to grow rapidly in all five. In 1993, the average population density of Uzbekistan was about 48.5 inhabitants per square kilometer.

The distribution of arable land in 1990 was estimated at only 0.15 hectares per person. In the early 1991s, Uzbekistan's population growth had an increasingly negative impact on the environment, on the economy, and on the potential for increased ethnic tension.

4.2 Climate Condition

Climate of Uzbekistan is extreme continental, arid and noted for abundance of solar radiation, small cloudiness, and poor atmospheric precipitation. The territory of the country is characterized by cold, unstable winter and dry, hot summer. Thermal regime in winter period is formed under influence of dry, cold, Arctic and Siberian air mass of the north and tropical air from the south. In summer, the territory is under influence of local tropical air. The mountain relief greatly effects on climate formation.

The average annual number of sunshine hours fluctuates between, 2700–2980 in the north and up to 2800–3130 in the south of the country. In this respect only California, which is situated in the southwest of the USA, can be match for Uzbekistan. The climate of Uzbekistan is sharply continental. It is expressed in high attitudes of daily and nightly, summer and winter temperatures. Dryness is a peculiar feature, which is expressed in a small quantity of precipitation making annually 200-300 millimeters on average, low air humidity in summer time and low nebulosity. All this determines a great number of sunny days. Daylight duration makes up 15 hours in summer, and not less than 9 hours in winter.

January is the coldest month, when temperature in the north may drop down to ($-5^0C...-8^0C$) degree Celsius, and even lower. The average temperature in January in the extreme south, near the town of Termez is (+2.8^{0}C…0^{0}C) degree Celsius. The absolute registered minimal temperature in winter is (–35^{0}C …–38^{0}C) degree Celsius. Winter lasts 1.5–2 months in the plains.

July is the hottest summer month, and July-August in Mountains. During that period the average temperature in plains and foothills makes up (+25^{0}C…+30^{0}C) degree Celsius in the south. The absolute summer maximum exceeds 42^{0}C degree Celsius. The maximum temperature registered was in 1914 in Termez when the heat reached 49.6^{0}C degree Celsius.

4.3 Precipitation

Mean annual amount of precipitation in a flat part ranges from 100-150 mm in desert zones to 200-400 mm in foothills. The greatest amount of precipitation (60-70%) drops out in winter and spring, where autumn precipitation is much less and absolutely insignificant precipitation observed in summer months. The droughty period in desert zones lasts 6-7 months starting from May to November while it is 4-5 months in foothills. As approaching foothills, the amount of precipitation increases up to 800-900 mm and more. A distribution of precipitation in mountains depends on height above sea level, forms of relief and exposition of slopes. Deficiency of moisture in the southern part of Uzbekistan for April-September reaches about 1300-1600 mm.

4.4 Environment

Environmental devastation in Uzbekistan is the best exemplified by the catastrophe of the Aral Sea. Because of diversion of the Amu-Darya and Syr-Dariya for cotton cultivation and other purposes, what once was the world's fourth largest inland sea has shrunk in the past 30 years to only about 1/3 of its volume in 1960s and less than half of its geographical size. The desiccation and salinization of the lake have caused extensive storms of salt and dust from the sea's dried bottom, wreaking havoc on the region's agriculture and ecosystems and on the population's health. Desertification has led to the large-scale loss of plant and animal life, loss of arable land, changed climatic conditions, depleted yields on the cultivated land that remains, and destruction of historical and cultural monuments. Every year, many tons of salts reportedly are carried as far as 800 kilometers away. Regional experts assert that salt and dust storms from the Aral Sea have raised the level of particulate matter in the earth's atmosphere by more than 5 percent, seriously affecting global climate change.

The Aral Sea disaster is only the most visible indicator of environmental decay, however. The Soviet approach to environmental management brought decades of poor water management and lack of water or sewage treatment facilities. The policies emphasized the present enormous environmental challenges throughout in Uzbekistan is as follows:

- Inordinately heavy use of pesticides, herbicides, defoliants, and fertilizers in the fields; and
- Construction of industrial enterprises without regard to human or environmental impact

4.4.1 Water Pollution

Large-scale use of chemicals for cotton cultivation, inefficient irrigation systems, and poor drainage systems are examples of the conditions that led to a high filtration of salinized and contaminated water back into the soil. In the early 1990s, the average application of chemical fertilizers and insecticides throughout the country was twenty to twenty-five kilograms per hectare, compared with the former average of three kilograms per hectare for the entire Soviet Union. As a result, the supply of fresh water has received further contaminants. Industrial pollutants have also damaged Uzbekistan's water. In the Amu Darya, concentrations of phenol and oil products have been measured at far above acceptable health standards.

According to the estimation of the Ministry of Environment about half of the country's population lives in regions where the water is severely polluted. The government estimated in 1995 that only 230 of the country's 8,000 industrial enterprises were following pollution control standards.

4.4.2 Air Pollution

Poor water management and heavy use of agricultural chemicals also have polluted the air. Salt and dust storms and the spraying of pesticides and defoliants for the cotton crop have led to severe degradation of air quality in rural areas. In urban areas, factories and auto emissions are a growing threat to air quality. Fewer than half of factory smokestacks in Uzbekistan are equipped with filtration devices, and none has the capacity to filter gaseous emissions. In addition, a high percentage of existing filters are defective or out of operation. Air pollution data for Tashkent, Ferghana, and Almalik shows all three cities exceeding recommended levels of nitrous dioxide and particulates. High levels of heavy metals such as lead, nickel, zinc, copper, mercury, and manganese have been found in Uzbekistan's atmosphere, mainly from the burning of fossil fuels, waste materials, and ferrous and nonferrous metallurgy.

4.5 Water Resources

Uzbekistan is one of the largest region of irrigated agriculture in Central Asia. The Amu-Darya, Syr-Darya, Zarafshan, Kashkadarya, Chirchik and Akhangaran Rivers are the principal sources for irrigation. The Amu-Darya, with a length of 1,437 km and the Syr-Darya of 2,137 km are the largest Rivers of the country. Both of them originate beyond the borders of Uzbekistan. There are very few lakes in the territory of the country. The largest of them is the Aral Sea, which is on brink of extinction. The most numerous are the small mountain lakes with areas of 1 km^2. During the last few decades, several artificial lakes, water reservoirs have been built in the country, among them are Charvak, Akhangaran, Chimqurgan and others.

Uzbekistan has considerable reserves of ground water, which are extensively used for water supply and irrigation. The republic is reach with its sources of mineral waters. Thanks to their chemical composition, they have salubrious properties. The most valuable hydrosulphuric, iodic, radon and slightly mineralized alkaline thermo mineral waters. The composition and effect of hydrosulphuric sources of the Ferghana and Surkhandarya artesian basins can match the Caucasian water sources.

At present, in Uzbekistan it is used about 42 km^3 of Transboundary Rivers flow, 34 km^3 of this is from Amu Darya and Syr-Darya. The surface flow formed in Uzbekistan makes up 11.47 km^3 and is given in Table 4.1. In strategy of water resources use the main interest is of available water resources, which take into account not only a natural flow, but also its regulation by reservoirs, and include use of return and underground water.

Table 4.1 Surface Water Resources

Basin	**River**	**Mean annual flow, (km^3)**
Amu-Darya	Surkhandarya	3,25
	Kashkadarya	1,06
	Zarafshan	0,51
	Total:	4,82
Syr-Darya	Small rivers of Ferghana Valley	1,50
	Midstream rivers	0,36
	Chirchik, Angren	4,79
	Total:	6,65
Total:		11,47

Source: Hydromet, 2001

Their estimated value was determined in basin Schemes (Master Plans) developed for Syr-Darya and Amu Darya (1983-1984) for present and future conditions of water management development in the states of the Aral Sea region.

Established volume of available water resources provides also feeding of Aral Seaside and Aral Sea using the rest volume of Syr-Darya and Amu-Darya flows. According to the schemes supply into Aral Seaside over Syr-Darya would make 3.25 km^3/year, and over Amu-Darya 3.2 km^3/year of sanitary drawdown, 1 km^3 of fishery drawdown and 1 km^3 for delta flooding. Thus, the stipulated supply in Aral Seaside area would be 8.4 km3 by two rivers yearly

4.6 Available Water Resources

Available water resources of the Republic of Uzbekistan are formed from renewed surface and underground water of natural and return water of anthropogenic origin. Water resources are subdivided into national and transboundary:

1) National water resources include flow of the local rivers, underground and return water formed within one country; and
2) Transboundary water resources are water (river, underground, return) located on the territory of two or more countries.

Volumes of actually available water resource of Uzbekistan within increased water availability by sources of formation and are given in Table 4.2. In low water years, these parameters are reduced up to 54.2 km^3 and lower that much less than limit and the volume established by Schemes and to be corrected on really developing water management conditions.

Table 4.2 Available Water Resources (mill. m3/year)

River Basin	Intake from River			Under-ground water use	Collector drainage flow	Available water resources
	Trans-Boundary	Small Rivers	Total			
Syr-Darya	10.49	9.20	19.69	1.59	4.21	25.49
Amu-Darya	23.26	10.64	33.90	1.004	2.63	37.53
Total	**33.75**	**19.84**	**53.59**	**2.59**	**6.84**	**63.02**

Source: Hydromet, 2001

National renewed water resources of the country in conditions of long-term regulated flow of Syr-Darya river and seasonal regulated flow of Amu-Darya makes 11.47 km^3/year or 18.4 % from total quantity of water consumption and 457 m^3/capita yearly at present level. The surface flow of the rivers undergoes significant changes due to anthropogenic impact. Up growth of water intake from the rivers into irrigation canals and losses in canals cause a quantitative flow reduction, and discharge of collector drainage water worsen its natural mode and quality.

4.7 Ground Water Resources

Total reserves of underground water over Uzbekistan is 18.9 km^3, including 7.6 km^3 of mineralized water less than 1.0 g/l, and 7.9 km^3 of water with 1.0g/l up to 3.0 g/l. As a whole in years of increased water, probability and mean water years requirement of water consumers are satisfied completely. In the Syr-Darya river basin, the Arnasay system of lakes, as sink for collector drainage water from irrigated area was formed in the territory of Syr-Darya and Djizzak oblasts. At present in the Republic there are 52 reservoirs with total volume of more than 19.3 km^3 including 21 reservoirs with total volume of 5 km^3 in Syr-Darya River Basin and 31reservoirs with total volume of more than 14.3 km^3 in the Amu-Darya River Basin.

In 2000, total water intake has made 54.2 km^3. This sum includes 47.8 km^3 of water intake from surface water and return flow and 6.4 km^3 of underground water. Irrigation intake from surface water has made 44.1 km^3 and 3.3 km^3 from underground water. Total intake by non-irrigation water users including irrevocable losses of power system of 104 Mm^3 and fishery of 368 Mm^3 has made 6.8 km^3.

4.8 Land Resources

The available land of the country is 44.4 mha of which about 11.8 mha are potentially suitable for irrigation, including 4.3 mha of existing irrigation area. The other 32.6 mha is desert, pastures, mountains, sandy soils etc. and are shownin Table 4.3. By

1990, the area of irrigated lands has increased by 1.6 times, as much as the agriculture production has increased. The long-term cultivation of a monoculture crop of Cotton constrained the crop rotations introduction that has resulted in decrease of efficiency of the irrigated lands. The concentration of humus in soil, which is a basis of productivity, has decreased for the latest decades by 30-40%. Lands with low and very low concentration of humus occupy about 40% of all irrigated lands. More than 57% of the currently irrigated area is concentrated in the desert and semi desert zones in naturally undrained land, which is subject to natural and secondary salinization. Remaining 43% falls to the soil of high-altitude zones.

Table 4.3 Land Resources of Uzbekistan (Mha)

Oblast	Gross area, ('000 ha)	Potentially suitable for irrigation			Pastures, hayfields, etc., ('000 ha)
		Total, ('000 ha)	Irrigated areas		
			Gross	Net	
Andijan	430.3	372.5	357.3	272.1	57.8
Namangan	717.5	415.9	370.1	277.8	301.6
Ferghana	715.3	556.3	508.2	356.9	159.0
Syr-Darya	427.6	359.6	357.9	293.7	68.0
Dzhizzak	2117.8	951.4	413.0	300.5	1166.4
Tashkent	1513.2	590.5	470.9	390.9	922.7
Samarkand	1677.4	1115.5	529.0	373.0	561.9
Bukhara	4193.7	978.0	454.3	273.6	3215.7
Navoi	10937.4	1416.9	152.0	124.7	9520.5
Surkhandarya	2009.9	763.6	438.4	328.2	1246.3
Kashkadarya	2856.8	1840.7	775.3	504.6	1016.1
Khorezm	681.6	335.8	288.4	275.3	345.8
Karakalpakstan	16100.6	2100.5	708.8	500.9	14000.1
City of Tashkent	31.2			5.4	
Total	**44410.3**	**11797.2**	**5856.71**	**4277.6**	**32613.1**

Source: 1992; Uzdaverloiykha, 2000

4.9 Land Surface

Republic of Uzbekistan covers 32% of the Aral Sea basin, which is divided into 2 parts: 1) turan drainless plain, and 2) mountain systems of the Pamir and Tien-Shan.

Turan drainless plain, surrounded by mountains, provides favorable conditions for geochemical flows in creating salt accumulation zone. The arid climate contributes to relic salt amounts in eluvial and eluvial-accumulative landscape types and hence to the soil salinisation. Relief and hydro-geological peculiar features make possible to identify three provinces: Low accumulative plains, Light plains and Mountain setting. Transition and accumulation of geochemical flows characterize low plains. There are exit areas, suffered from surface salt accumulation, recent hydromorphic landscapes with close groundwater table (<3 m) as well as areas, for which soil salinisation is especially characteristic at high depth. In high plains and plateaus, salt affected soils and the soils with gypsum are dominant. They are stable in their salinity or subjected to slow salt removal

4.10 Land Quality

The main factor in the qualitative assessment of land is its fertility and this is determined by bonitation. The bonitation of land is the comparative assessment of the land quality, and productivity with a representative level of agricultural activity. Bonitation involves an analysis of the soil properties, both natural and human-induced, that determine its crop carrying capacity, both its natural productive capacity and that obtained through agricultural activities.

The bonitation carried out in the period of 1996 to 1997 for irrigated land has a 100-degree scale. The highest score is attributed to soils with the highest fertility, or 40 quintal of cotton per hectare. A yielding capacity of 0.4 quintal/hectare gives a value of one. Table-4.4 classifies the land according to these assessments. The categories of land suitable for irrigation are defined as follows:

I. Very good land capable of producing 81-100 percent of the potential yield;

II. Good land capable of producing 61-80 percent of the potential yield;

III. Moderate quality land capable of producing 41-60 percent of potential yield;

IV and V. Poor land capable of producing 40 percent of potential yield

Table-4.4 Quality of land suitable for irrigation

Zone	Quality of land suitable for irrigation (% of irrigated land)			
	I	II	III	IV and V
Karakalpakstan Republic	0	7	39	54
Oblasts				
Andijan	16	54	20	10
Bukhara	12	37	32	19
Djizak	2	29	54	15
Kashkadarya	3	24	60	13
Namangan	26	30	26	18
Samarkand	19	51	24	6
Surkhandarya	25	46	21	8
Sirdarya	1	33	41	24
Tashkent	18	47	30	5
Fergana	29	31	23	17
Khorezm	40	26	19	15

4.11 Land Use

Total area of agricultural land in Uzbekistan is 26.8 mha of which arable land 3.8 mha, perennial plantings 0.4 mha, and remaining 22.3 mha are occupied by hayfields and pastures. Land use in 2000, is illustrated in Figs. 4.2 and 4.3. Ratio of land use types in irrigated zone and general structure of used areas is differed in irrigated zone the arable land of 77.5% prevails. In total agriculturally used area the arable land occupies only 13.1% and the other 77.8% is occupied by hayfields and pastures concentrated in dry zone. Arable land is annually cultivated area under tilled crops. Natural conditions of Uzbekistan allow growing one yield of the main crops annually. Cultivation of repeated crops with the purpose to grow after crop (after winter wheat early potato and vegetables) is insignificant and limited, mainly, due to deficiency of irrigating water.

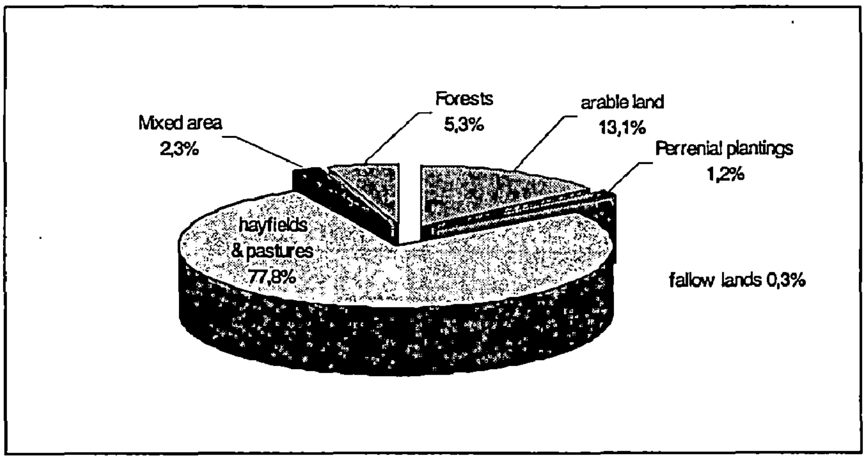


Fig. 4.2 Ratio of Areas According to Land Use Type in 2000

In respect of quality, the irrigated agricultural land in Uzbekistan is mainly characterized by average and good fertility. In the country, 30% of the irrigated area is of good and high class of fertility, 45% of average and 25% of the lowered and low fertility.

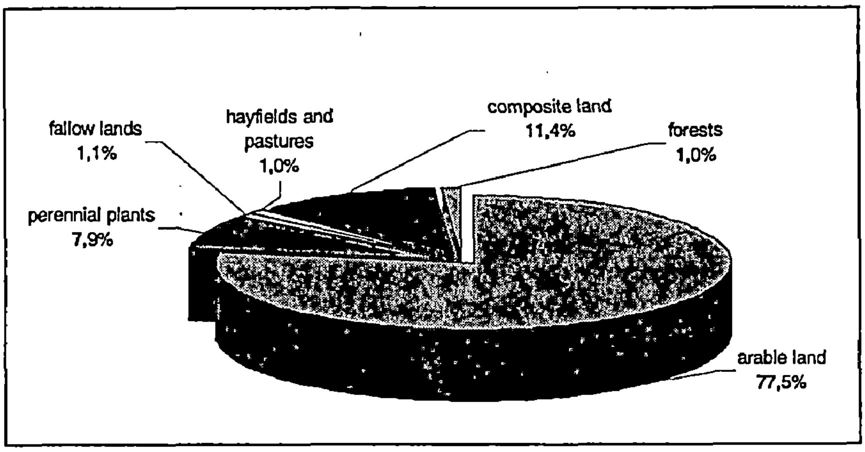


Fig. 4.3 Ratio of Irrigated Areas by Land Use Types in 2000

In Uzbekistan, practically, there are no more undeveloped arable lands. Therefore, the growth of agricultural production in future should be provided by efficient and intensive use of available cultivated areas. Such intensification will require switching the control of existing farms over the private sector, so that these farms could respond more effectively to improved system of incentives, developed as a result of legal, political and constitutional reforms. Uzbekistan has carried out programs of farm privatization. The main forms of management have been defined and the multi-branched economy with various forms of ownership has been organized.

At present, the priority has been given to three main forms of management as they have been identified as potentially prospective are as follows:

1) Small-Produsers-Dekhkan Farms (more than 3 mln.);
2) Medium Commodity Producers (more than 22,000 units);
3) The Agricultural Cooperatives, Shirkat Farms (they are only land users).

4.12 Main Soil Types

Soil is the greatest gift of nature, the source of our richness. All life in the Earth depends on a thin fertile soil layer that covers the surface of land. It is known that the fertile layer of soil is formed over a long period. However, we may lose it in a relatively few years with careless treatment and by not maintaining or improving it. The expansion of a particular soil variant type in Uzbekistan is attributed to natural-zonal features. Thus, on most plains with continental climate a desert type of soil prevails, while on contemporary river plains with their favorable soil moisture, there are as a rule hydromorphic soils-meadow-desert, meadow-swamp, swamp and solonchak soils.

The soil cover of foothills and mountain ranges slightly differs from that of plains and has other irregularities. There is a vertical zonality of physical-geographic conditions typical of mountain countries. A decisive factor in this natural environment is climate changes occur with increase in height above sea level, including a decrease in air temperature and an increase of total precipitation up to certain limits, in other words, with the increase of absolute height, a gradual change of hydrothermal regime was observed. In addition, climate and geomorphologic conditions predetermine the direction in which wind blown erosion products from mountain rocks will move. In Uzbekistan, natural pasture dominates in the desert zone. Distinguishing features of the mostly widespread types of soil in this zone are a) desert-brown-desert soils; b) desert-sandy soils; c) takyr soils; and d) brown-brown soils.

The most extensive major soil grouping on the territory of Uzbekistan is Calcisols. It covers more than 5.3 mha or about 11.85% of the total area. The second most extensive major soil grouping is Solonchaks with about 5,212 ha or more than 11.6% of the total area including 3.60% with Calcisol and Arenosols. Fig. 4.4 represents the most extensive soil groups of Uzbekistan.

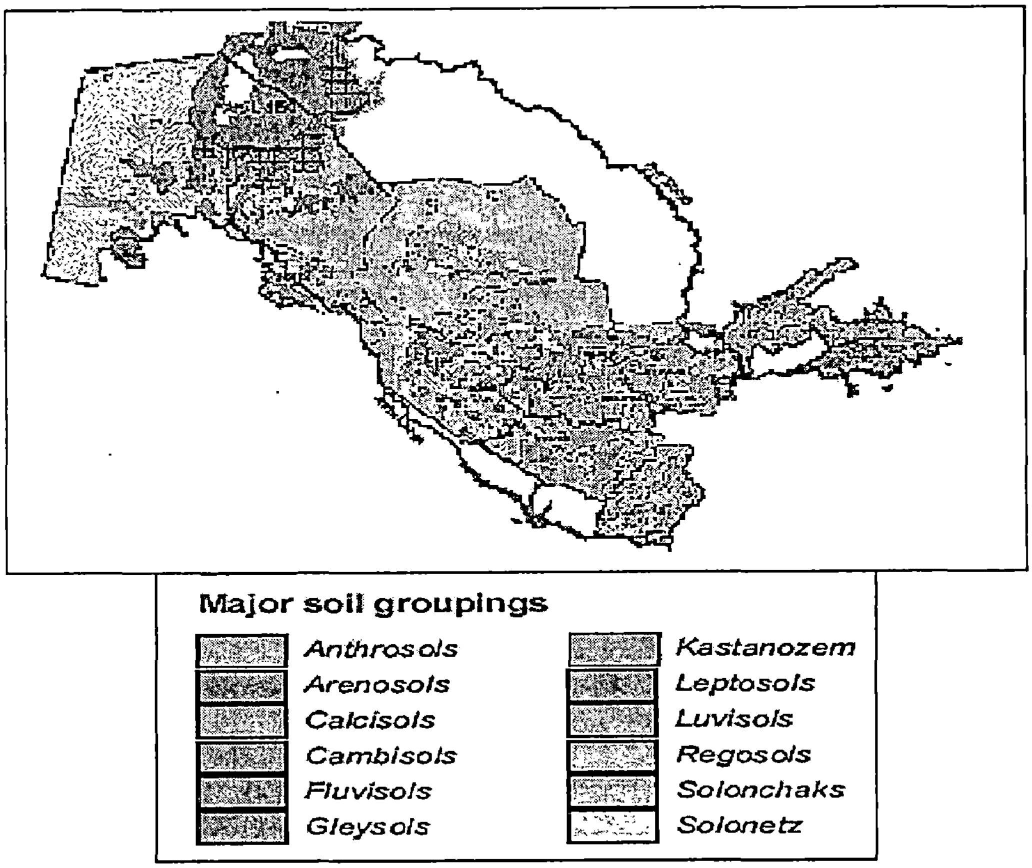


Fig. 4.4 Map of Soils of Uzbekistan

4.13 Soil Types by Food and Agricultural Organization (FAO)

In 2000, TACIS ISEAM Project (Information System for Environment and Agriculture Monitoring) commenced introduction international soil classification and for the fist time FAO Soil Map of Uzbekistan of 1:1 500 000 scale had been prepared. Legend of the soil map had been made according to WRB Soil Resources. On the territory of Uzbekistan 12 main FAO soil groups are identified. The most widespread FAO soil group is Calcisols. It occupies more than 5.3 mha or up to 11.85% of the total area. The second greatest soil group is Solonchaks 5.2 mha or 11.6% of the total, including 3.6% of Calcisol and Arenosols. Cambisol covers more than 5.1 mha or 11.33% of the total. About 12% of the territory or 5.4 mha is occupied by Solonetz of Ustyurt, etc. Arenosols and Regosols cover 2.1 mha and 2.3 mha respectively. Four main groups of soil of Fluvisol, Gleysols, Kastanozem and Anthrosols cover jointly 2.5 mha or about 5.53% of the total area. More than 34.5% or 14.5 mha of area is covered by sand.

4.14 Irrigated and Rainfed Agriculture

In Uzbekistan, the rainfed area covers more than 747,000 ha with rainfall exceeding 200 mm per year, yielding between 0.8 and 2.0 tons of grain per hectare. However, in view of their extent, these areas play an important role in grain production and is shown in Fig. 4.5.

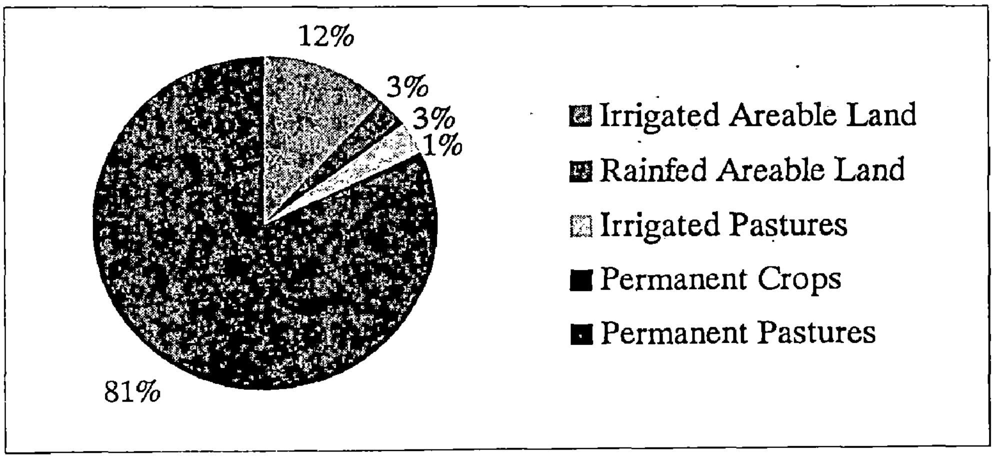


Fig. 4.5 Agricultural area of Uzbekistan

In rainfed areas, inputs are low and problems are developing in maintaining soil fertility under the predominant cereal-based systems in the absence of fertilizers. The emerging small farmers need assistance with enterprise development and the introduction of new crops and rotations. Under the extensive cropping systems of the former Soviet Union, the predominant rotations included annual fallow, and large areas remain unsown each year. The opportunity exists for developing biodiversified farming based on integration of crop and livestock production.

Studies in rainfed farming conditions of Uzbekistan at a Gallaral site demonstrated that in a dry year, moldboard plowing has been the best tillage method for winter wheat. However, further studies should be continued with more adequate conservation tillage equipment and more efficient weed control under minimum tillage technologies for energy-use efficiency.

CHAPTER V

DEVELOPMENT AND OPERATION OF DRAINAGE SYSTEMS FOR FARMS

5.1 Introduction

Because of complex natural and climatic conditions in many regions of the Country it is impossible to develop agriculture without reclamation. In 2000, the total irrigated area in the Republic was 4.3 mha of which 2.9 mha were provided by drainage. At present the only way to improve salinized lands is to wash soils and use artificial drainage. The last decade was characterized by sharp reduction of expenditure on operation of irrigation and particularly drainage systems which varied from U$ 5/ha to US$ 7.5/ha a year compared with US$ 50-80/ha a year according to standard (designed) costs. Certain complications were introduced into organization of operation and maintenance of drainage systems by agriculture reconstruction and formation of many "independent" farms within former collective and state farms. Therefore, nearly all the inter-farm nets in former collective and state farms turn the inter-farm ones, the operations of which at present are not financed or financed insufficiently; the situation resulted in sharp deterioration of drainage systems. During few years their capacities had been reduced by 60 to 30% of designed or primary levels. The land reclamation condition deterioration due to salinization and excessive moisture in soils, unplanned and non-optimal irrigation, reduced water supply, as well as absence of incentives for farmers to improve irrigation and drainage system operation contribute to decrease of productivity of irrigated lands and irrigation water.

The great expenditures in materials, works, time and money are needed to maintain reclamation systems and facilities in operable condition. In Syr-Darya region, for maintenance of open collector-drainage network, more than 477 km of inter-farm collectors and 929 km of inter-farm drains are cleaned every year; the total amount of earthworks comes to 7.69 Mm^3 in a year. Actually, repair and rehabilitation works were implemented on 250-300 km of closed horizontal drains a year, while the total length of this drain type was 9402 km in 1999. It is necessary to note, that repair and clearing of collector and drainage nets in regions are implemented unevenly, without consideration of irrigated land reclamation condition.

5.2 Objectives

The maintenance of open collector net capacity at required level is the main condition, encoring drainage in lands with horizontal drainage systems. At present, the repair and rehabilitation works on horizontal drainage systems are planned without taking into account land reclamation condition indices, actual reclamation regimes, indices of drain and collector net reliability, natural and economical, and meteorological conditions. Therefore, considering these issues, present work objectives should be towards as follows:

- to study natural regularities of faults in collector and drainage network, and effects of its capacity decrease on irrigated land reclamation condition and crop yields;
- to develop scientifically grounded methods for calculation of terms and amounts of repair and rehabilitation works on drainage systems taking into consideration the possibilities to ensure minimal infiltration to groundwater;
- to introduce water-saving irrigation and washing technologies ensuring favorable water-salt regimes in irrigated lands and high crop yields.

5.3 Brief Description of Natural and Economic Conditions

Cooperative farm No 1, named after G. Gulyam is situated in Sh. Rashidov district, in the Syr-Darya province, on the territory of first line of Golodnaya Stepp in south-eastern tract of Uzbekistan. The plot under investigation is situated in south-eastern part of farm and bordered on KTR-1a canal in the south, and 1-H-13 canal in the north. Its boundaries are U-1 distribution canal in the west, and R-2-5 collector in the east. The territory is a flat, plain, slightly sloped to north and north-east in order of 0.0008-0.003. The considered territory belongs to southern part of central zone of Central Asian deserts, with light serozyoms (desert land soils) and is characterized by sharp continental climate with average annual temperature of air of 10.4°C. July is the hottest month with average monthly temperature of 29.5°C while in January, the average monthly temperature falls 0.2°C below zero, and is the coldest month. An absolute maximum temperature is 47°C and an absolute minimum is 34°C below zero. The period without frosts and with the sum of positive temperatures equals to 4400-5000°C continues for 205-228 days.

The average annual precipitation amounts to 340 mm/year out of which 30 to 37% falls in winter, 42 to 48% in spring, 3-4% in summer and 16-18% in autumn. The average annual relative air humidity is 52%, but in the vegetative period it reduces up to 40%. High temperatures and low relative humidity contribute high evaporation in warm seasons. The average annual evaporation amounts to 1600 mm/year. Thus, the humidity deficiency is 1260 mm/year. The aridity of the climate is supplemented by intensive wind action. The South-Eastern winds are prevailing ones. Average annual wind velocity is 3.2 m/s. The average number of days with high wind of 15 m/s amounts to 49, while the maximum one is 70 days.

High groundwater table level is formed due to high seepage losses from irrigation canals, water distribution systems, and partly from precipitation. Groundwater lies at 1 to 3 m below ground surface and its mineralization amounts to 5-20 g/l. The main types of mineralization are sulfate and chloride-sulfate ones. The major part of lands is slightly or moderately salinized. Irrigated lands are used for tilled crop growing. The main crops are Cotton and grain mainly Wheat. Water from Syr-Darya, the source of irrigation, is delivered through south Golodnostepp canal, Kurgantepa branch, canal KTR-1 and KTR-1a. The plot under investigation is irrigated by distributing flumes U-1, U-2 and U-3 originated from on-farm canal KTR-1a with a length of 8 km.

5.4 Surveys on Location

Irrigation and drainage system is a complex of hydro-technical facilities at different levels in irrigated lands which in combination with irrigation regime and agro-technical methods are intended to: a) improve radically unfavorable environmental conditions; b) increase soil fertility with the purpose to get high crop yields; and c) the most efficient use of land and water resources without negative influence on environment. Therefore, a survey on technical condition of irrigation and drainage system is so important. The surveys enable finding defects timely, establish service life of every element and component of irrigation and drainage system and predict deadlines of implementation and amount of repair and operation works. That is why, we carried out surveys on collector-drainage network in plot under investigation. The plot is situated in farm named after G.Gulyam, in Sh. Rashidov district in the Syr-Darya province. The main irrigation source is canal KTR-1-A from which water is delivered through flumes U-1, U-2 and U-3 and is given in Figs. 5.1 and 5.2. Flume canal length varies from 2364 to 2670 m and due to creation of many individual small farms supplied by the same irrigation network there are many handmade outlets in flumes.

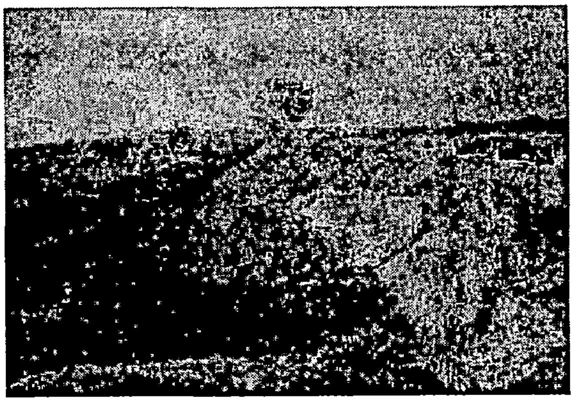


Fig. 5.1 KTR-1-A canal

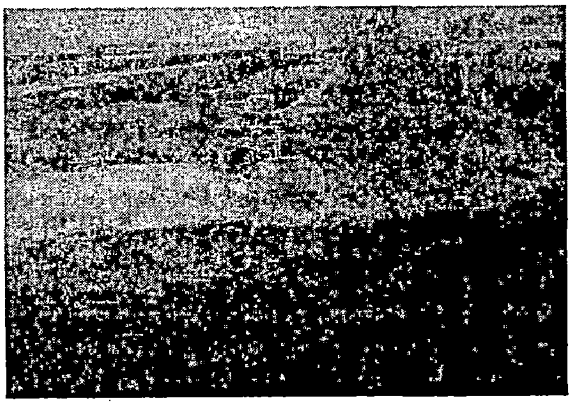


Fig. 5.2 Rise of flume canal U-2

At present, there are 11 farms in the plot area. Collector and drainage net in studied plot represents a system of open and closed collectors, adjoined by closed horizontal drains. There are two collectors namely K-2-1-4 and K-2-1-5 and are illustrated in Figs. 5.3 and 5.4. Both collectors are constructed as half-open and half-closed ones. Therefore, we surveyed separately every part of the collector in detail where 57 closed drains including 12 ones constructed from ceramic and asbestos-cement pipes, hanged to all these open and closed collectors were found.

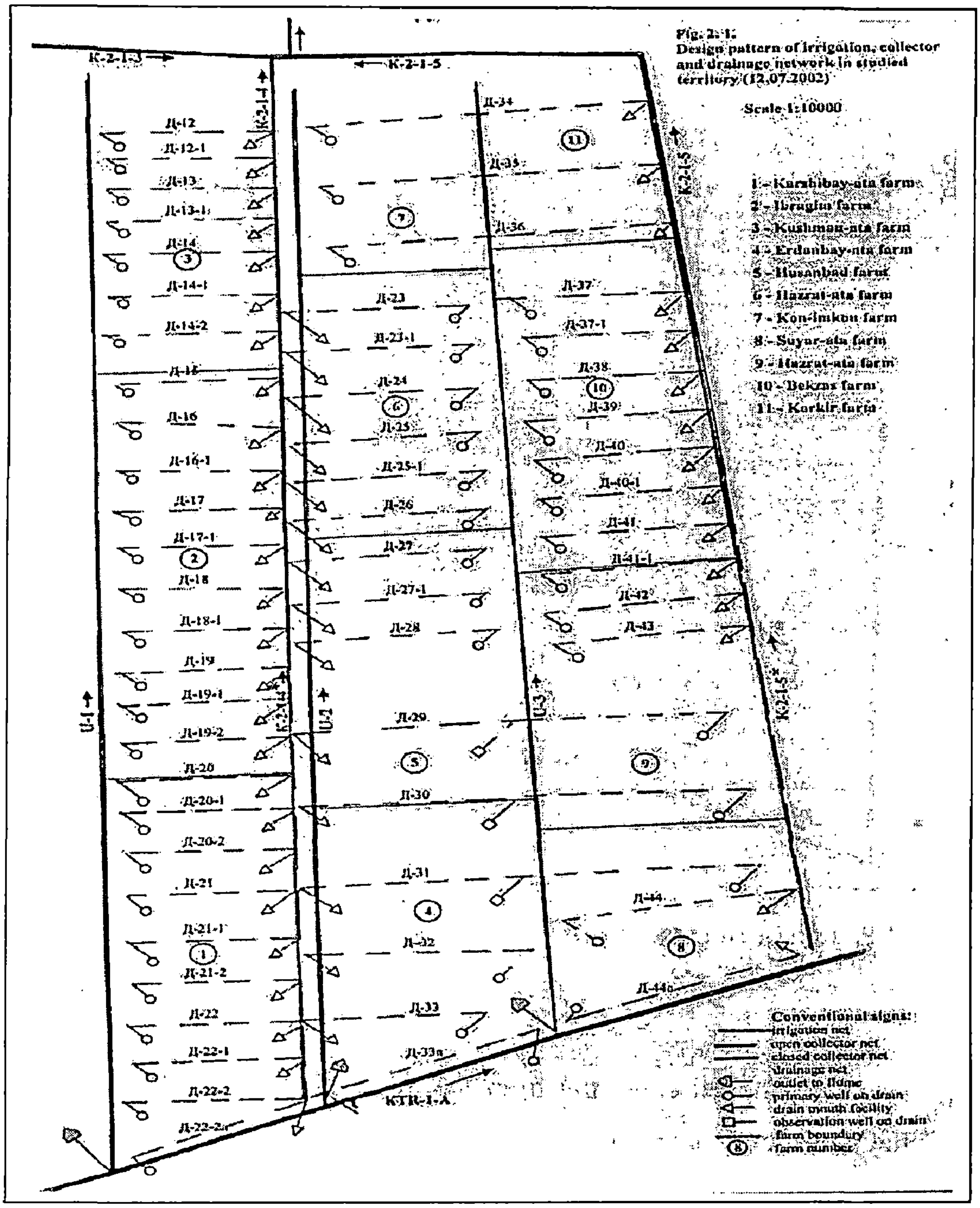


Fig.5.3 Design Pattern of Irrigation, Collector and Drainage Network

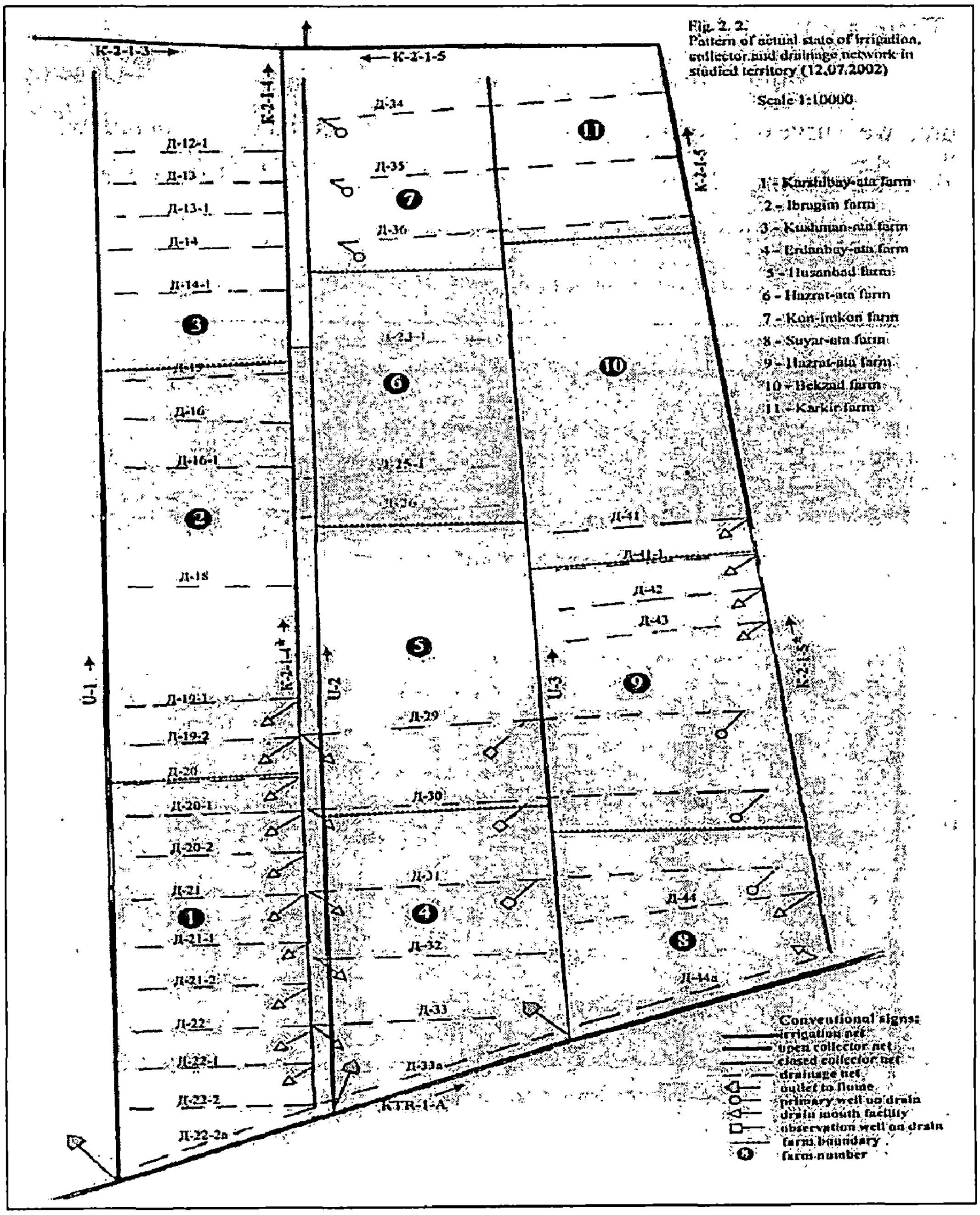


Fig. 5.4 Pattern of Actual State of Irrigation, Collector and Drainage Network

We began survey of open collectors from the left bank of K-2-1-4 collector. The width of the collector at picket 0 was 23 m of upper level and 14 m of lower. A spillway with 1 m wide threshold is constructed at 50 m distance from collector rise. During the survey it was operating at flooded regime. The spillway slightly supports the collector stream. There is a small bridge made of old logs near the spillway. The place is used also for livestock watering. A drain without pipes and mouth facilities buried under slope was found at picket 2+16 m and it was surrounded by dense weeds. The flume net was silted, weedy in some places, some flumes are replaced by non-standard ones, that is why water pours out and washes off flume base. Fig. 5.5 shows present condition of U-2 Flume in the plot. The collector width was measured again at picket 5+50 in characteristic place with low number of landslides as shown in Fig. 5.6. The width of the collector drain at this picket was 21 m of upper part and 11.5 m of lower point.

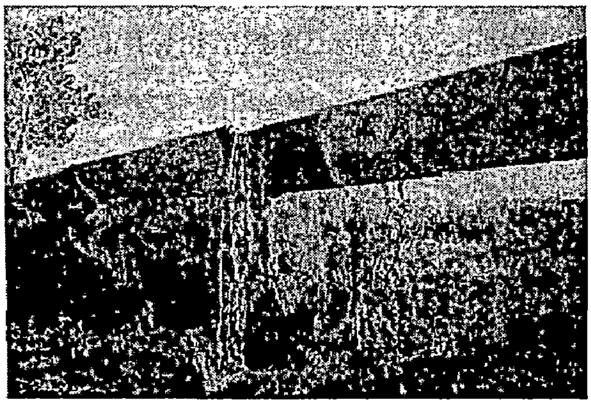


Fig. 5.5 U-2 Flume condition

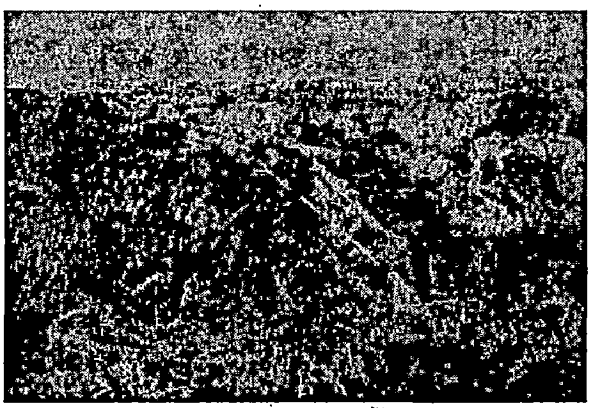


Fig. 5.6 Measurements in K-2-1-4 collector

The first waste water outlet (from irrigated lands of neighboring farm) was found at picket 2+52 m. The outlet is a 50 mm iron pipe protruded above collector for 3-4 m. The pipe is laid under reverse filling of collector and is quite useful for instrumental measurements. Other 2 drains without mouth facilities and spillways (only corrugated pipe was seen) were found at pickets' 2+95 and 4+19 m. These drains also were surrounded by dense weeds. Their discharge can be measured by only volumetric method. The second waste water outlet was found from the same neighboring farm at picket 0.5+80. The outlet is actually a great breaking of irrigation water into collector construction. This outlet without any engineering construction and equipment begins actually at irrigated field boundary. Water swept away reverse filling and slopes of the system.

The number of livestock watering places and handmade bridges are naturally the same as that at the left bank. There is a discharge into collector at the picket 4+03 m. The first operating drain was found at the picket 7+22 m facing flume 307, flume canal U-2. It was a polyethylene closed drain, 63 mm, wrapt in polyethylene coating and is given in Fig. 5.7. Technical condition of slopes is satisfactory at section from picket 7 to picket 8. There is an outlet for waste water from Hazrat-ata farm at picket 8+14 m. The outlet is an iron pipe laid under slope and dam. Next operating drains were found under slope landslides at pickets 10+22 and 11+30 m, shown in Fig. 5.8. Digging showed that the mouth pipe was below level of water in collector. Measurements of the drains were carried out using furrow discharge method It should be noted that a lot of trees, mainly elms and in some places poplar, grow parallel to the collector. There are no trees above routes of detected drains. It is very likely that drain clogging was caused by tree roots. The locations indicate that these drains are D-23-1 and D-25-1 of the design.

Fig. 5.7
Technical Condition of (D-23-1) Drain

Fig. 5.8
Technical Condition of (D-25-1) Drain

Due to high water level in collector eight closed drains which according to design have to flow to this collector were not detected at the section. The general technical condition of collector can be evaluated as unsatisfactory. There are dense weeds along all the collector length. The condition of collector K-2-1-5 is much worse than that of collector K-2-1-4. The secondary soil salinization is observed more often here, and the groundwater level is higher too. The last time, the open collectors at the surveyed plot were cleared using machinery two years ago. After that repair, daily surveys and maintenance works were practically not conducted here. The dense weeds at banks, slopes and dams of collector are not exterminated. The main weeds are Alhagi Adans, Karelinia Lees, sedge, and Sorghum halepense and steppe besom.

None of the above-mentioned drains have observation wells at present although they were provided in design and constructed. The wells were demolished mainly during functioning of State farm in 1980th. The collector mouth and its junction with open collector are not equipped with any engineering facilities. Drain capacities were evaluated mainly using mouth facilities installed at collector. The mouth facilities at collector as well as observation wells are constructed mainly from 3-5 m long one-piece monolithic Ferro-concrete pipes. In most cases, the Ferro-concrete monolithic rings are set on the pipes. The ring height is 100 cm; its diameter is 92 cm. Some wells were repaired in last years, they are constructed from ferroconcrete rings with more than 1 m diameter, and in consequence, the wells are not hermetic. In Fig. 5.9 we can see that the upper ring of observation well was taken off away for other purposes. In this part of collector, wells are clogged by weeds and silt, but collector is in operative condition.

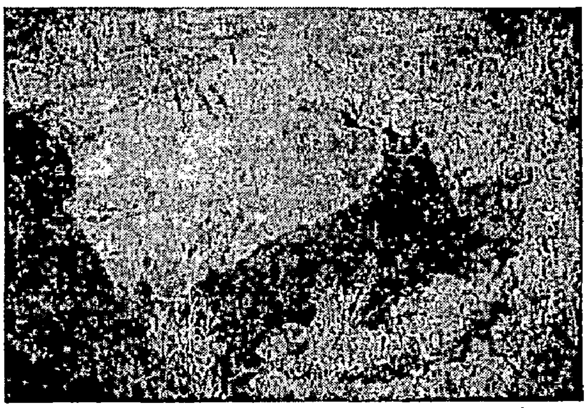


Fig. 5.9 Condition of mouth well

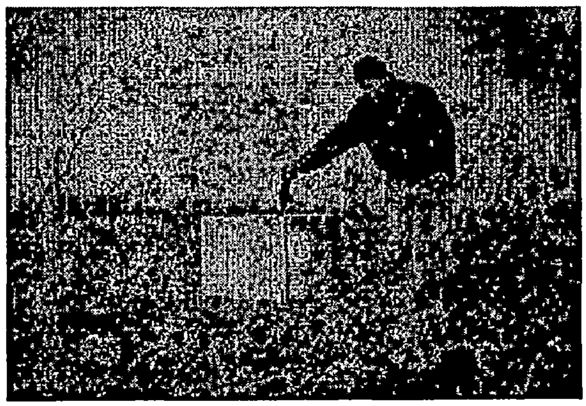


Fig. 5.10 Height of well above-ground

The well heights vary from 20 cm below ground level up to 90 cm above which is shown in Fig. 5.10 above. These wells are clogged by garbage of plant origin and silt layers. Collector operates partly at more or less satisfactory condition, but water level in wells is higher than the collector pipe marks. Almost no wells are hermetic. Weeds are growing in hermetization places; in some cases, well rings are shifted. Some wells are broken at upper parts, others are pierced by 10 cm and more in diameter holes for irrigation water discharge.

5.5 Results of Field Salinity and Observations of Winter Wheat Irrigation

From July 10 to 13 surveys to determine salinity and concentration of nutrients in soils of area of 270 ha were performed. Sampling of soil was made on 22 points (at 2 points in each farm, figure 2.2) every 20 cm of depth down to 1 m. Soil analyses display that the soils are lightly loamy, layers of clay sand and medium loamy soils are to be found in some places. Volume weight in topsoil (0-40 cm) is equal on average to 1.49 and in the lower part of the soil-to 1.53 g/cm^3. According to laboratory chemical analyses, the salinity has chloride-sulphate and sulphate types. Salinity extent of the soil layer of 0-1 m varies from 0.31 to 1.5, about 0.8 % of arid soil weight on the average, i.e., salinity varies from non-salted category to middle-salted one, low-salted soils predominate. The analyses show that humus by layers fluctuates within 0.12-0.89 % of arid soil weight, what is evidence of that soils are referred to poor and very poor categories. Concentration of active phosphorus is on average around 10.75 mg/kg of the soil (category by provision is middle), concentration of active potassium on average is 212.04 mg/kg (category by provision is middle), and nitrates - 37.41 mg/kg (category by provision is normal) to arid soil weight.

Sowing wheat was carried out in November 4, 2002. For organizational reasons observations over actual irrigation mode were began from 6th November and completed in December 2, 2002 on total area of 10.49 ha. The plot in question was equipped with measuring instruments. On the mentioned area with winter wheat following observations were performed as followings: 1) Soil moisture on the control points was defined before and after irrigation; 2) Water discharge delivered to field and furrows; and 3) Streaming up by furrows was determined and their leveling was made to define irrigation technique elements' parameters.

Metering and observations of delivered irrigation water to temporary sprinklers were made by means of the trapezoidal weir of Chipoletty, and in the furrows using the weir of Thomson. Metering technological discharges at the end of irrigated furrows was executed using the weir of Thomson. Discharges to furrows varied from 0.175 to 0.835 1/s. Length of the furrows were from 100 to 200 m. Average slope of the furrows was 0.0048.

During the observation period there were no significant curvature in water table graph; water table in inter-drains with exception of periodically irrigated plots was rather even. In period of winter washings when water table will rises to its maximum values the observations on drain water, which record the depression curve in inter-drains, are intensified. The data on salt content in drains, water table depth in drainage wells and in studied area, and drain discharges and are presented in Tables 5.1, 5.2, 5.3 and 5.4.

Table 5.1 Changes of salt content in drainage water

Date	D-23 (0)	D-23-1 (1)	D-25-1 (2)	D-26 (3)
05.11.2002	3.184	2.136	4.370	3.412
01.12.2002	3.480	3.600	3.680	2.960
10.12.2002	2.820	3.730	3.150	2.390

Table 5.2 Water table depth in drainage wells (DW)

Date	Well number				
	1	2	3	4	5
20.10.2002	2.90	2.82	3.02	2.98	2.95
25.10.2002	2.96	2.87	3.08	3.04	3.02
31.10.2002	2.64	2.94	2.85	3.13	3.20
05.11.2002	2.81	2.72	2.94	3.67	2.84
10.11.2002	3.41	3.12	2.71	2.90	2.83
15.11.2002	2.60	2.89	2.83	3.57	2.95
20.11.2002	3.11	2.70	2.84	3.07	2.92
25.11.2002	3.31	2.70	2.86		2.89
30.11.2002	2.91	3.02	3.00		2.84
05.12.2002	2.58	2.52	2.49		2.67
10.12.2002	2.67	2.56	2.71		2.72
15.12.2002	2.71	2.59	2.83	2.72	3.22
20.12.2002	2.58	2.49	2.73	2.62	2.69

Table 5.3 Average daily discharges of investigated drains

Date	D-23 (0)	D-23-1 (1)	D-25-1 (2)	D-26 (3)
26.09.2002		0.00	0.20	0.40
02.10.2002		0.00	0.10	0.54
07.10.2002		0.05	0.19	0.33
12.10.2002		0.03	0.09	0.22
18.10.2002		0.00	0.09	0.07
20.10.2002		0.05	0.05	0.03
25.10.2002		0.06	0.07	0.00
31.10.2002		0.11	0.06	0.05
05.11.2002	0.03	0.14	0.11	0.07
10.11.2002	0.00	0.13	0.26	0.19
15.11.2002	0.05	0.26	0.35	0.15
20.11.2002	0.13	0.09	0.07	0.11
25.11.2002	0.26	0.22	0.13	0.19
30.11.2002	0.30	0.20	0.28	0.24
05.12.2002	0.26	0.17	0.22	0.11
10.12.2002	0.24	0.51	0.09	0.00

Table 5.4 Water table depth in studied area (Hazrat-Ota farm)

Date	Well number											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
30.09.2002	3.46	3.28	2.14	2.50	2.48	1.69	3.27	2.49	2.73			
05.10.2002	3.48	3.33	3.22	2.70	2.64	1.83	3.35	2.61	2.81			
10.10.2002	3.14	3.37	3.28	2.63	2.70	1.44	3.22	2.78	2.86			
15.10.2002	3.32	3.42	3.35	3.03	2.78	0.94	3.47	2.97	2.84			
20.10.2002	3.20	3.45	3.25	2.89	2.79	0.79	3.52	2.98	2.71	3.84	3.51	3.46
25.10.2002	2.98	3.49	3.27	3.02	2.84	1.10	3.55	3.01	2.64	3.17	1.42	3.52
31.10.2002	1.78	3.28	3.12	3.23	2.66	1.79	3.44	2.98	2.89	3.47	1.65	3.29
05.11.2002	2.36	2.67	3.38	3.10	2.62	1.36	3.17	2.89	2.37	304	2.49	3.61
10.11.2002	2.22	3.24	2.86	1.46	2.59	1.45	2.93	2.89	3.24	3.11	1.86	3.13
15.11.2002	2.52	3.42	1.62	1.84	2.82	2.39	3.15	2.69	3.05	3.23	2.89	3.51
20.11.2002	2.42	2.87	2.48	1.91	2.8	2.26	3.18	2.78	2.27		2.29	3.02
25.11.2002	0.98	2.86	2.30	2.31	2.6	1.45	3.19	0.00	2.97		1.79	3.07
30.11.2002	1.56	2.35	2.00	2.61	22	2.12	2.84	0.00	3.17		1.96	2.96
05.12.2002	1.90	152	1.96	1,.52	2.9	1.09	0.00	0.00	2.20		1.44	1.99
10.12.2002	2.11	1.75	1.94	2.44	1.2	0.79	0.00	0.00	2.18		1.44	2.24

CHAPTER VI

ESTIMATION OF CROPS WATER REQUIREMENT USING FAO "CropWat-4" SOFTWARE PACKAGE

6.1 Introduction

Crop water requirement refers to the total amount of water that the crop requires for optimum production. The difference between the crop water requirements and the effective rainfall is the net crop water requirement or net irrigation requirement. In its calculation, the following terms used are hereby explained:

1. Average effective rainfall (Pe) – This is the rainfall amount stored in the root zone. It is calculated using the FAO method
   Pe = 0.8P – 25 if P>=75mm/month
   Pe = 0.6P – 10 if P<=75mm/month
2. ETo – Reference or potential crop evapotranspiration (mm)
3. ETc – Evapotranspiartion of a particular crop (mm)
4. Kc – Crop coefficient for evapotranspiration (ETc/ETo). FAO crop coefficients adopted.
5. NIR – Net irrigation requirement (ETc + Seepage or Percolation-Pe)

6.2 Objectives and the Scope of Estimation

The evapotranspiration has been computed for the years of 2003 and 2004, using the CropWat-4 software, which utilizes the Penman-modified method and Table-5.1 given below gives the climatic factors considered and the resultant reference/potential evapotranspiration. Its main objectives are:

- To calculate: i) Reference evapotranspiration; ii) Crop water requirements; and iii) Crop irrigation requirements.

- To develop: i) Irrigation schedules under various management conditions; and ii) Scheme water supply.
- To evaluate: i) Rain fed production and drought effects; and ii) Efficiency of irrigation practices.

The development of irrigation schedules and evaluation of rainfed and irrigation practices are based on a daily soil-water balance using various options for water supply and irrigation management conditions. Scheme water supply is calculated according to the cropping pattern provided.

6.3 Data Input

Calculations of the crop water requirements and irrigation requirements were carried out with inputs of climatic, crop and soil data. For the estimation of crop water requirements (CWR) the model requires:

- *Reference Crop Evapotranspiration (Eto)* values calculated using the FAO Penman-Montieth equation based on 10days/monthly climatic data such as minimum and maximum air temperature, relative humidity, sunshine duration and wind speed;
- *Rainfall data* (daily/decade/monthly data); monthly rainfall is divided into a number of rain storm each month;
- *Cropping Pattern* consisting of the planting date, crop coefficient data files (including Kc values, stage days, root depth, depletion fraction) and the area planted (0-100% of the total area);
- *Soil type* total available soil moisture, maximum rooting depth, initial soil moisture depletion (% of total available moisture TAM); and
- *Scheduling Criteria* several options can be selected regarding the calculation of application timing and application depth (irrigate to return the soil back to field capacity when all the easily available moisture has been used).

6.4 Data Output

Once all the data is entered the software automatically calculates the results as tables or plotted in graphs. The times step of the results can be any convenient time step like daily, weekly, 10 days or monthly. The output parameters for each crop in the cropping pattern are as follows:

- Reference crop evapotranspiration – ETo (mm/period);
- Crop Kc - average values of crop coefficient for each time step;
- Effective rain (mm/period) - the amount of water that enters the soil;
- Crop water requirements – CWR or Etm (mm/period);
- Irrigation requirements –IWR (mm/period);
- Total available moisture –TAM (mm);
- Readily available moisture – RAM (mm);
- Actual crop evapotranspiration – ETc (mm);
- Ratio of actual crop evapotranspiration to the maximum crop evapotranspiration - ETc/ETm (%);
- Daily soil moisture deficit (mm);
- Irrigation interval (days) and irrigation depth applied (mm);
- Lost irrigation (mm) – irrigation water that is not stored in the soil (i.e. either surface runoff or percolation);
- Estimated yields reduction due to crop stress (when ETc/ETm is below 100%).

6.5 Calculation methods

The values of decade or monthly Reference Crop Evapotranspiration (Eto) are converted into daily values using four distribution models (the default is a polynomial curve fitting). The model calculates the Crop Water Requirements using the equation:

✓ CWR = ETo * Kc * Area planted

This means that the peak CWR in mm/day can be less than the peak ETo value when less than 100% of the area is planted in the cropping pattern. The average values of crop coefficient for each time step are estimated by linear interpolation between the Kc values for each crop development stage. The "Crop Kc" values are calculated as:

- ✓ Kc * Crop Area

Therefore, if the crop covers only 50% of the area, the Crop Kc values will be half of the Kc values in the crop coefficient data. For crop water requirements and scheduling purposes, the monthly total rainfall has to be distributed into equivalent daily values. The software does this in two steps as followings:

1. The rainfall from month to month is smoothed into a continuous curve (the default curve is a polynomial curve, but can be selected other smoothing methods available in the program linear interpolation between monthly values).
2. Next the model assumes that the monthly rain falls in six separate rainstorms, one every 5 days (the number of the rainstorms can be changed).

The model has available four effective rainfall methods (the USDA SCS method is the default). For the scheduling calculations can be selected two options: i) irrigation scheduling; and ii) for daily soil moisture balance.

The Irrigation Scheduling option shows the status of the soil moisture every time new water enters the soil, by either rainfall or a calculated irrigation application. Daily Soil Moisture Balance option shows the status of the soil every day throughout the cropping pattern, how the soil moisture changes in the growing season. User defined irrigation events and other adjustments to the daily soil moisture balance can be made when the Scheduling Criteria are set to "user-defined". Total Available Moisture (TAM) in the soil for the crop during the growing season is calculated as:

- ✓ Field Capacity - Wilting Point * Current rooting depth of the crop

Readily Available Moisture (RAM) is calculated as:

- ✓ Total Available Moisture (TAM) * P

Where,

P - depletion fraction as defined in the crop coefficient (Kc) file.

To avoid crop stress, the calculated soil moisture deficit should not fall bellow the readily available moisture.

6.6 Software Results

All field crops need soil, water, air and sunlight to grow. Crops need water for evaporation and transpiration. The plant roots extract water from the root zone of soil to live and grow. The water does not remain in the plant, but escape to atmosphere as vapor through plant surface. This process is called transpiration. Water applied to the field also escapes from the soil surface to atmosphere in the from of vapor, which is known as evaporation. The combination of two is known as evapotranspiration.

As already mentioned, the Software requires climate data, cropping pattern, soil characteristics as input data. In response to the inputs, the Software provides evapotranspiration, net irrigation requirement at any specified time domain and are given in Tables 6.1 and 6.2. Crops water requirement was calculated for Cotton crop and Winter Wheat crop, as they are the main agricultural crops in study area. During cotton growth season, the maximum Eto was observed in the month of July 2003, where daily Eto was 5.94 mm while the minimum Eto of 1.75 mm in the month of September. Average daily Eto worked out to be 4.59 mm/day. Total Eto for the whole crop season was 917.41 mm/period, where total rainfall is 105.60 mm/period for Syr-Draya Region. Similarly, during Winter Wheat crop season, the maximum Eto was observed in the month of May, where daily Eto was 5.37 mm/day while the minimum Eto of 0.56 mm/day in the month January. Average daily Eto worked out to be 1.99 mm/day. Total Eto for the whole crop season was 416.91 mm/period, where total rainfall is 254.30 mm/period. Total irrigation water requirements without any loss for the main crops in the study area are as follows: Cotton crop-521.72 mm, Winter wheat-117.16 mm. The results obtained from the CropWat software are given in Tables 6.1, 6.2, 6.3 and 6.4 below:

Table 6.1 Climate and ETo (grass) Data for 2003

Country: Uzbekistan Latitude: 40.380 North Longitude: 68.050 East
Station: Dustlik Altitude: 273 m above M.S.L

Month	Max. Temp. (^0C)	Min. Temp. (^0C)	Humidity (%)	Wind Speed. (Km/d)	Sunshine (Hours)	Solar Rad. (MJ/m2/d)	ETo (mm/d)
January	9.6	0.9	74.7	139.1	2.7	5.8	0.93
February	9.7	-0.3	74.7	135.6	4.0	8.8	1.21
March	12.9	2.4	74.9	146	3.5	10.8	1.75
April	17.6	7.3	72.8	137.4	8.5	19.9	3.05
May	23.8	10.9	65.6	145.2	9.6	23.3	4.42
June	29.5	15.4	58.6	144.3	11.2	26.2	5.71
July	33.5	17.7	41.1	56.2	12.8	28.1	5.54
August	32.8	17.1	40.7	0	11.9	25.1	3.92
September	27.8	12.9	45.5	0	9.3	18.8	2.49
October	23.6	9.1	50.0	0	7.2	12.9	1.30
November	12.8	3.7	73.5	0	6.0	9.0	0.54
December	7.2	-2.8	78.6	0	2.9	5.4	0.29
Average	**20.07**	**7.86**	**62.56**	**75.32**	**7.47**	**16.18**	**2.60**

Table 6.2 Climate and ETo (grass) Data for 2004

Month	Max. Temp. (^0C)	Min. Temp. (^0C)	Humidity (%)	Wind Speed. (Km/d)	Sunshine (Hours)	Solar Rad. (MJ/m2/d)	ETo (mm/d)
January	8.4	0.4	80.7	0	2.7	5.8	0.4
February	12.5	1.5	67.0	0	4.0	8.8	0.8
March	14.7	3.9	71.0	0	3.5	10.8	1.3
April	20.3	7.6	65.2	0	8.5	19.9	2.7
May	27.9	12.7	52.0	0	9.6	23.3	3.7
June	32.9	16.3	34.6	0	11.2	26.2	4.3
July	33.1	18.4	43.7	0.9	12.8	28.1	4.8
August	32.8	16.8	39.7	3.5	11.9	25.1	4.0
September	28.7	12.8	38.4	3.5	9.3	18.8	2.5
October	19.6	6.0	53.0	3.5	7.2	12.9	1.2
November	16.4	6.5	71.3	0.9	6.0	9.0	0.6
December	8.1	-0.9	78.8	0.0	2.9	5.4	0.3
Average	**21.3**	**8.5**	**58.0**	**1.0**	**7.5**	**16.2**	**2.2**

Table 6.3 Results of Estimated Crop Water Requirements for COTTON crop in 2003

Crop: COTTON   Planting date: 15/03/2004   Calculation time step: 10 days   Irrigation Efficiency: 65%

Date	ETo (mm/period)	Crop Area (%)	Crop Coefficient (Kc)	CWR (ETm) (mm/period)	Total Rain (mm/period)	Effect. Rain (mm/period)	Net Irrig-on Req. (mm/period	Field Water Supply (l/s/ha)
1	2	3	4	5	6	7	8	9
15/3	22.90	60	0.21	4.81	12.58	11.50	0	0
25/3	27.78	60	0.21	5.83	12.32	11.28	0	0
4/4	32.76	60	0.21	6.88	12.56	11.52	0	0
14/4	37.70	60	0.27	10.07	13.28	12.20	0	0
24/4	42.44	60	0.37	15.66	14.23	13.10	2.56	0.05
4/5	46.81	60	0.47	22.04	14.83	13.68	8.36	0.15
14/5	50.70	60	0.57	29.04	14.03	12.97	16.06	0.29
24/5	53.98	60	0.67	36.41	10.18	9.48	26.93	0.48
3/6	56.55	60	0.72	40.72	1.56	1.49	39.23	0.70
13/6	58.34	60	0.72	42.00	0	0	42.00	0.75
23/6	59.29	60	0.72	42.69	0	0	42.69	0.76
3/7	59.37	60	0.72	42.75	0	0	42.75	0.76
13/7	58.59	60	0.72	42.19	0	0	42.19	0.75
23/7	56.97	60	0.72	41.02	0	0	41.02	0.73
2/8	54.55	60	0.68	37.33	0	0	37.33	0.66
12/8	51.41	60	0.62	31.82	0	0	31.82	0.57
22/8	47.65	60	0.55	26.38	0	0	26.38	0.47
1/9	43.37	60	0.49	21.17	0	0	21.17	0.38
11/9	38.72	60	0.42	16.37	0	0	16.37	0.29
21/9	17.53	60	0.37	6.54	0.03	0.03	6.52	0.23
Total	**917.41**			**521.72**	**105.60**	**97.25**	**443.38**	**[0.4]**

Table 6.4 Results of Estimated Crop Water Requirements for Winter Wheat crop in 2003-2004

Crop: WINTER WHEAT Planting date: 4/11/2003 Calculation time step: 10 days Irrigation Efficiency: 70%

Date	ETo (mm/period)	Crop Area (%)	Crop Kc	CWR (ETm) (mm/period)	Total Rain (mm/period)	Effect. Rain (mm/period)	Net Irrig-on Req. (mm/period)	Field Water Supply (l/s/ha)
1	2	3	4	5	6	7	8	9
4/11	13.51	40	0.24	3.24	0.72	0.71	2.53	0.04
14/11	10.03	40	0.24	2.41	0.00	0	2.41	0.04
24/11	7.24	40	0.24	1.74	5.36	5.14	0	0
4/12	5.21	40	0.24	1.25	11.08	10.41	0	0
14/12	3.99	40	0.24	0.96	14.46	13.45	0	0
24/12	3.58	40	0.24	0.86	15.81	14.62	0	0
3/1	3.55	40	0.24	0.85	14.59	13.53	0	0
13/1	3.97	40	0.24	0.95	15.09	13.94	0	0
23/1	5.22	40	0.24	1.25	15.32	14.11	0	0
2/2	7.30	40	0.24	1.75	15.20	13.96	0	0
12/2	10.17	40	0.26	2.62	14.75	13.51	0	0
22/2	13.72	40	0.29	3.94	14.05	12.85	0	0
4/3	17.85	40	0.32	5.66	13.27	12.13	0	0
14/3	22.42	40	0.35	7.78	12.63	11.55	0	0
24/3	27.28	40	0.36	9.82	12.33	11.28	0	0
3/4	32.27	40	0.36	11.62	12.51	11.47	0.14	0
13/4	37.22	40	0.36	13.40	13.19	12.12	1.28	0.02
23/4	41.98	40	0.36	15.11	14.14	13.02	2.09	0.03
3/5	46.40	40	0.31	14.32	14.82	13.66	0.66	0.01
3/5	50.34	40	0.22	10.92	14.22	13.14	0	0
23/5	53.68	40	0.13	6.71	10.76	10.01	0	0
Total	**416.91**	**416.91**		**117.16**	**254.30**	**234.61**	**9.11**	**[0.01]**

CHAPTER VII

APPLICATION OF DAILY SOIL WATER BALANCE SIMULATION MODEL "WaSim"

7.1 Introduction

WaSim was developed at Hydraulic Research (HR) Wallingford and Cranfield University with support from Department for International Development (DFID) of UK. It is a computer-based package for the teaching and demonstration of issues involved in irrigation, drainage and salinity. The model allows simulation of the soil water/salinity relationships in response to different management strategies (e.g. drainage designs and water management practices) and environmental scenarios (e.g. weather data, soil types, cropping patterns). The software provides the following capabilities as follows:

- WaSim simulates drainage to sub-surface tile (pipe) drains;
- WaSim runs on a daily time-step using actual rainfall and reference evapo-transpiration data (an associated WaSim-ET program is provided to calculate reference evapotranspiration from weather station data) Simulations of up to 30 years in duration can be undertaken;
- Up to 3 crops (+ fallow) can be specified in rotation;
- Soil characteristics for a single layered soil can be specified; and
- WaSim can also be run as an unsaturated water balance simulation model, with irrigation, drainage/water table and salinity options switched off.

7.2 Objectives of WaSim

The objective of the WaSim is to simulate controlled drainage using weirs situated in open drain or sub-surface drainage system and and to assess the impacts on the soil water balance, water table depths, drain flow and crop response. The model carries out a one-dimensional daily soil water balance. It aims to simulate the soil water storage and rates of input (infiltration) and output (evapotranspiration and drainage) of water in response to climate, irrigation and seepage where relevant. The upper boundary is the soil surface and the lower boundary is the impermeable layer. Fig. 7.1 shows that the water stored between two boundaries in five stores are: i) surface (0-0.15m) layer; ii) active root zone (0.15m root depth); iii) unsaturated compartment below the root zone (root depth-water table); iv) saturated compartment above drain depth (water table-drain depth); and v) saturated compartment below drain depth (drain depth-impermeable layer).

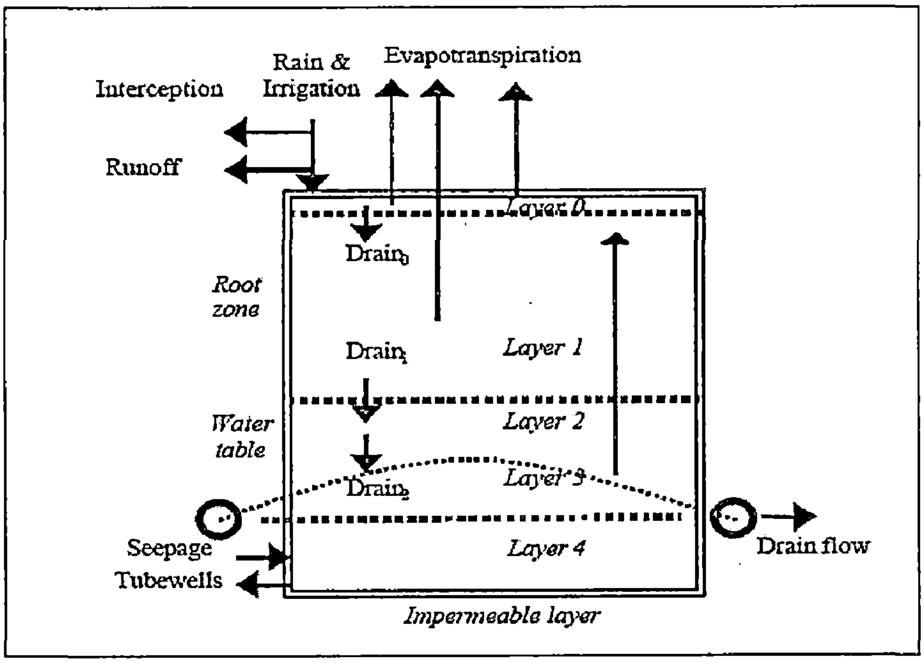


Fig. 7.1 Overview of soil water balance

The boundary between compartments one and two will change as the roots grow. Before plants root reaches 0.15 m, compartment one will have zero thickness. Similarly, the boundary between compartments 2 and 3 will fluctuate with the water table.

7.3 Data Input

- *Climate:* The model requires daily reference evapotranspiration and rainfall data. An accompanying utility, WaSimET is provided for calculating reference evapotranspiration from daily climate data using the Penman-Monteith, FAO Modified-Penman, or Penman methods. Climate data is imported from text files and screened for missing or out-of-range data. Data errors are then flagged and can be edited with WaSim.

- *Crops and Soils:* Up to three crops can be combined in a cropping pattern. For each crop, information is required on the cover development and rooting depths. Basic soil moisture characteristics are required, but typical guidance values provided. The crop and soil information is added to a database for future reference.

- *Irrigation:* Irrigation schedule has been developed for individual crop. Irrigation is basically scheduled in two ways:
    1. *Rule based scheduling:* The cropping season can be divided in to a maximum of 12 periods, during which different scheduling rules can be applied. The rules (e.g. irrigate at 25mm soil water deficit and refill to field capacity) determine the timing of irrigation and the amounts to be applied.
    2. *Calendar scheduling:* Irrigations can be specified for fixed dates to simulate irrigation by a fixed calendar or it can be changed. This option can also be used to simulate the impact of an actual irrigation schedule.

7.4 Drainage

The drainage system is defined in terms of drain diameter, depth and spacing. The model also allows for a simple representation of the impacts of canal seepage and tube well extraction. The model can also be run without drainage or as a free draining system. Drains can also be closed for part of the year to simulate controlled drainage for sub-irrigation. The salinity of the irrigation water and salt tolerance can be specified for each crop in the cropping pattern.

7.6 Model Results

As above mentioned WaSim aims to simulate the soil and water relationship in response to different management strategies like drainage design, water management, weather data and soil types and, cropping pattern. The model is easy to use; it has minimum data requirements, good visualization of model calculations, a reasonable level of accuracy and is flexible in term of the range of water management situations that can be simulated. The field data collected from experimental site of Kushman-Ata farm in Sh. Rashidov district in the Syr-Darya province of Uzbekistan, have been used to predict soil, water and crop response.

As a result, maximum outputs have been obtained in terms of soil and water relationship in different layers of soil like top soil, active root zone, and saturated and unsaturated zones using minimum data. In addition, the advantages of this model are its flexibility and understandable options for calculating different parameters and plotting of the graphs that are required for the study. WaSim can store five different scenarios at a time and allows to compare one with another. Desired results were obtained after running the model for five times by changing its options, choosing different scenarios in terms of climatic condition, soil type, sowing period, irrigation scheduling as they are explained in data input paragraph in this chapter.

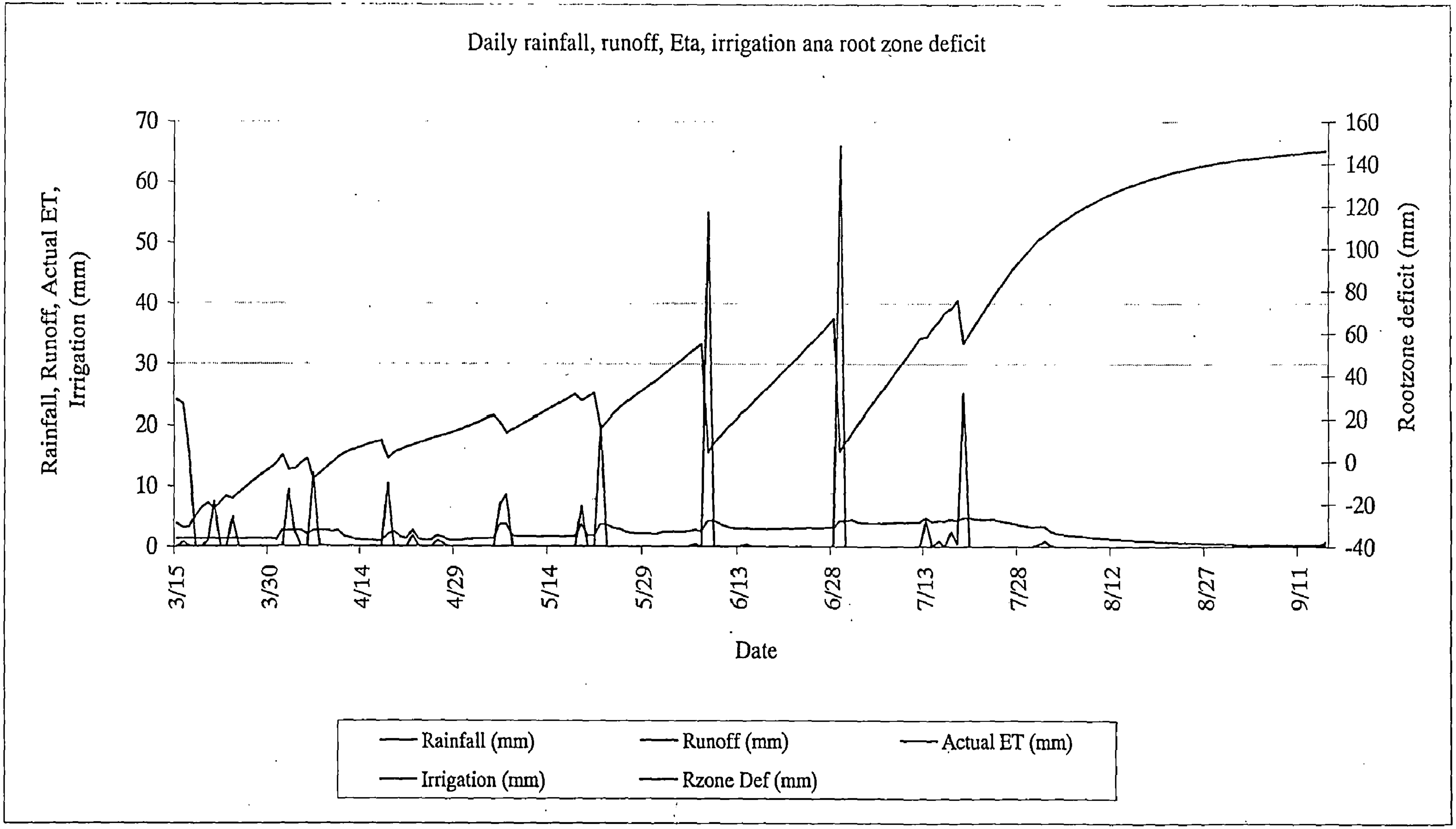
However, there were some difficulties, as model cannot plot more than three different parameters in a single graph. Due to this limitation, all simulated data were copied in spreadsheet in order to plot graphs with more than three parameters. This is the only disadvantage of this model.

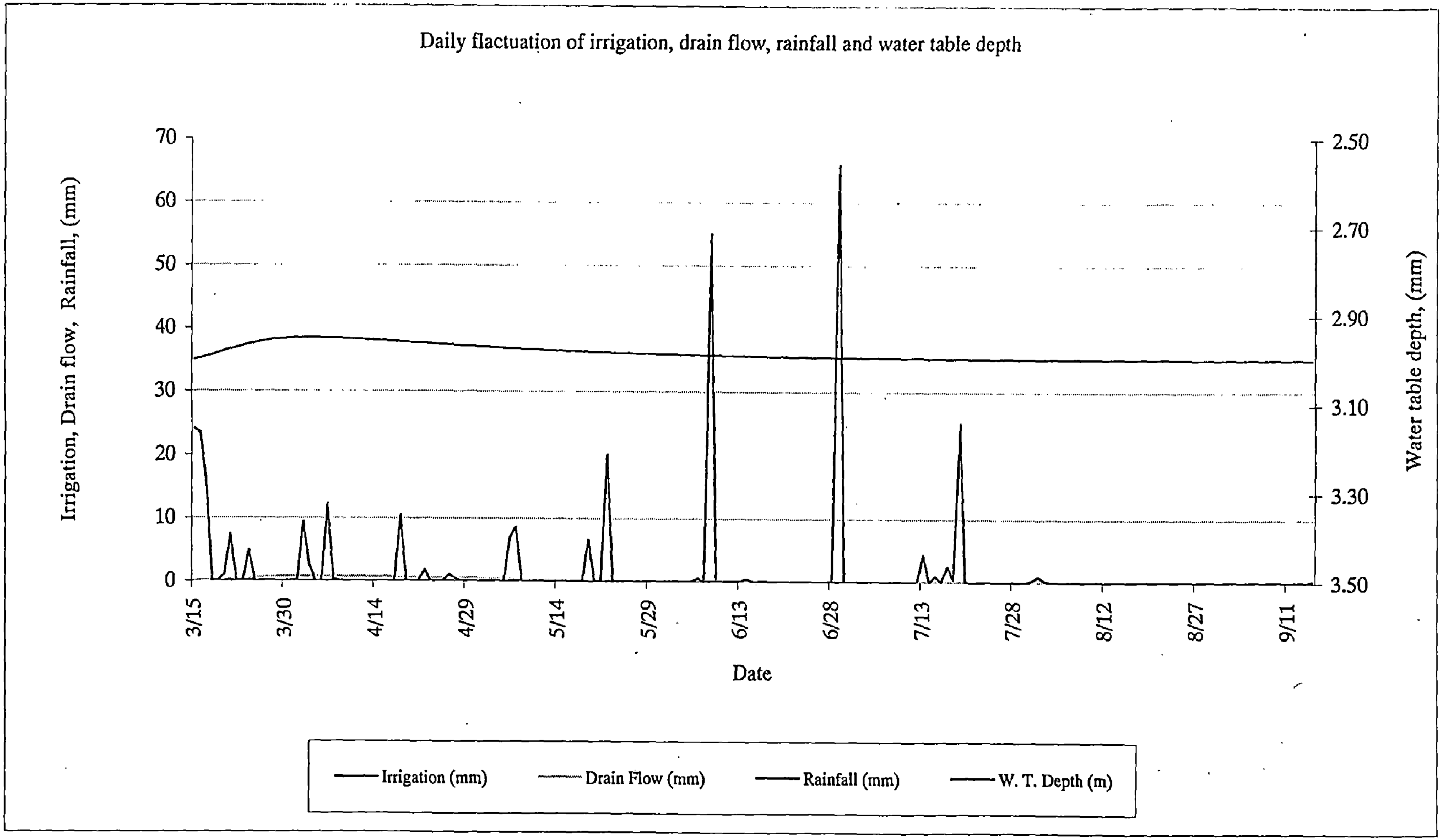
As it can be seen from Fig. 7.3, which depicts daily fluctuation of rainfall, runoff, evepotranspiration (ETc), depth of irrigation water applied and deficit of moisture in root zone during the crop period. Crop period is plotted as abscissa and daily rainfall, runoff, ETc, depth of irrigation and deficit of moisture in root zone as ordinate. Rainfall was not adequate to produce surface runoff during the whole cropping period. Moisture deficit in root zone decreases when irrigations water is applied or rainfall occurs. During mid of crop period, there was no rainfall at all and the moisture deficit in root zone reached up to maximum point, so, irrigation had to be applied. Therefore, two irrigations were applied on June 6 and 29 based on irrigation at fixed depletion (%TAM) to bring the soil moisture level up to field capacity. Maximum daily Etc (4.80 mm/day) has been observed on July 19 during full covering stage, while the ETc was negligible at harvesting stage.

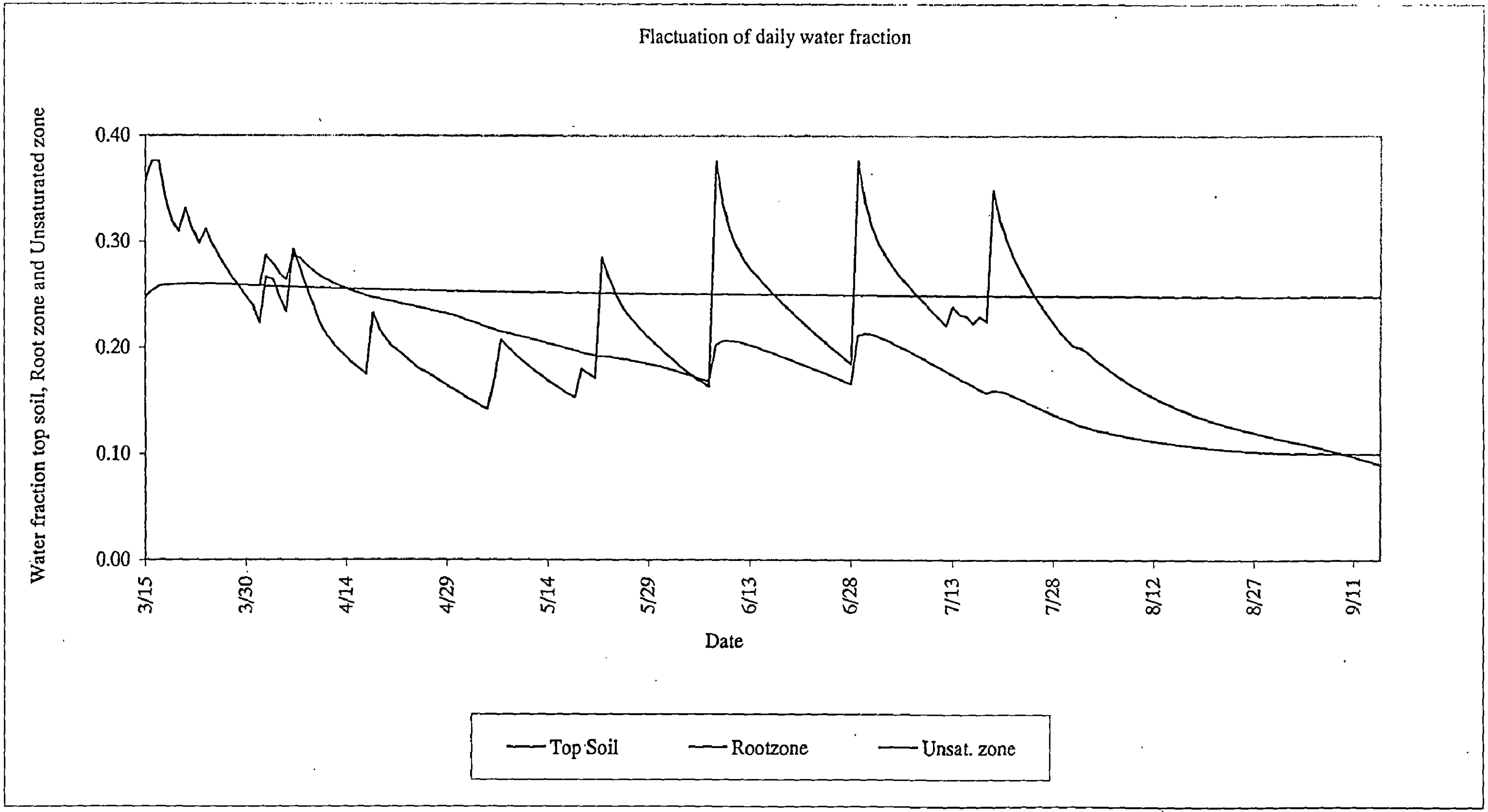
Fig. 7.4 depicts a plot of period and depth of irrigation water applied, drain flow, rainfall and variation of water table depth with respect to time, during the crop period. Due to inadequate rainfall during the whole crop period as well as controlled irrigation, ground water table seems almost constant and drain flow observed was insignificant. Irrigation is applied to just fulfill crop water requirement, hence, it does not contribute to groundwater. Due to this, there was no rise in water table depth.

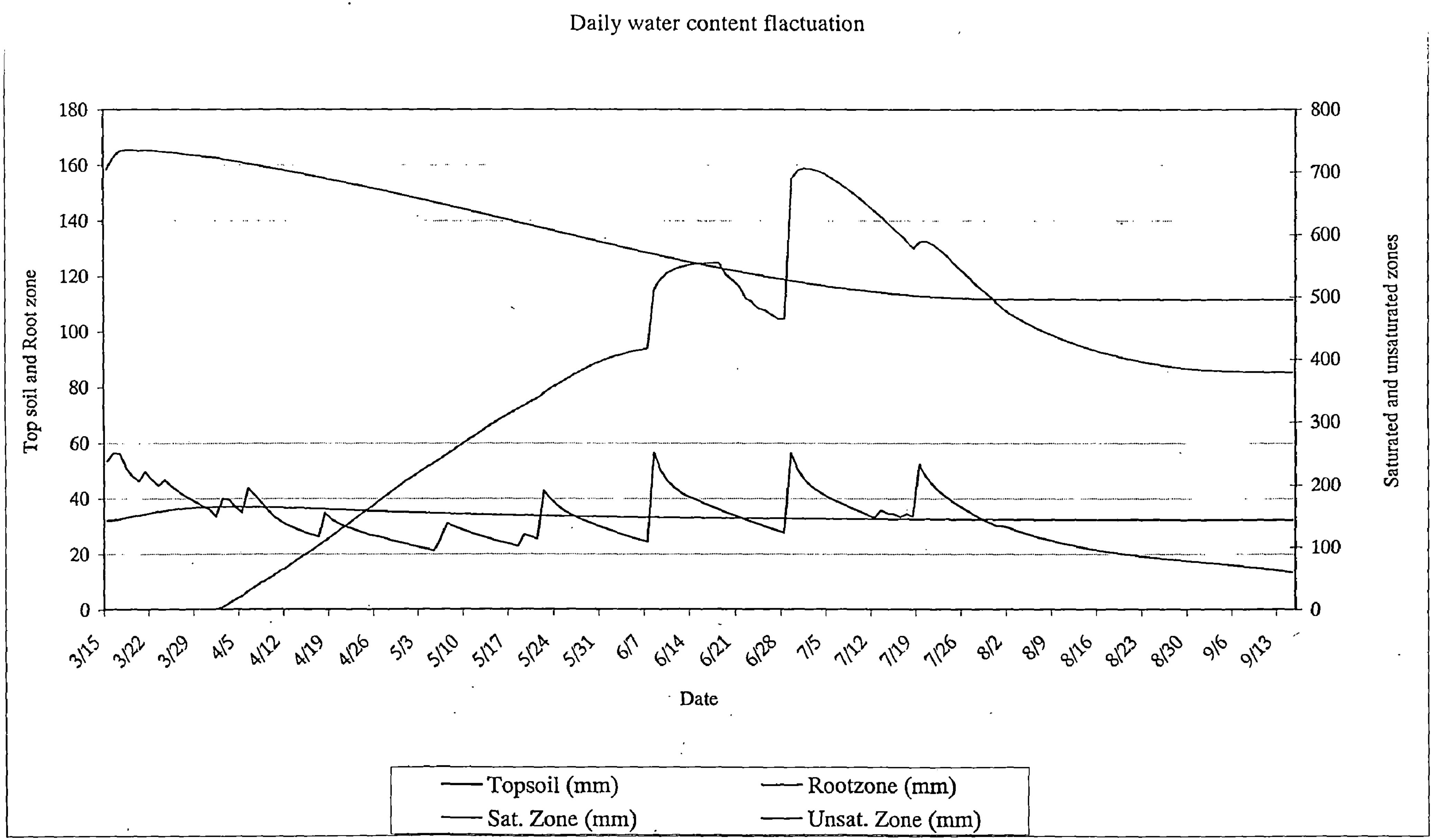
Fig. 7.5 shows a plot of daily fluctuation of water fraction in top soil, crop root zone and unsaturated zone for the crop period. If there is rainfall or irrigation, water fraction in top soil increases. Water fraction in root zone depth will increase only after irrigation or significant rainfall. As mentioned above, because of inadequate rainfall as well as controlled irrigation, there is no any deep percolation, hence water fraction in unsaturated zone isalmost constant.

Conclusively, WaSim is easy to use, has minimal data requirements, good visualization of model calculations, and a reasonable level of accuracy and is flexible in terms of the range of water management situations that can be simulated. Thus, WaSim is found to be suitable as a tool to design different controlled drainage strategies for different situations.


Daily rainfall, runoff, Eta, irrigation ana root zone deficit
Rainfall, Runoff, Actual ET, Irrigation (mm)
70
60
50
40
30
20
10
0
Rootzone deficit (mm)
160
140
120
100
80
60
40
20
0
-20
-40
3/15
3/30
4/14
4/29
5/14
5/29
6/13
6/28
7/13
7/28
8/12
8/27
9/11
Date
Rainfall (mm)
Runoff (mm)
Actual ET (mm)
Irrigation (mm)
Rzone Def (mm)


Daily flactuation of irrigation, drain flow, rainfall and water table depth
Irrigation, Drain flow, Rainfall, (mm)
70
60
50
40
30
20
10
0
Water table depth, (mm)
2.50
2.70
2.90
3.10
3.30
3.50
3/15
3/30
4/14
4/29
5/14
5/29
6/13
6/28
7/13
7/28
8/12
8/27
9/11
Date
Irrigation (mm)
Drain Flow (mm)
Rainfall (mm)
W. T. Depth (m)


Flactuation of daily water fraction
Water fraction top soil, Root zone and Unsaturated zone
0.40
0.30
0.20
0.10
0.00
3/15
3/30
4/14
4/29
5/14
5/29
6/13
6/28
7/13
7/28
8/12
8/27
9/11
Date
Top Soil
Rootzone
Unsat. zone



Daily water content flactuation
Top soil and Root zone
Saturated and unsaturated zones
0
20
40
60
80
100
120
140
160
180
0
100
200
300
400
500
600
700
800
3/15
3/22
3/29
4/5
4/12
4/19
4/26
5/3
5/10
5/17
5/24
5/31
6/7
6/14
6/21
6/28
7/5
7/12
7/19
7/26
8/2
8/9
8/16
8/23
8/30
9/6
9/13
Date
Topsoil (mm)
Rootzone (mm)
Sat. Zone (mm)
Unsat. Zone (mm)

Table 7.1 Results of WaSim simulation model

Scenario: COTTON_25.05.06.drr
Climate File: F:\WaSim\Climate data 2003-04.cld
Drainage Type: Subsuface Tile Drain

Crop: Cotton
Soil Type: Sandy Loam
Sowing Date: 3/15/2004
Harvesing Date: 9/15/2004

Irrigation: Furrow Irrigation
Initial Soil Water Deficit: 0 m
Initial Water Table Depth: 3 m

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Intercep-tion (mm)	Runoff (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	Water Fraction Top Soil	Water Fraction Root-zone	Water Fraction Unsat. zone	W.C. in Top Soil (mm)	W.C. in Root-zone (mm)	W.C in Sat. Zone (mm)	W.C. in Unsat. Zone (mm)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
3/15/04	1	0.10	0	24.10	0	0.01	1.30	0	-29.06	3.00	0.00	0.36	0.25	0.25	53.56	0.00	704.19	142.74
3/16/04	1	0.10	0	23.40	0	0.84	1.30	0	-31.08	3.00	0.00	0.38	0.25	0.25	56.41	0.00	721.84	143.50
3/17/04	1	0.10	0	15.20	0	0.02	1.30	0	-30.76	2.99	0.03	0.38	0.26	0.26	56.41	0.00	733.87	145.33
3/18/04	1	0.11	0	0.00	0	0	1.30	0	-25.26	2.99	0.08	0.34	0.26	0.26	51.28	0.00	735.59	147.34
3/19/04	1	0.11	0	0.00	0	0	1.30	0	-21.59	2.99	0.15	0.32	0.26	0.26	48.03	0.00	735.42	149.32
3/20/04	1	0.11	0	1.00	0	0	1.30	0	-19.48	2.98	0.21	0.31	0.26	0.26	46.40	0.00	734.68	151.18
3/21/04	1	0.11	0	7.40	0	0	1.30	0	-22.26	2.98	0.27	0.33	0.26	0.26	49.71	0.00	735.26	153.12
3/22/04	1	0.11	0	0.00	0	0	1.30	0	-18.88	2.97	0.33	0.31	0.26	0.26	46.90	0.00	734.61	154.95
3/23/04	1	0.12	0	0.00	0	0	1.30	0	-16.09	2.97	0.39	0.30	0.26	0.26	44.74	0.00	733.41	156.61
3/24/04	1	0.12	0	4.80	0	0	1.30	0	-17.45	2.97	0.45	0.31	0.26	0.26	46.78	0.00	732.86	158.19
3/25/04	1	0.12	0	0.00	0	0	1.30	0	-14.58	2.96	0.50	0.30	0.26	0.26	44.64	0.00	731.78	159.60
3/26/04	1	0.13	0.01	0.00	0	0	1.30	0	-12.03	2.96	0.54	0.29	0.26	0.26	42.87	0.00	730.48	160.83
3/27/04	1	0.13	0.01	0.00	0	0	1.30	0	-9.65	2.96	0.58	0.28	0.26	0.26	41.31	0.00	729.11	161.87
3/28/04	1	0.13	0.02	0.00	0	0	1.30	0	-7.36	2.96	0.62	0.27	0.26	0.26	39.90	0.00	727.76	162.72
3/29/04	1	0.14	0.03	0.00	0	0	1.30	0	-5.10	2.95	0.65	0.26	0.26	0.26	38.56	0.00	726.47	163.40
3/30/04	1	0.14	0.03	0.00	0	0	1.30	0	-2.83	2.95	0.67	0.25	0.26	0.26	37.26	0.00	725.28	163.92
3/31/04	1	0.14	0.04	0.00	0	0	1.15	0	-0.66	2.95	0.69	0.24	0.26	0.26	36.11	0.00	724.21	164.31
4/1/04	1	0.15	0.05	0.00	0	0	2.70	0	3.11	2.95	0.70	0.22	0.26	0.26	33.41	0.00	723.24	164.58
4/2/04	1	0.15	0.05	9.40	0	0	2.70	0	-3.40	2.95	0.71	0.27	0.29	0.26	40.00	1.04	721.44	164.75
4/3/04	1	0.16	0.06	2.50	0	0	2.70	0	-3.24	2.95	0.71	0.26	0.28	0.26	39.70	2.34	719.45	164.83
4/4/04	1	0.16	0.06	0.00	0	0	2.70	0	-0.59	2.95	0.72	0.25	0.27	0.26	37.02	3.58	717.48	164.83
4/5/04	1	0.17	0.07	0.00	0	0	2.02	0	1.38	2.95	0.72	0.23	0.26	0.26	35.02	4.86	715.53	164.76
4/6/04	1	0.17	0.08	12.20	0	0	2.70	0	-8.11	2.95	0.71	0.29	0.29	0.26	43.89	6.78	713.65	164.64
4/7/04	1	0.18	0.08	0.30	0	0	2.70	0	-5.69	2.95	0.71	0.28	0.28	0.26	41.28	8.30	711.78	164.48
4/8/04	1	0.18	0.09	0.00	0	0	2.70	0	-2.99	2.95	0.70	0.26	0.28	0.26	38.59	9.67	709.90	164.28

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Intercep-tion (mm)	Runoff (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	Water Fraction Top Soil	Water Fraction Root-zone	Water Fraction Unsat. zone	W.C. in Top Soil (mm)	W.C. in Root-zone (mm)	W.C in Sat. Zone (mm)	W.C. in Unsat. Zone (mm)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
4/9/04	1	0.19	0.10	0.00	0	0	2.52	0	-0.48	2.95	0.70	0.24	0.27	0.26	36.12	11.06	707.99	164.05
4/10/04	1	0.20	0.10	0.00	0	0	2.70	0	2.20	2.95	0.69	0.22	0.27	0.26	33.49	12.48	706.07	163.79
4/11/04	1	0.20	0.11	0.00	0	0	1.73	0	3.89	2.95	0.68	0.21	0.26	0.26	31.85	13.93	704.14	163.50
4/12/04	1	0.21	0.12	0.00	0	0	1.35	0	5.20	2.95	0.67	0.20	0.26	0.26	30.61	15.41	702.19	163.19
4/13/04	1	0.22	0.12	0.00	0	0	1.19	0	6.34	2.96	0.66	0.20	0.26	0.26	29.56	16.92	700.22	162.86
4/14/04	1	0.22	0.13	0.00	0	0	1.09	0	7.37	2.96	0.65	0.19	0.26	0.26	28.62	18.45	698.23	162.51
4/15/04	1	0.23	0.14	0.00	0	0	1.03	0	8.34	2.96	0.64	0.19	0.25	0.26	27.76	20.01	696.22	162.15
4/16/04	1	0.24	0.14	0.00	0	0	0.99	0	9.26	2.96	0.63	0.18	0.25	0.26	26.97	21.58	694.20	161.78
4/17/04	1	0.24	0.15	0.00	0	0	0.96	0	10.14	2.96	0.61	0.17	0.25	0.25	26.23	23.18	692.16	161.40
4/18/04	1	0.25	0.15	10.40	0	0	2.01	0	1.68	2.96	0.60	0.23	0.25	0.25	34.85	24.79	690.10	161.01
4/19/04	1	0.26	0.16	0.00	0	0	2.52	0	4.13	2.96	0.59	0.22	0.25	0.25	32.52	26.48	688.01	160.62
4/20/04	1	0.27	0.17	0.00	0	0	1.61	0	5.67	2.96	0.58	0.21	0.24	0.25	31.13	28.17	685.92	160.23
4/21/04	1	0.27	0.17	0.00	0	0	1.37	0	6.97	2.96	0.56	0.20	0.24	0.25	30.01	29.88	683.80	159.83
4/22/04	1	0.28	0.18	1.80	0	0	2.70	0	7.79	2.96	0.55	0.20	0.24	0.25	29.38	31.59	681.66	159.44
4/23/04	1	0.29	0.19	0.00	0	0	1.17	0	8.89	2.96	0.54	0.19	0.24	0.25	28.50	33.31	679.50	159.05
4/24/04	1	0.30	0.19	0.00	0	0	1.12	0	9.94	2.96	0.53	0.18	0.24	0.25	27.69	35.04	677.32	158.66
4/25/04	1	0.30	0.20	0.00	0	0	1.09	0	10.95	2.97	0.51	0.18	0.24	0.25	26.94	36.78	675.12	158.27
4/26/04	1	0.31	0.21	1.00	0	0	1.86	0	11.74	2.97	0.50	0.18	0.24	0.25	26.45	38.52	672.90	157.89
4/27/04	1	0.32	0.22	0.50	0	0	1.44	0	12.61	2.97	0.49	0.17	0.23	0.25	25.90	40.26	670.66	157.52
4/28/04	1	0.33	0.22	0.00	0	0	1.04	0	13.58	2.97	0.47	0.17	0.23	0.25	25.27	42.00	668.40	157.15
4/29/04	1	0.34	0.23	0.00	0	0	1.04	0	14.55	2.97	0.46	0.16	0.23	0.25	24.67	43.74	666.12	156.78
4/30/04	1	0.35	0.24	0.00	0	0	1.04	0	15.52	2.97	0.45	0.16	0.23	0.25	24.10	45.47	663.82	156.42
5/1/04	1	0.36	0.25	0.00	0	0	1.29	0	16.74	2.97	0.44	0.16	0.23	0.25	23.49	47.02	661.50	156.07
5/2/04	1	0.37	0.26	0.00	0	0	1.30	0	17.97	2.97	0.43	0.15	0.23	0.25	22.90	48.55	659.17	155.73
5/3/04	1	0.37	0.27	0.00	0	0	1.32	0	19.22	2.97	0.42	0.15	0.22	0.25	22.34	50.07	656.82	155.39
5/4/04	1	0.38	0.27	0.00	0	0	1.33	0	20.48	2.97	0.41	0.15	0.22	0.25	21.80	51.56	654.45	155.06
5/5/04	1	0.39	0.28	0.00	0	0	1.35	0	21.76	2.97	0.40	0.14	0.22	0.25	21.29	53.04	652.07	154.74
5/6/04	1	0.40	0.29	6.90	0	0	3.70	0	18.49	2.97	0.38	0.17	0.22	0.25	25.36	54.50	649.67	154.42
5/7/04	1	0.41	0.30	8.60	0	0	3.70	0	13.52	2.97	0.37	0.21	0.21	0.25	31.08	56.03	647.25	154.11
5/8/04	1	0.42	0.31	0.00	0	0	1.76	0	15.21	2.98	0.36	0.20	0.21	0.25	30.07	57.64	644.83	153.81
5/9/04	1	0.43	0.31	0.00	0	0	1.71	0	16.85	2.98	0.35	0.19	0.21	0.25	29.15	59.23	642.39	153.52
5/10/04	1	0.44	0.32	0.00	0	0	1.69	0	18.46	2.98	0.35	0.19	0.21	0.25	28.29	60.80	639.93	153.24
5/11/04	1	0.45	0.33	0.00	0	0	1.67	0	20.07	2.98	0.34	0.18	0.21	0.25	27.48	62.33	637.47	152.96
5/12/04	1	0.46	0.34	0.00	0	0	1.67	0	21.67	2.98	0.33	0.18	0.21	0.25	26.73	63.84	635.00	152.69

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Intercep-tion (mm)	Runoff (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	Water Fraction Top Soil	Water Fraction Root-zone	Water Fraction Unsat. zone	W.C. in Top Soil (mm)	W.C. in Root-zone (mm)	W.C in Sat. Zone (mm)	W.C. in Unsat. Zone (mm)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
5/13/04	1	0.47	0.35	0.00	0	0	1.67	0	23.27	2.98	0.32	0.17	0.21	0.25	26.01	65.31	632.52	152.42
5/14/04	1	0.48	0.36	0.00	0	0	1.67	0	24.88	2.98	0.31	0.17	0.20	0.25	25.33	66.75	630.03	152.17
5/15/04	1	0.49	0.36	0.00	0	0	1.68	0	26.49	2.98	0.30	0.16	0.20	0.25	24.68	68.16	627.54	151.92
5/16/04	1	0.50	0.37	0.00	0	0	1.69	0	28.12	2.98	0.29	0.16	0.20	0.25	24.06	69.54	625.04	151.68
5/17/04	1	0.51	0.38	0.00	0	0	1.71	0	29.77	2.98	0.29	0.16	0.20	0.25	23.46	70.88	622.53	151.44
5/18/04	1	0.52	0.39	0.00	0	0	1.72	0	31.42	2.98	0.28	0.15	0.20	0.25	22.89	72.18	620.02	151.21
5/19/04	1	0.53	0.40	6.60	0	0	3.70	0	28.46	2.98	0.27	0.18	0.20	0.25	26.99	73.45	617.51	150.99
5/20/04	1	0.54	0.40	0.00	0	0	1.84	0	30.23	2.98	0.26	0.18	0.19	0.25	26.28	74.79	615.00	150.77
5/21/04	1	0.55	0.41	0.00	0	0	1.85	0	32.02	2.98	0.26	0.17	0.19	0.25	25.59	76.09	612.49	150.56
5/22/04	1	0.56	0.42	20.10	0	0	3.70	0	15.56	2.98	0.25	0.28	0.19	0.25	42.75	77.80	609.98	150.36
5/23/04	1	0.57	0.43	0.00	0	0	3.70	0	19.20	2.98	0.24	0.27	0.19	0.25	39.86	79.45	607.47	150.16
5/24/04	1	0.58	0.44	0.00	0	0	3.14	0	22.28	2.98	0.24	0.25	0.19	0.25	37.70	80.93	604.96	149.97
5/25/04	1	0.58	0.44	0.00	0	0	2.93	0	25.15	2.98	0.23	0.24	0.19	0.25	35.82	82.33	602.46	149.78
5/26/04	1	0.59	0.45	0.00	0	0	2.42	0	27.52	2.98	0.23	0.23	0.19	0.25	34.50	83.68	599.96	149.60
5/27/04	1	0.60	0.46	0.00	0	0	2.29	0	29.74	2.99	0.22	0.22	0.19	0.25	33.37	84.97	597.47	149.43
5/28/04	1	0.61	0.47	0.00	0	0	2.22	0	31.91	2.99	0.21	0.22	0.19	0.25	32.35	86.21	594.99	149.26
5/29/04	1	0.62	0.48	0.00	0	0	2.19	0	34.04	2.99	0.21	0.21	0.18	0.25	31.40	87.40	592.51	149.09
5/30/04	1	0.63	0.49	0.00	0	0	2.18	0	36.16	2.99	0.20	0.20	0.18	0.25	30.52	88.54	590.05	148.93
5/31/04	1	0.64	0.49	0.00	0	0	2.17	0	38.27	2.99	0.20	0.20	0.18	0.25	29.68	89.62	587.59	148.78
6/1/04	1	0.65	0.50	0.00	0	0	2.47	0	40.69	2.99	0.19	0.19	0.18	0.25	28.80	90.43	585.15	148.62
6/2/04	1	0.66	0.51	0.00	0	0	2.48	0	43.12	2.99	0.19	0.19	0.18	0.25	27.96	91.17	582.72	148.48
6/3/04	1	0.67	0.52	0.00	0	0	2.50	0	45.57	2.99	0.18	0.18	0.18	0.25	27.15	91.85	580.31	148.33
6/4/04	1	0.68	0.53	0.00	0	0	2.52	0	48.03	2.99	0.18	0.18	0.17	0.25	26.37	92.47	577.91	148.20
6/5/04	1	0.69	0.53	0.00	0	0	2.54	0	50.52	2.99	0.17	0.17	0.17	0.25	25.63	93.02	575.52	148.06
6/6/04	1	0.70	0.54	0.50	0	0	2.79	0	52.76	2.99	0.17	0.17	0.17	0.25	25.18	93.51	573.16	147.93
6/7/04	1	0.71	0.55	0.00	0	0	2.58	0	55.29	2.99	0.17	0.16	0.17	0.25	24.48	93.93	570.81	147.81
6/8/04	1	0.72	0.56	0.00	0	0	4.30	55	4.54	2.99	0.16	0.38	0.20	0.25	56.41	114.99	568.48	147.68
6/9/04	1	0.73	0.57	0.00	0	0	4.30	0	8.79	2.99	0.16	0.34	0.21	0.25	50.37	119.00	566.18	147.56
6/10/04	1	0.74	0.58	0.00	0	0	3.81	0	12.55	2.99	0.15	0.31	0.21	0.25	46.71	121.09	563.89	147.45
6/11/04	1	0.75	0.58	0.00	0	0	3.41	0	15.92	2.99	0.15	0.29	0.21	0.25	44.24	122.37	561.63	147.34
6/12/04	1	0.75	0.59	0.00	0	0	3.09	0	18.96	2.99	0.15	0.28	0.20	0.25	42.49	123.23	559.39	147.23
6/13/04	1	0.76	0.60	0.00	0	0	3.00	0	21.92	2.99	0.14	0.27	0.20	0.25	41.08	123.82	557.18	147.12
6/14/04	1	0.77	0.61	0.50	0	0	3.17	0	24.54	2.99	0.14	0.27	0.20	0.25	40.14	124.24	554.99	147.02
6/15/04	1	0.78	0.62	0.00	0	0	2.96	0	27.46	2.99	0.14	0.26	0.20	0.25	39.03	124.52	552.83	146.92

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Intercep-tion (mm)	Runoff (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	Water Fraction Top Soil	Water Fraction Root-zone	Water Fraction Unsat. zone	W.C. in Top Soil (mm)	W.C. in Root-zone (mm)	W.C in Sat. Zone (mm)	W.C. in Unsat. Zone (mm)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
6/16/04	1	0.79	0.62	0.00	0	0	2.96	0	30.38	2.99	0.13	0.25	0.20	0.25	38.00	124.68	550.70	146.82
6/17/04	1	0.80	0.63	0.00	0	0	2.97	0	33.30	2.99	0.13	0.25	0.19	0.25	37.02	124.76	548.59	146.73
6/18/04	1	0.80	0.64	0.00	0	0	2.98	0	36.25	2.99	0.13	0.24	0.19	0.25	36.08	124.76	546.52	146.64
6/19/04	1	0.81	0.65	0.00	0	0	3.00	0	39.20	2.99	0.12	0.23	0.19	0.25	35.15	124.69	544.48	146.55
6/20/04	1	0.82	0.66	0.00	0	0	3.02	0	42.18	2.99	0.12	0.23	0.19	0.25	34.25	124.55	542.46	146.47
6/21/04	1	0.83	0.67	0.00	0	0	3.04	0	45.19	2.99	0.12	0.22	0.18	0.25	33.37	124.33	540.49	146.38
6/22/04	1	0.84	0.67	0.00	0	0	3.06	0	48.21	2.99	0.12	0.22	0.18	0.25	32.51	124.04	538.54	146.30
6/23/04	1	0.84	0.68	0.00	0	0	3.09	0	51.26	2.99	0.11	0.21	0.18	0.25	31.67	123.67	536.63	146.22
6/24/04	1	0.85	0.69	0.00	0	0	3.11	0	54.34	2.99	0.11	0.21	0.18	0.25	30.84	123.23	534.75	146.15
6/25/04	1	0.86	0.70	0.00	0	0	3.14	0	57.45	2.99	0.11	0.20	0.17	0.25	30.03	122.71	532.91	146.07
6/26/04	1	0.86	0.71	0.00	0	0	3.17	0	60.58	2.99	0.11	0.19	0.17	0.25	29.23	122.10	531.11	146.00
6/27/04	1	0.87	0.71	0.00	0	0	3.19	0	63.74	2.99	0.10	0.19	0.17	0.25	28.45	121.42	529.35	145.93
6/28/04	1	0.88	0.72	0.00	0	0	3.22	0	66.93	2.99	0.10	0.18	0.17	0.25	27.68	120.66	527.62	145.86
6/29/04	1	0.89	0.73	0.00	0	0	4.30	66	5.20	2.99	0.10	0.38	0.21	0.25	56.41	155.29	525.93	145.80
6/30/04	1	0.89	0.74	0.00	0	0	4.30	0	9.47	2.99	0.10	0.34	0.21	0.25	50.78	158.23	524.29	145.73
7/1/04	1	0.90	0.75	0.00	0	0	4.46	0	13.90	2.99	0.10	0.31	0.21	0.25	47.23	158.89	522.68	145.67
7/2/04	1	0.90	0.76	0.00	0	0	4.12	0	17.99	2.99	0.09	0.30	0.21	0.25	44.86	158.67	521.12	145.61
7/3/04	1	0.91	0.76	0.00	0	0	3.97	0	21.94	2.99	0.09	0.29	0.21	0.25	43.09	157.96	519.60	145.55
7/4/04	1	0.92	0.77	0.00	0	0	3.94	0	25.85	2.99	0.09	0.28	0.20	0.25	41.64	156.92	518.12	145.49
7/5/04	1	0.92	0.78	0.00	0	0	3.94	0	29.77	2.99	0.09	0.27	0.20	0.25	40.37	155.64	516.69	145.44
7/6/04	1	0.93	0.79	0.00	0	0	3.95	0	33.69	2.99	0.09	0.26	0.20	0.25	39.23	154.20	515.30	145.38
7/7/04	1	0.93	0.80	0.00	0	0	3.97	0	37.64	2.99	0.08	0.25	0.20	0.25	38.16	152.61	513.95	145.33
7/8/04	1	0.94	0.80	0.00	0	0	3.99	0	41.61	2.99	0.08	0.25	0.19	0.25	37.13	150.92	512.65	145.28
7/9/04	1	0.94	0.81	0.00	0	0	4.02	0	45.60	2.99	0.08	0.24	0.19	0.25	36.11	149.14	511.40	145.23
7/10/04	1	0.95	0.82	0.00	0	0	4.04	0	49.63	2.99	0.08	0.23	0.18	0.25	35.11	147.27	510.19	145.18
7/11/04	1	0.95	0.83	0.00	0	0	4.07	0	53.68	2.99	0.08	0.23	0.18	0.25	34.12	145.31	509.03	145.14
7/12/04	1	0.96	0.84	0.00	0	0	4.10	0	57.77	2.99	0.08	0.22	0.18	0.25	33.14	143.27	507.92	145.09
7/13/04	1	0.96	0.84	4.30	0	0	4.80	0	58.25	2.99	0.08	0.24	0.17	0.25	35.81	141.14	506.86	145.05
7/14/04	1	0.96	0.85	0.00	0	0	4.17	0	62.40	2.99	0.07	0.23	0.17	0.25	34.71	139.05	505.84	145.00
7/15/04	1	0.97	0.86	1.00	0	0	4.34	0	65.72	2.99	0.07	0.23	0.17	0.25	34.48	136.88	504.88	144.96
7/16/04	1	0.97	0.87	0.00	0	0	4.23	0	69.94	3.00	0.07	0.22	0.16	0.25	33.36	134.65	503.96	144.92
7/17/04	1	0.97	0.88	2.50	0	0	4.57	0	72.00	3.00	0.07	0.23	0.16	0.25	34.44	132.33	503.10	144.88
7/18/04	1	0.98	0.89	0.50	0	0	4.36	0	75.84	3.00	0.07	0.22	0.16	0.25	33.68	130.02	502.28	144.84
7/19/04	1	0.98	0.89	25.10	0	0.00	4.80	0	55.53	3.00	0.07	0.35	0.16	0.25	52.37	132.36	501.52	144.81

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Intercep-tion (mm)	Runoff (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	Water Fraction Top Soil	Water Fraction Root-zone	Water Fraction Unsat. zone	W.C. in Top Soil (mm)	W.C. in Root-zone (mm)	W.C in Sat. Zone (mm)	W.C. in Unsat. Zone (mm)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
7/20/04	1	0.98	0.90	0.00	0	0	4.80	0	60.32	3.00	0.07	0.32	0.16	0.25	48.11	132.50	500.81	144.77
7/21/04	1	0.99	0.91	0.00	0	0	4.64	0	64.95	3.00	0.07	0.30	0.16	0.25	45.17	131.43	500.14	144.73
7/22/04	1	0.99	0.92	0.00	0	0	4.55	0	69.50	3.00	0.06	0.29	0.15	0.25	42.91	129.72	499.54	144.70
7/23/04	1	0.99	0.93	0.00	0	0	4.54	0	74.03	3.00	0.06	0.27	0.15	0.25	40.99	127.63	498.98	144.67
7/24/04	1	0.99	0.93	0.00	0	0	4.55	0	78.57	3.00	0.06	0.26	0.15	0.25	39.24	125.30	498.47	144.63
7/25/04	1	0.99	0.94	0.00	0	0	4.33	0	82.90	3.00	0.06	0.25	0.15	0.25	37.66	122.97	498.02	144.60
7/26/04	1	1.00	0.95	0.00	0	0	4.10	0	86.99	3.00	0.06	0.24	0.14	0.25	36.19	120.72	497.62	144.57
7/27/04	1	1.00	0.96	0.00	0	0	3.88	0	90.86	3.00	0.06	0.23	0.14	0.25	34.81	118.54	497.27	144.54
7/28/04	1	1.00	0.97	0.00	0	0	3.67	0	94.53	3.00	0.06	0.22	0.14	0.25	33.51	116.43	496.98	144.51
7/29/04	1	1.00	0.98	0.00	0	0	3.47	0	98.00	3.00	0.06	0.22	0.13	0.25	32.29	114.39	496.74	144.48
7/30/04	1	1.00	0.98	0.00	0	0	3.28	0	101.28	3.00	0.06	0.21	0.13	0.25	31.14	112.42	496.55	144.46
7/31/04	1	1.00	0.99	0.30	0	0	3.40	0	104.37	3.00	0.06	0.20	0.13	0.25	30.26	110.32	496.41	144.43
8/1/04	1	1.00	1.00	1.00	0	0	3.43	0	106.80	3.00	0.05	0.20	0.13	0.25	30.05	108.14	496.33	144.40
8/2/04	1	1.00	1.00	0.30	0	0	2.60	0	109.11	3.00	0.05	0.20	0.13	0.25	29.40	106.49	496.30	144.38
8/3/04	1	1.00	1.00	0.00	0	0	2.18	0	111.29	3.00	0.05	0.19	0.12	0.25	28.59	105.12	496.27	144.35
8/4/04	1	1.00	1.00	0.00	0	0	2.06	0	113.35	3.00	0.05	0.19	0.12	0.25	27.83	103.82	496.24	144.33
8/5/04	1	1.00	1.00	0.00	0	0	1.95	0	115.31	3.00	0.05	0.18	0.12	0.25	27.10	102.59	496.21	144.31
8/6/04	1	1.00	1.00	0.00	0	0	1.85	0	117.16	3.00	0.05	0.18	0.12	0.25	26.42	101.43	496.19	144.28
8/7/04	1	1.00	1.00	0.00	0	0	1.75	0	118.91	3.00	0.05	0.17	0.12	0.25	25.77	100.32	496.16	144.26
8/8/04	1	1.00	1.00	0.00	0	0	1.66	0	120.57	3.00	0.05	0.17	0.12	0.25	25.15	99.28	496.13	144.24
8/9/04	1	1.00	1.00	0.00	0	0	1.57	0	122.14	3.00	0.05	0.16	0.12	0.25	24.57	98.29	496.10	144.22
8/10/04	1	1.00	1.00	0.00	0	0	1.49	0	123.62	3.00	0.05	0.16	0.11	0.25	24.02	97.36	496.07	144.20
8/11/04	1	1.00	1.00	0.00	0	0	1.41	0	125.03	3.00	0.05	0.16	0.11	0.25	23.50	96.47	496.05	144.18
8/12/04	1	1.00	1.00	0.00	0	0	1.33	0	126.36	3.00	0.05	0.15	0.11	0.25	23.01	95.63	496.02	144.16
8/13/04	1	1.00	1.00	0.00	0	0	1.26	0	127.62	3.00	0.05	0.15	0.11	0.25	22.54	94.84	495.99	144.14
8/14/04	1	1.00	1.00	0.00	0	0	1.19	0	128.82	3.00	0.05	0.15	0.11	0.25	22.10	94.09	495.97	144.12
8/15/04	1	1.00	1.00	0.00	0	0	1.13	0	129.95	3.00	0.04	0.14	0.11	0.25	21.68	93.38	495.94	144.10
8/16/04	1	1.00	1.00	0.00	0	0	1.07	0	131.01	3.00	0.04	0.14	0.11	0.25	21.28	92.70	495.91	144.08
8/17/04	1	1.00	1.00	0.00	0	0	1.01	0	132.03	3.00	0.04	0.14	0.11	0.25	20.91	92.06	495.89	144.06
8/18/04	1	1.00	1.00	0.00	0	0	0.96	0	132.99	3.00	0.04	0.14	0.11	0.25	20.55	91.46	495.86	144.05
8/19/04	1	1.00	1.00	0.00	0	0	0.91	0	133.89	3.00	0.04	0.13	0.11	0.25	20.22	90.89	495.84	144.03
8/20/04	1	1.00	1.00	0.00	0	0	0.86	0	134.75	3.00	0.04	0.13	0.11	0.25	19.90	90.35	495.81	144.01
8/21/04	1	1.00	1.00	0.00	0	0	0.81	0	135.57	3.00	0.04	0.13	0.11	0.25	19.60	89.84	495.79	144.00
8/22/04	1	1.00	1.00	0.00	0	0	0.77	0	136.34	3.00	0.04	0.13	0.11	0.25	19.31	89.35	495.76	143.98

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Intercep-tion (mm)	Runoff (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	Water Fraction Top Soil	Water Fraction Root-zone	Water Fraction Unsat. zone	W.C. in Top Soil (mm)	W.C. in Root-zone (mm)	W.C in Sat. Zone (mm)	W.C. in Unsat. Zone (mm)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
8/23/04	1	1.00	1.00	0.00	0	0	0.73	0	137.06	3.00	0.04	0.13	0.10	0.25	19.04	88.89	495.74	143.97
8/24/04	1	1.00	1.00	0.00	0	0	0.69	0	137.75	3.00	0.04	0.13	0.10	0.25	18.79	88.46	495.71	143.95
8/25/04	1	1.00	1.00	0.00	0	0	0.65	0	138.41	3.00	0.04	0.12	0.10	0.25	18.54	88.05	495.69	143.94
8/26/04	1	1.00	1.00	0.00	0	0	0.62	0	139.03	3.00	0.04	0.12	0.10	0.25	18.32	87.66	495.66	143.92
8/27/04	1	1.00	0.95	0.00	0	0	0.58	0	139.61	3.00	0.04	0.12	0.10	0.25	18.08	87.31	495.64	143.91
8/28/04	1	1.00	0.90	0.00	0	0	0.55	0	140.16	3.00	0.04	0.12	0.10	0.25	17.85	86.99	495.61	143.89
8/29/04	1	1.00	0.86	0.00	0	0	0.52	0	140.68	3.00	0.04	0.12	0.10	0.25	17.62	86.71	495.59	143.88
8/30/04	1	1.00	0.81	0.00	0	0	0.49	0	141.17	3.00	0.04	0.12	0.10	0.25	17.38	86.45	495.56	143.87
8/31/04	1	1.00	0.76	0.00	0	0	0.47	0	141.63	3.00	0.04	0.11	0.10	0.25	17.15	86.22	495.54	143.85
9/1/04	1	1.00	0.71	0.00	0	0	0.32	0	141.96	3.00	0.04	0.11	0.10	0.25	16.95	86.09	495.52	143.84
9/2/04	1	1.00	0.67	0.00	0	0	0.32	0	142.28	3.00	0.04	0.11	0.10	0.25	16.75	85.97	495.49	143.83
9/3/04	1	1.00	0.62	0.00	0	0	0.32	0	142.59	3.00	0.04	0.11	0.10	0.25	16.54	85.86	495.47	143.81
9/4/04	1	1.00	0.57	0.00	0	0	0.31	0	142.91	3.00	0.04	0.11	0.10	0.25	16.33	85.76	495.45	143.80
9/5/04	1	1.00	0.52	0.00	0	0	0.31	0	143.22	3.00	0.03	0.11	0.10	0.25	16.11	85.68	495.43	143.79
9/6/04	1	1.00	0.48	0.00	0	0	0.31	0	143.52	3.00	0.03	0.11	0.10	0.25	15.88	85.60	495.40	143.78
9/7/04	1	1.00	0.43	0.00	0	0	0.31	0	143.83	3.00	0.03	0.10	0.10	0.25	15.64	85.53	495.38	143.77
9/8/04	1	1.00	0.38	0.00	0	0	0.30	0	144.13	3.00	0.03	0.10	0.10	0.25	15.40	85.47	495.36	143.76
9/9/04	1	1.00	0.33	0.00	0	0	0.30	0	144.44	3.00	0.03	0.10	0.10	0.25	15.15	85.42	495.34	143.74
9/10/04	1	1.00	0.29	0.00	0	0	0.30	0	144.74	3.00	0.03	0.10	0.10	0.25	14.89	85.37	495.31	143.73
9/11/04	1	1.00	0.24	0.00	0	0	0.30	0	145.04	3.00	0.03	0.10	0.10	0.25	14.62	85.33	495.29	143.72
9/12/04	1	1.00	0.19	0.00	0	0	0.30	0	145.35	3.00	0.03	0.10	0.10	0.25	14.35	85.31	495.27	143.71
9/13/04	1	1.00	0.14	0.00	0	0	0.31	0	145.65	3.00	0.03	0.09	0.10	0.25	14.06	85.28	495.25	143.70
9/14/04	1	1.00	0.10	0.00	0	0	0.31	0	145.96	3.00	0.03	0.09	0.10	0.25	13.77	85.27	495.23	143.69
9/15/04	1	1.00	0.05	0.30	0	0	0.61	0	146.27	3.00	0.03	0.09	0.10	0.25	13.48	85.25	495.21	143.68

CHAPTER VIII

RESULTS AND DISCUSSIONS

Uzbekistan has a big potential reserve of the area suitable for irrigation, but water resources limit the development of irrigation. Emphases must be given to bring into use the irrigation methods which will assist in solving problems like irrigation water saving, improvement of production and conservation of soil fertility and its structure. Keeping in view the above background ICARDA has established as integrated research site at Boykozon farm, in the Tashkent Province of northeastern Uzbekistan. The site represents the typical agro-ecological and mixed farming system of Uzbekistan. Several advanced irrigation techniques are tested on the field. Encouraging results of water and soil conservation have been obtained form these studies and are given in Table 8.1. The techniques include the follows methods as:

1) Use of Joyak (Zigzag) furrows for irrigation of winter wheat crop;
2) Use of Portable Polyethylene Chutes (PPCH-50) with adjustable aperture for irrigation of potato crop;
3) Use of Self-pressurized Drip Irrigation System for Young Vineyards and Vegetables on abrupt biases;
4) Use of Drainage Water for irrigation;
5) Use of Goffered Hoses for irrigation of corn for a silo; and
6) Use of Shielded Polyethylene Films for production of stock-beet crop.

Performances of all these techniques are compared with the traditional (control) irrigation techniques used in the country. The concept of efficiency as enumerated in above techniques is not evaluating the performance of the irrigation systems when but is intended to assess the reliability and flexibility of deliveries required to improve demand management. A new performance parameter indicating irrigation performance relative to crop yield is used in this study. Results of this study showed that above techniques have higher water productivity and irrigation efficiency.

- Soil erosion is decreased from 3.48 t/ha to 0.52 t/ha as compared with traditional irrigation method and Zigzag (Joyak) technique due to reduction in the velocity of water flow in the furrow. The excess water at the end of furrow is 2.0-2.35 times less when compared to the control. The water productivity increased from 211.3-253.2 m^3/ha to 103.3-184.3 m^3/ha. Conclusively, research of Joyak (Zigzag) irrigation of Winter Wheat indicated that high water-saving efficiency as well as protection of soil from erosion cab be achieved. However, zigzag irrigation technology has its own limitations: during the period of harvesting, intersected furrows are made leveled so as avoid difficulty for the movement of tractor "combiner". And hence, it is necessary to develop mechanisms for cutting zigzag furrows.

- In case of PPCH-50, they have provided a uniform water jet to each furrow. From studies it was observed that the chutes eliminated seepage losses and ensured uniform distribution of water among the furrows. In addition, they provided full control over the timing and amount of water applied to each furrow. The water saving up to 50% of traditionally used amount can be obtained for same yield and due to less runoff the soil erosion was reduced from 3.1 t/ha to 0.4 t/ha. Water productivity has also doubled from 1.6 to 3.4 kg/m^3 for growing of summer-sown potatoes

- When there is an increase in deficiency of water resources, the drip irrigation system is necessary for cultivation of vineyards and vegetables in a foothill zone. In 2001, advanced Self-pressurized Drip Irrigation technology tested at Boykozon site was found to be efficient for production of young vineyards, vegetables and melons grown in the inter-row spacing. Using this technology, farmers can benefit from reduced irrigation rate from 660 to 220 m^3/ha and secure profit from vegetables and melon during the first three unproductive years of vineyard establishment. Various research experiments have shown economy of irrigation water by drip irrigation. For young vineyards, water economy of 69.3% has been achieved, while, for vegetables, it ranged from 81 to 83% and is about 87.9% for watermelons. Based on these experiments, numbers of research indications have been drawn and are explained in detail in Chapter 3.

- In the territory of "Boykazon" farm 273 ha of land has been chosen for experimental research on use of marginal waters for irrigation of Maize of 0.6 ha, Potato 0.6 ha and Apple trees of 0.6 ha. Within the theme of ICARDA, a new convenient technology for lifting and delivering wastewaters from collector to those farms along the collector has been developed. It requires small initial cash outlays and some extra labor, but produces an attractive return on these investments. Reuse of wastewater on the irrigated areas with the raised biases showed that it effectively increased soil fertility, facilitated irrigating inconveniently and earlier non-irrigable areas with smaller expenses of work. It also enables more production and reduced water removal from irrigated territory.

- In 2000, Goffered hoses were used on very abrupt biases. On a bias of 0.08-0.14, the coefficient of irrigation efficiency increases from 0.79 at the use of the primary discharge in usual conditions of irrigation to 0.87 by selecting discharge through furrows and lengths of furrow i.e. installation of position of hoses for irrigation having a length of 35-50 m against 50 m as usual irrigation. Experiments of using Goffered hoses have shown their efficiency on irrigation of winter wheat and corn for silo. However, it is necessary to develop adjustable apertures for Goffered hoses to control water discharge in furrows.

- Obvious advantages of irrigation by Shielded Polyethylene Films are the best thermo-physical properties of ground, the best microbiological regime of ground, absence of condensation of ground by wheels of ploughing tractor, full elimination of irrigational erosion and promote formation of higher yield. Therefore, in 2000 the yield of Stock-beet by this method of irrigation was 118 t/ha, compared with traditional (control) irrigation of 104 t/ha. As a significant part of ground surface covered by polyethylene films, evaporation from the soil surface has been prevented. Since this technology keeps soil moisture, that could have been lost due to evaporation, it proved to have high irrigation efficiency particularly for crops such as stock beet. However, it is necessary to develop mechanisms for stacking of films to the field at the beginning of vegetative period as well as removal of them at the end of the season. In addition, it is important to establish the color and thickness of films, which are most suitable for different crops. It is important to improve technology of water distribution and design of polyethylene films as well.

Table 8.1 Results of advanced irrigation techniques compared with the traditional irrigation

Parameters	Control Irrigation	Zigzag Irrigation (Joyak)	Control Irrigation	Irrigation by PPCh-50	Control Irrigation	Goffered Hoses
Nomber of irrigation	3	3	10	10	5	5
Total irrigation (gross and net, m^3/ha)	3510 2500	3510 2600	11653 8369	9930 7928	7109 5635	4285 3735
Irrigation efficiency	0.71	0.78	0.72	0.80	0.79	0.87
Soil erosion, t/ha	3.48	0.52	3.1	0.4	2.7	1.3
Production, quintal/ha	32.4	37.2	31.2	32.4	227	308
Net irrigation consumption, m^3	77.2	64.8	268.2	244.7	24.9	12.1
Slope	0.08 - 0.11		0.07-0.074		0.08-0.04	
Length of furrow, m	66	160	67	67	50	50
Area, ha	0.2	0.2	0.3	0.3	0.28	0.28
Water discharge, l/s			0.15	0.08	0.09	0.06

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS

1. Land and water are the most important natural resources and are regarded as the permanent assets in the service of mankind. Agriculture plays an important role in the economy of Uzbekistan. About 15 million people (60% of total population) depend directly or indirectly on agriculture. 34.6% of the Gross Domestic Product (GDP) is derived from Agriculture. The available land of the republic is 44.4 mha of which about 11.8 mha are potentially suitable for irrigation including 4.277 mha of existing irrigation area. The other 32.6 mha is desert pastures, mountains, sandy soils. The average annual precipitation in the plains is about 80-90 mm to the east and in southern parts of the country the amount reaches 890-1000 mm. During vegetation period precipitation is less; therefore all crops must be irrigated so as to fulfill their water requirements. Main irrigated crops are Cotton, Grain and Vegetables. Commonly used irrigation methods are furrow, border, and basin.

2. In dry areas, water is the most limiting factor in crop production. Every drop of water must be carefully conserved and used. The moisture availability to the growing crops is the most significant single factor limiting production. It seems logical that consideration of this production factor must therefore receive high priority. Hence, the importance of the use of supplemental irrigation to provide the moisture needed by the crops, when rainfall fails to do so at the right time and life-saving amount could hardly be exaggerated.

3. Soil is the basic natural resources in agriculture. Among the major soil factors affecting crop production and water-use efficiency are soil type and depth. Soil fertility is the key to sound management of farming systems. Adequate fertility

ensures the most efficient use of available water. When soil fertility limits yield, the use of fertilizers will result in more grain or dry matter per unit available water, thus increasing water-use efficiency. This increase occurs because adequate fertility stimulates early growth, increases root development and leaf surface area.

4. Tillage and soil surface management are among the important factors for successful management of soil-water-crop-climate systems. Tillage has a direct bearing on soil structure, soil surface evaporation, soil erosion, seedbed preparation, infiltration, aeration, and weed control. It is necessary to reduce soil tillage to prevent both the negative changes in soil structure and avoid soil compacting in the case of heavy machine use. Thus, the yield in the country is significantly lower than in other developed countries with similar climate conditions, and therefore it is necessary to:
   - Raise the seed quality;
   - Increase the use of fertilizers and pesticides (which has sharply decreased in the last decade);
   - Implement sufficient cultivation practices and timely harvesting; and
   - Improve the farming culture in general.

In this Dissertation, studies involve critical review of irrigation practices used, introduction of appropriate irrigation technologies that will assist in solving in many social economic problems particularly, irrigation water saving, conservation of soil fertility and its structure, facilitation of irrigation processes and, improvement in yield in irrigated areas of Uzbekistan. Many researchers have maintained two problems, which are prevailing in almost all irrigated agricultural areas in Uzbekistan, are:

i) Low productivity from the available water due to considerable amount of water flows off the field during irrigation; and

ii) Loss of soil by erosion due to runoff from irrigated fields taking away large amount of soil and nutrients.

Thus, studies showed that the concentration of humus in soil, which is basis of production, has decreased for the latest decades by 30-40%. Annual soil erosion of the country averages 51 t/ha, while that of irrigation efficiency is less than 60%. Water erosion affected land is more than 4 mha or about 20% of non-irrigated areas particularly, in the Surkhandarya, Samarkand, Kashkadarya provinces from 50 to 60%. Irrigation erosion is observed on irrigated area of about 262,100 ha. It is the consequence of inappropriate irrigation methods or irrigation by flooding method on poor land leveling. Wind erosion is observed on the area over 2.0 mha of the irrigated land. Currently in Uzbekistan, total agricultural area subjected to salinization is 3.7 mha of which 1.1 mha is the land of medium and highly salinized. Therefore, the Government is facing a great challenge transition from a centrally planned irrigation management system with the low water-use efficiency to a system, which can provide precise and strong incentives for efficient use of scare water resources. It is necessary to adopt the following practices:

- Introduce a water-pricing system;
- Improve the water resources management system; and
- Renovation and maintenance of the irrigation system.

Thus, these techniques can be used as improved irrigation method with the purpose of conservation and management of water and soil resources in dry agriculture areas of Uzbekistan.

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