EFFICIENT WATER MANAGEMENT THROUGH IMPROVED IRRIGATION SYSTEM IN A DISTRICT OF TASKENT, UZBEKISTAN

A DISSERTATION

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

I hereby certify that the work which is being presented in this Dissertation entitled "**EFFICIENT WATER MANAGEMENT THROUGH IMPROVED IRRIGATION SYSTEM IN A DISTRICT OF TASHKENT, 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 2006 to June 2007 under the supervision of Dr. DEEPAK KHARE, Associate Professor WRDM, (IIT) Roorkee.

I have not submitted the matter in this Dissertation for the award of any other Degree.

June, 2007 **DJAMSHID R. TURSUNOV**

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Dr. DEEPAK KHARE
Associate Professor WRDM, (IIT) Roorkee

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ABSTRACT

The Republic of Uzbekistan is including 12 viloyats or provinces and the autonomous Karakalpakstan Republic. Agriculture accounts for 26 percent of the country's GDP. The total land area of Uzbekistan amounts to 44.9 million ha, of which 23.5 million ha are in pasture. A total of 4.3 million ha are irrigated, of which 3.3 million ha are irrigated arable land and one million ha irrigated pasture. There is a rainfed arable area of 0.8 million ha. Yields in the rainfed area are low but the area makes an important contribution to national grain production.

Prior to independence the monoculture of cotton led to problems of land degradation. Cotton production has since fallen and there has been a substantial expansion in the grain area and production. This has permitted a large reduction in grain imports.

Since independence, a new agricultural infrastructure has been put into place. The family "dekhan" farms account for more than 60 percent of the agricultural production.

Aral Sea's problem and its coastal area basin is widely known and do not require detailed description. The drying up of the Sea created hundreds kilometers of salty area around. The Sea has lost its fishery, transportation, biological and most important its life's natural significance as a result of unbalanced water consumption during the last 30 years. The Aral 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. Simultaneously, the delta of the Amu-Darya and Syr-Darya Rivers has advanced into the Sea. The Sea Bottom has been converted into a source of salt and dusty storms caused by progressive accumulation on considerable distance from the former water's edge. Contamination of river water has exceeded permissible concentration limits, especially at midstream and downstream. That's why problem of Aral Sea found like one of the global problem in the world.

Land and Water are the most important natural resources and are regarded as the permanent assets in the service of mankind. About 44% of total irrigated area of the country in concentrated in Syr-Darya rivar 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. 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.

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. Currently in Uzbekistan, total agricultural area subjected to salinization is 3.723 million ha of which 1.081 million ha is the land of medium and highly salinized.

Further agricultural growth can be achieved in the country only through the more efficient use of already utilized water resources and an increase in land productivity. For these purposes more attention is started to pay to Irrigation Water Use Efficiency, which is currently improved by modern Irrigation Systems. And only such above processes can solve the problem of water availability in Republic of Uzbekistan.

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RUz	Republic of Uzbekistan
MAWR	Ministry of Agriculture and Water Resources
UzNIIHI	Uzbek Scientific Research Cotton Growing Institute
FAO	Food and Agriculture Organization
ICARDA	International Center for Agricultural Research in the Dry Areas
Hydromet	Institute of Hydro-Meteorology
SANIIRI	Central Asian Scientific Research Institute for Irrigation
NPAEP	National Plan of Action on Environmental Protection
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
CWR	Crop Water Requirements
CWU	Crop Water Use
ETc	Crop evapotranspiration
NIWR	Net Irrigation Water Requirement
GIWR	Gross Irrigation Water Requirement
DIWR	Deficit Irrigation Water Requirement
RZD	Root Zone Depth
UC	Uniformity
A	Adequacy
SI	Supplemental Irrigation

CHAPTER I

INTRODUCTION

1.1 Location and General Description of the Study Area

The Republic of Uzbekistan is situated in the central part of Central Asian region on the crossroads of the historical "Silk Road", which a certain degree has left its imprint on the socio-economical development of agriculture, industry, trade, and in people's interrelations and mentality. 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 per cent of the total land, while irrigated lands occupy 4.3 million ha are seasonal pastures. 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 Zerafshan River. The development of agriculture is constrained by scare water for 90 per cent of areas under crops.

Republic of Uzbekistan is the largest country of the Central Asia, is located between 37° and 45° northern latitude and 56° and 73° eastern longitude. Uzbekistan borders on Kazakhstan in the north, Kyrgyz Republic and Tajikistan in the east, and Afghanistan and Turkmenistan in the south is shown in (Fig.1.1).

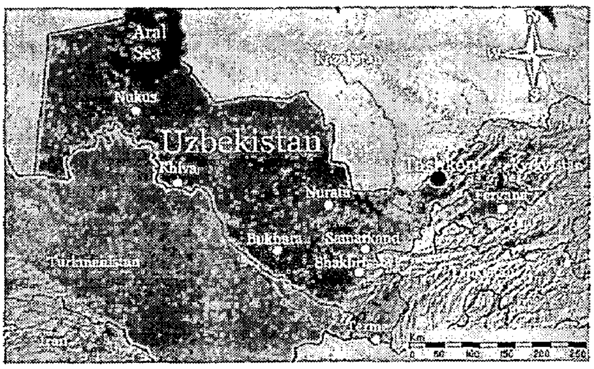


Fig.1.1. Political map of Uzbekistan

Administratively, the country is divided into 12 viloyats (oblasts or 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.

1.2 The Aral Sea

All the Central Asian countries, especially the Republic of Uzbekistan, are important cotton exporters. The area of irrigated land grew by more than 3.0 million hectares 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 percent of annual water resources were consumed, leaving only four cubic kilometers 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.

The near total diversion of the water destined for the Aral Sea has resulted in extreme consequences for the Sea, its tributaries and the surrounding ecosystems. 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 per cent of its volume, and has shrunk to 50 percent of its previous surface area. Its shores have receded dramatically, in some places more than 120 kilometers. Over 33 thousand square kilometers 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 the health of animals and people.

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.

Kazakhstan and Uzbekistan as 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:

- to stabilize the environment of the Aral Sea;
- to rehabilitate the disaster zone around the Sea;
- to improve the management of international waters of the basin;
- to build the capacity of regional institutions to plan and implement these programmes.

1.3 Status of Agricultural Production

In the Republic of Uzbekistan there are 1,389 collective (shirkats) 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.

Prior to independence the monoculture of the crop has led to problems of land degradation, especially from salinization and waterlogging. However, cereal production has increased substantially. During the past three years alone, the area under cereals, especially wheat, has been extended by more than 300 thousand ha, to reach more than one million ha in 2001. Cereal production has reached 3.5 million tonnes as shown above in (Fig.1.2) and the importation of the food grain has been reduced more than six-fold.

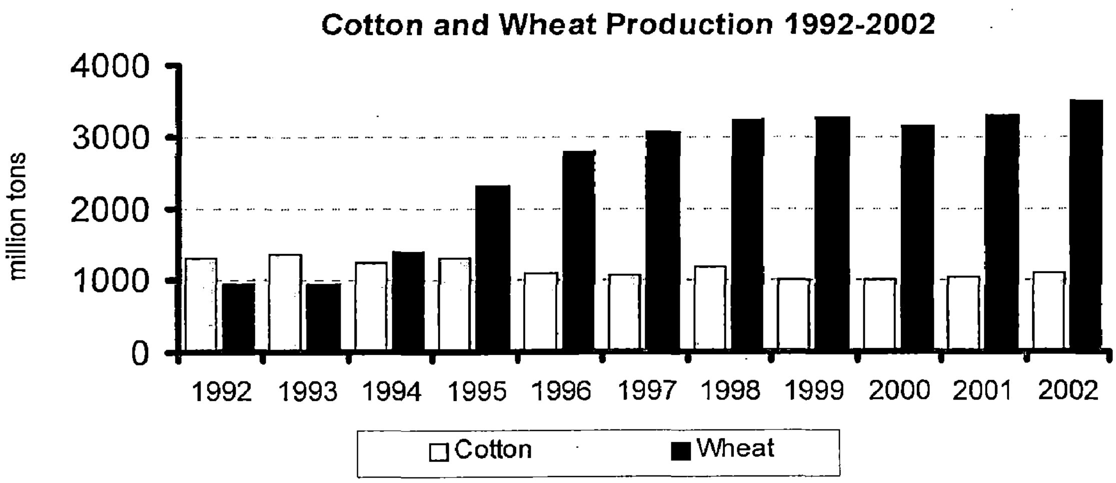


Fig.1.2. Cotton and wheat production, 1992 to 2002

1.4 Water Resources Management and Soils

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 per cent 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.

The problem of soil resources conservation and improvement of aoil 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.

The next priority aspect of conducting reforms is the system of water resources management. In Uzbekistan, there is a trend to reduce amount of water used per unit of area and to introduce an effective strategy of water resources use. The Government is facing a great challenge as transition from a centrally planned irrigation management system with the low water-use efficiency to system, which can provide precise and strong incentives for efficient use of scarce water resources.

1.5 Problem Identification

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 per cent of the population is employed in this sector. In Uzbekistan the irrigated agriculture is the main foodstuff source, which provides up to 96 per cent 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 million ha, of them 1.36 million ha was allocated under grain, including 1.1 million ha for wheat. The total of grain and leguminous crops has made 2.9 million tons 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.

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 soil compacting in the case of heavy machine use. The Soil and Water Management Research Unit conducts basic and fundamental research:

- To improve crop productivity and water use efficiency in irrigated and dry land cropping systems through the development of advanced irrigation technologies and tillage/residue management practices;
- That develops soil and water management practices to sustain the soil resource and enhance water quality. Mission goals are accomplished through a better understanding of soil-plant-water relations and the dynamics governing energy

and water fluxes at the soil-plant-atmosphere interface, particularly in semi-arid environments; and

- Agro-chemicals in dry land and irrigated cropping systems.

At present, the Government supplies water for irrigation farming on charge-free basis. The necessity 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 foe 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 of Study

Populations of the regions with dry areas currently are getting suffer with losses of big amount of water. This situation is bearing them to difficulty of socio – economic statistics. To improve Water Use Efficiency which is going to be the main foundations of Irrigation Water Management in agricultural structure have to been achieved the following objectives:

- To upgrade agricultural production through creating and applying modern methods of effective use of water, which can save water resources not just in country particularly also in whole region.
- To convert rainfed to irrigated agriculture using cropping systems due to appropriate farm-level management of irrigation and drainage, and save our limited available amount of water as efficient as possible.
- To realize the compensation of applying amounts of water resources for all application system losses and lack of efficiency.
- To accept that control of all production input components coupled with good management of the on-farm natural resources is the key to produce more crop per drop.
- To improve water management and cropping system using modern methods of supplemental irrigation scheduling through minimize evaporation and seepage losses.

1.7 Organization of the Thesis

The achievement of study objectives above is combined in seven chapters. Chapter 1 is an introduction, which gives general idea about Uzbekistan, where status of agriculture production is important component of socio-economical statistics of the country. Chapter 2 is Literature Review which deals water and soil resources conservation practices, development of irrigation and drainage systems, water logging and soil salinity development in irrigated agriculture particularly, in arid and semi arid areas. Chapter 3 is a study area, which deals about field experimental practices as particular location, which held tightly for realize appropriate results using modern irrigation systems that have recently been improved. It gives idea about surface irrigation mainly furrow, as well as drip and sprinkler irrigation practices under various steepness of slope of irrigated areas. In Chapter 4 is named as Farm Irrigation and Water Management, described adaptation of modern Irrigation Systems for dry area's condition. Manually management and cropping pattern of using such systems is given in Chapter 5 – Supplemental Irrigation Scheduling.

CHAPTER II

LITERATURE REVIEW

2.1 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:

- ➢ Greater reliance on water charges, local funds and private sector involvement to finance the rehabilitation and modernization of the irrigation infrastructure (both on-farm and inter-farm);
- ➢ Involving farmers in the operation and management of irrigation systems and increasing the incentives for them to improve the cost recovery mechanism;

- Strengthening the legal and institutional basis, in particular for the fee-based use of water; and
- 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 towards:

- Water saving and water conservation; and
- 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.

2.2 Irrigation and Drainage Development

To the beginning of the last century, the total irrigated area in present territory of Uzbekistan has reached 1.2 mill. ha, and by the end of the century has increased up to 4.28 mill. ha 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. 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, the total irrigated area in the Republic was 4.269000 ha and out of this 2893400 ha area were 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. The present work objectives are:

1) 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;

2) 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;
3) To introduce water-saving irrigation and washing technologies ensuring favorable water-salt regimes in irrigated lands and high crop yields.

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.

2.3 Water Resources-Economy Complex

Problems of Irrigated Agriculture in the Aral Sea Basin need to be treated with special attention. High water consumption of irrigated agriculture in the Syr-Darya River Basin is a result of low technical level of irrigation systems, lack of scheduling and regulation of water supply infringement of irrigation technology, low land-reclaiming efficiency of drainage, and increased salinity of irrigation sources. The increase of non-renewable water consumption has led to the situation whereby 2/3 of the irrigated lands is salinized and requires in 1.9/2.0 times more water for irrigation than has been stipulated by the irrigation project. Therefore, during the last few years, despite apparently sufficient water uptake, the water deficit has increased not only for irrigation but also for municipal needs as well.

The problems of irrigated agriculture, water resources-economy complex, and ecological status in lower reaches of the Aral Sea Basin Rivers cannot be solved by improvement of technical level of irrigation systems and technologies alone. Qualitatively, new approaches to carry out a technical policy in water resources economy of the region are required. They must ensure preservation of the Aral Sea boundaries, increase the irrigated lands' productivity, improve the water supply to the settlement and remote rangelands, and restore or at least stabilize the natural environmental complex.

The successful fulfillment of above programs for land reclamation and water resources-economy assumes the following developments:

- Justify the criterion for ecological and economical efficiency of water resources-economy, and develop, on their basis, schemes, under the market economy, for complex use and protection of water resources in both main river basins and small rivers;
- Develop a normative base and legislative proposals for introduction of a water pricing system with account of limited cost of water delivery to the consumers and negative ecological and economical consequences caused by over exploitation and contamination of water resources;
- Determine the effects of ranges of irrigation scheduling and drainage intensity upon parameters of leaching requirements, and salt transport in different types of soil;
- Establish modular plots and resource-saving technologies for irrigation of areas under crop rotation using various methods and to define ranges of irrigation technology elements that stabilize the process of soil fertility maintenance and restoration; and
- Develop mathematical models, algorithms, and software that will ensure the computerization of management and automation of technological processes in water-resources economy systems of the country.

The suggested list scientific research activities water resources-economy complex will reduce, at various stages, the destruction rates of water installations during the formation period of the new economic mechanism under privatization of water resources economy and that of agricultural complex. It will ensure conditions for establishing high technological processes. Thus, the whole scientific research will be directed to development of new technology for resources saving, production of ecologically safe products, improvement of environment of environmental status, and establishment of socio-economic and legal basis for successful functioning of all management entities.

2.4 Management of Water and Land Salinity

In the long term, sustaining agricultural production, preventing further deterioration of ground and surface water quality, and avoiding severe economic losses are impossible without resolving the problem of increasing land and water salinity in the country. The main priority areas for actions regarding water and land desalinization include:

- Development of a coherent and cost-effective strategy to address the salinity problem at the national level;
- Development of the predictive capacity to forecast salt mobilization from the subsoil and river salinity;
- Development of salinity standards for the river basins;
- Improvement of the system of land and water salinity monitoring and control;
- Development and evaluation of the best technical and economic options to address the issues of water and soil salinization;
- Increasing public awareness about salinization issues; and
- Development and implementation of improved drainage systems (currently the ground and vertical drainage is in place only on 30% of the irrigated land).

The salinity problem in the Aral Sea basin needs to be addressed not only at the national but also at the regional level Managing Watersheds. Watershed management plays an important role in implementing the integrated land and water management system and in protection against the continuing degradation of water and land resources such as salinity, land erosion, floods, mudflows, and sedimentation of rivers, reservoirs and irrigation canals. To implement the watershed management principle, the following actions are recommended:

- To develop the watershed management programs, first, in the Fergana, Kashkadaryin, and Surhandaryin oblasts, including an assessment of the present status of the watersheds (soil types, vegetation, level of soil erosion, and land slides), and development of an action plan on integrated land and water management in the watershed areas;

- In the long-term, to develop an appropriate institutional and legal framework that would require the introduction of the principle of integrated watershed management in the legal and regulatory frameworks;
- To institutionalize the implementation of this integrated approach by establishing watershed management agencies and involving local communities in managing watershed areas.

2.5 Future Development

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.

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.

2.6 Land Use

Total area of agricultural land in Uzbekistan is 26.754 mill. ha of which arable land - 3.757 mill. ha, perennial plantings - 0.353 mill. ha, and remaining 22.263 mill. ha are occupied by hayfields and pastures. Land use in 2000 is illustrated in (Fig.2.1

and Fig.2.2). Ratio of land use types in irrigated zone and general structure of used areas is differed in irrigated zone the arable land (77.5%) prevails. In total agriculturally used area the arable land occupies only (13.1%) and (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.

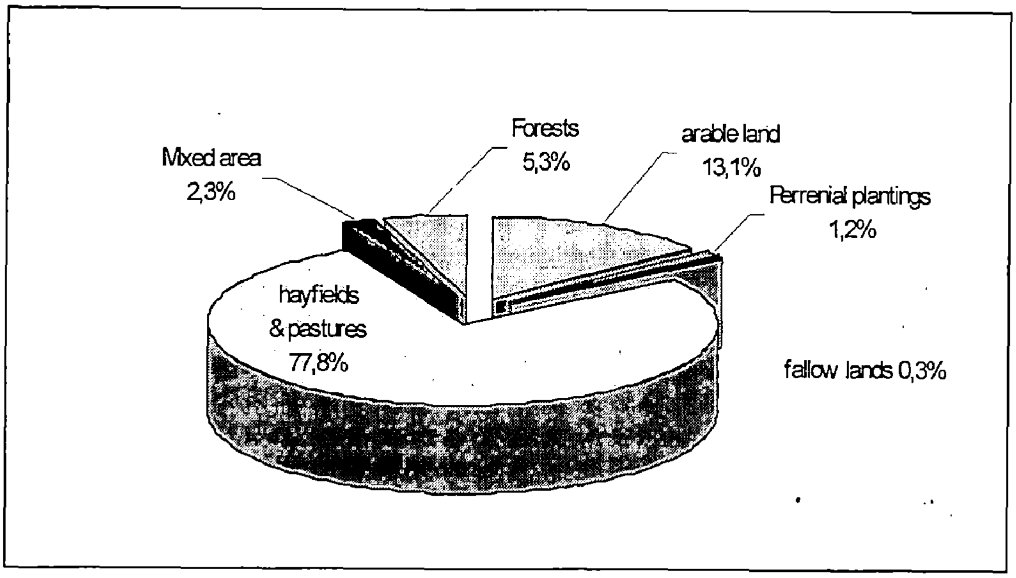


Fig.2.1 Ratio of Areas According to Land Use Type in 2000

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. In Uzbekistan, there are practically 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.

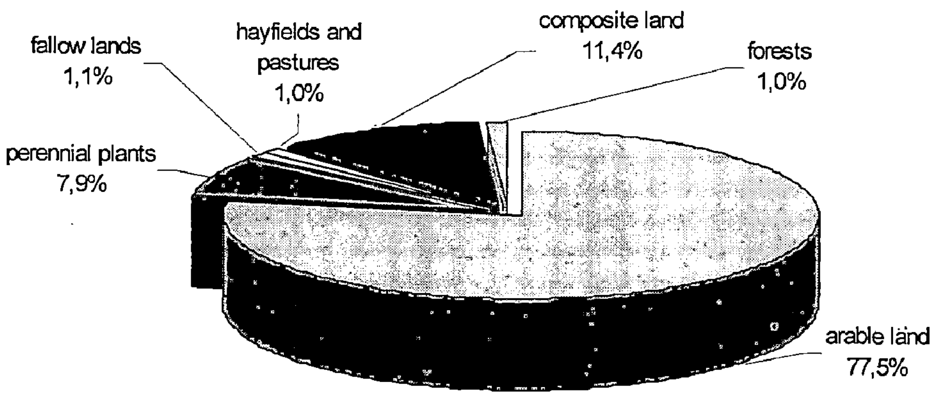


Fig.2.2 Ratio of Irrigated Areas by Land Use Types in 2000

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 given below:

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

2.7 Environmental Impact on Land Use

To date 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.

2.8 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;
- Further support to farm restructuring and development of individual farming;
- 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:

- 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.

2.9 Waterlogging

Intensive rise of ground water level in irrigated area is a consequence of high seepage losses from canals and irrigation fields (low efficiency of irrigating systems and water application) and inadequacy (or absence) 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 hydromorphism. 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 2m, 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. 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 the 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 5-10g/l and 10-15 g/l composes accordingly 17.3% and 10.0 % of total irrigated area. In Djizak region, its various ranch of 1.0-2.2 m and average depth according 1.29 -2.03m. Ground water mineralization is chloridesulphate and sulphate from 2.2 to 17.8 g/l (Soil Institute, 2001). Existing practices of irrigation and leaching does not provide an adequate desalination of irrigated salt affected soils and gypsiferous soils in Hunger and Djizzak steppes.

2.10 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.

Diversity of soil forming rocks, ecological regimes, vegetation, extreme continental climate, and vastness of the territory contribute to great diversity and complexity of soil cover in the republic. 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. Of course, there are also numerous transitional forms of soil formation.

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 is observed. Also, climate and geomorphological 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: Desert-brown-desert soils; Desert-sandy soils; Takyr soils; and Brown-brown soils.

The most extensive major soil grouping on the territory of Uzbekistan is Calcisols. It covers more than 5.30004 million ha, or about 11.85% of the total area. The second most extensive major soil grouping is Solonchaks with about 5211.87 thousand ha, or more than 11.6% of the total area including 3.60% with Calcisol and Arenosols. (Fig.2.3) represents the most extensive soil grouping of Uzbekistan

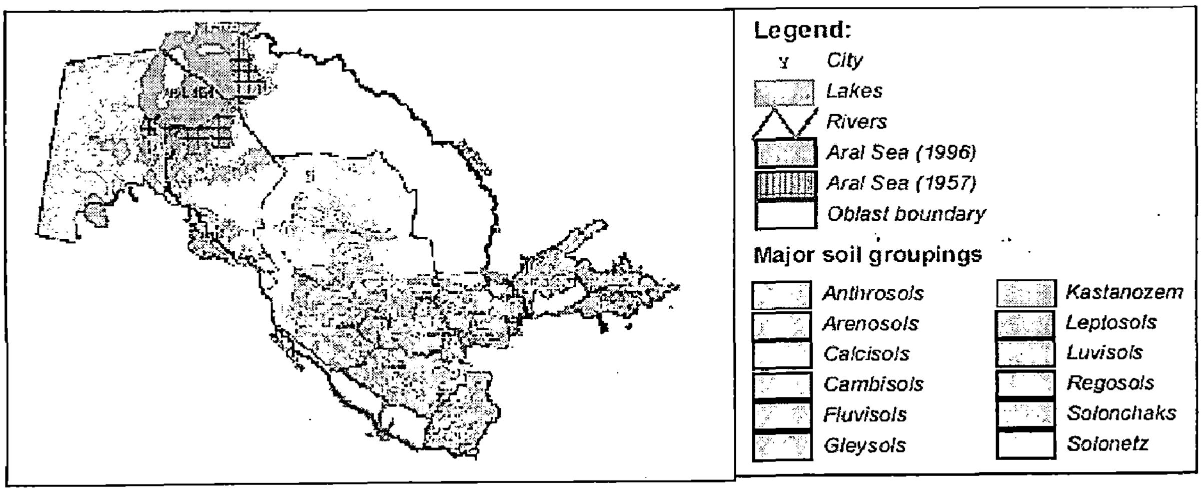


Fig.2.3 Map of the Soils of Uzbekistan

2.11 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.

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

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.

2.12 Soil Erosion

Wind erosion is observed on the area over 2.0 million ha 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 million ha 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 million ha. 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 million tons. These aerosols comprise sulphate, chlorides and even heavy metals.

2.13 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 million hectares. 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.

2.14 Soil Types by Food and Agricultural Organization (FAO)

In 2000, TACIS ISEAM Project 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 5.300 mill. ha or up to 11.85% of the total area. The second greatest soil group is Solonchaks 5.212 mill. ha (or 11.6%) including 3.6% of Calcisol and Arenosols. Cambisol covers more than 5.068 mill. ha (11.33%). About 12% of the territory (5.366 mill. ha) is occupied by Solonetz of Ustyurt, etc. Arenosols and Regosols cover 2.064 mill. ha and 2.271 mill. ha respectively. Four main groups of soil (Fluvisol, Gleysols, Kastanozem and Anthrosols cover jointly 2.475 mill. ha or about 5.53% of the area. More than 34.5% (14.529 mill. ha) of the area is occupied by sand.

2.15 Water Use and Water Use Efficiency

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

$$WUE = \frac{Crop\,\mathrm{Pr}\,oduction}{WaterUsedForThe\,\mathrm{Pr}\,oduction} \quad \ldots\ldots \text{ (“Crop per Drop”)}$$

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 (WUE) 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.

2.16 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.

2.16.1 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. The more humid the atmosphere, the greater the WUE is, all other things being equal. Dryland 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.

2.16.2 Soil

Soil is the basic resource in agriculture. Sustainability of agricultural production depends heavily on its proper management. 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. 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.

2.16.3 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. 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. 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.

2.16.4 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. Among essential management factors and/or decisions that have a direct impact on farm productivity and income are related to the proper selection of:

- Crop varieties most adapted to the local environment;
- Sowing date and seeding rate;
- Crop rotation (with or without livestock) and tillage;
- Type, amount and timing of fertilizer application;
- Weed control (timing and techniques);
- Pest and disease control; and
- Crop harvesting (timing and technique)

2.17 Water Harvesting and Supplemental Irrigation (SI) for Improved 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.

The concept of water harvesting is not new. It has been practiced for thousand of tears to utilize ephemeral streams in natural wadis and support the livelihood of people in the arid and semi-arid regions. Rainwater harvesting techniques for agriculture were extensively practiced in past throughout much of North America, Latin America, Middle East, North Africa, China and India.

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. The goals of water harvesting are:

- Supplying drinking water for man and animals, and water for other domestic purposes;
- Making land productive (grazing, marginal and arable);
- Increasing yield in drought-prone areas;
- Minimizing desertification of tree cultivation; and
- 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. 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.

Supplemental Irrigation may be 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. The concept of (SI) in rain fed areas having limited water resources has three bases as are given below:

i. Water applied to rain fed crops which normally produce without irrigation;
ii. Since, rainfall is the principal source of moisture for rain fed crops, SI are applied only when rainfall is inadequate; and

iii. 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. 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.

2.18 Development of Crop Management

The main agricultural crops are cotton and grain, mainly wheat. In 1999, all area under crops on the irrigated area has made 3.565 mill. ha, including cotton (1.517 mill. ha or 42.6%) and grain (1.359 mill. ha or 38.1%), of these 1.1 mill. ha of wheat and 0.164 mill. ha of rice. Potato, vegetables, and melon fields have occupied 0.227 mill. ha and fodder crops 0.414 mill. ha. Small grains are sown on rain fed arable land. However, yearly productivity changes greatly. Economically favorable is small grains cultivation on rainfed area once in 3 to 5 years depending on region and climatic conditions.

Monoculture of cotton and a surplus of irrigation after applying excessively high rates of mineral fertilizers have gradually decreased organic matter in the soil. In one word, a process of dehumification has started. The areas under perennial legumes for crop rotations have been reduced to a minimum. The result of long term experiments indicate that under monoculture production without applying fertilizers the organic matter content decreases by 40%, while with systematic application of mineral fertilizers the losses of organic matter are rather smaller. In crop rotation treatments, the restoration of organic matter content in the soil under alfalfa up to its initial index has been observed within a few years. However, under cotton, the organic matter has been decreased. Consequently, the crop rotation practices do not ensure the organic matter reproduction organic matter on a larger scale.

In connection with this, alongside with introducing the crop rotation practices, it is necessary to apply organic fertilizers, such as manure, plant residues, industrial and municipal wastes containing organic substances. Today, in the irrigated zone of the country, these 8-10 tons of manure applied for each hectare are not nearly sufficient to provide a positive balance of organic matter in the soil. To maintain such balance, it is necessary to apply not less than 15 tons per hectare of organic fertilizers. Followings are should be developed:

- Schemes of crop rotation with decreased cotton share to 40:60, 50:50 that should contribute to progressive reproduction of soil organic matter;
- Sustainable system of joint application of both organic and mineral fertilizers according to soil conditions;
- Enhanced methods of forecasting the soil fertility and conditions of plant nutrition; and
- System of soil irrigation and tillage that contributes to increasing the organic matter content in soil.

2.19 Assessing and Improving Farm-level Irrigation to Ensure the Sustainability of Irrigated Cropping Systems

Under this component, in Uzbekistan agriculture management practices to improve salt-water balance in soils prone to salinization are being conducted for sustainable resource use and increased crop productivity. In Uzbekistan, the research sites are situated in the drainage-impacted areas of Golodnaya Steppe, respectively, where mainly cotton production has been practiced over a long period. Soil salinization caused by poor technical status of drainage network and application of inappropriate irrigation technologies has led to low water use efficiency and significant yield losses. Therefore, the research priorities have been assigned to developing and testing advanced irrigation technologies that would improve irrigation water use efficiency and eventually also the soil reclamation.

Research results in Uzbekistan demonstrated that sub-irrigation could be another option to increase available water for crops. At the experimental site in Ferghana valley, closing horizontal drainage outlets increased groundwater share for irrigation thus contributing to better crop yield. It was demonstrated by winter wheat yield reducing at longer distances to a closed drainage outlet.

2.20 Irrigated and Rainfed Agriculture

In Uzbekistan, the rainfed area covers more than 747 thousand ha with rainfall exceeding 200 mm per year, yielding between 0.8 and 2.0 tonnes of grain per hectare. However, in view of their extent, these areas play an important role in grain production (Fig.2.4).

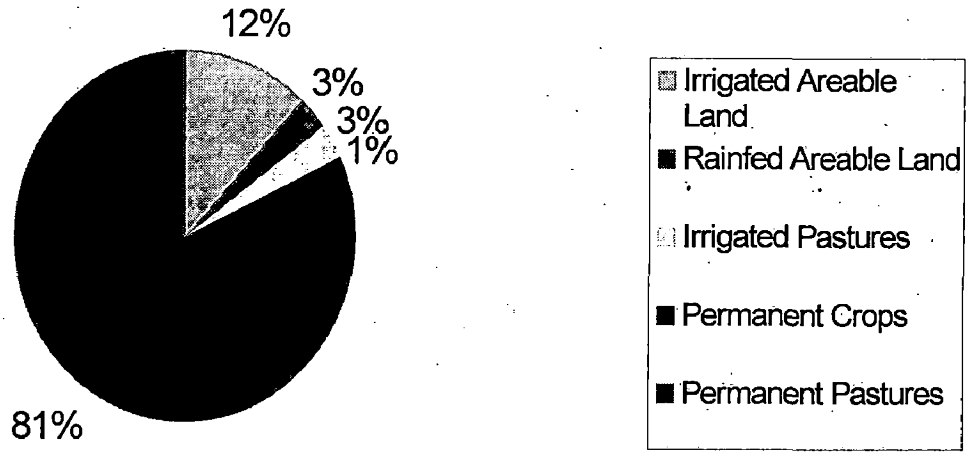


Fig.2.4 Agricultural area

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 biodiversities 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 III

STUDY AREA AND DATA ACQUISITION

3.1 Introduction

As reliable study area of the lands of Uzbekistan is taken not very large farm Boykozon, where since 1998 ICARDA established and integrated research site in the Tashkent Province of northeastern part of country (Fig.3.1). Relief and climatic zone of that area is very suitable for applying many kinds of crops. The site represents the typical agro-ecologies and mixed farming systems of the steeply sloping hill country of Central Asia. It was selected as a suitable place at which to conduct the integrated research needed to address the common problems of low agricultural productivity and degradation of the natural resource base.

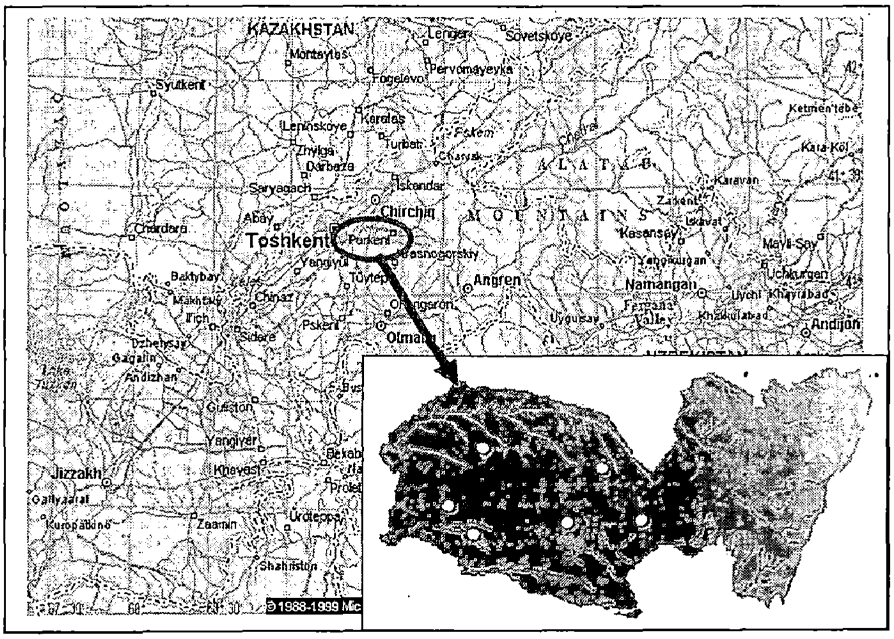


Fig.3.1 Map of Boykozon farm in the Tashkent Province of North-Eastern Uzbekistan

The area of Boykozon farm in is 8,000 ha, including 6,000 ha of rangelands, wheat, vegetables, fodder crops, fruit trees and grapes. There are 1,300 people working on the farm. High slopes of land causing soil erosion and other serious problems in soil and water management are the major constraint to sustainable agriculture development in the farm. The climate of Boykozon shows the extremes of weather, typical of continental locations. In winter, temperatures frequently fall below freezing, while in summer they approved nearly (40^0C) forty degrees centigrade.

The main emphasis is given to water and irrigation management through testing and improving 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 prevail at the site, as throughout much of Uzbekistan's irrigated area:

- 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 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...–8) degree Celsius, and even lower. The average temperature in January in the extreme south, near the town of Termez is (+2.8...0) degree Celsius. The absolute registered minimal temperature in winter is (–35...–38) 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...+30) degree Celsius in the south. The absolute summer maximum exceeds 42 degree Celsius. The maximum temperature was registered in 1914 in Termez when the heat reached 49.6 degree Celsius. The temperature can reach 70 degree Celsius during summer month in the regions of the republic.

3.3 Precipitation

Mean annual amount of precipitation in a flat part ranges from 100-150 mm (desert) to 200-400 mm (foothills). The greatest amount of precipitation drops out in winter and spring months (60-70%). Autumn precipitation is much less and absolutely insignificant precipitation is observed in summer months. The droughty period in desert lasts 6-7 months (May until November), in foothills; it is reduced to 4-5 months. As approaching foothills, the amount of precipitation increases up to 800-900 mm and more. 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.

3.4 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 thirty years to only about one-third of its 1960 volume and less than half its 1960 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 below present enormous environmental challenges throughout Uzbekistan:

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

3.5 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, the length of which is 1,437 kilometers, and the Syr-Darya of 2,137 kilometers are the largest Rivers. Both of them originate beyond the borders of Uzbekistan. There are very few lakes in the territory of the country. The largest of them, the Aral Sea, is one on brink of extinction. The most numerous are the small mountain lakes with areas of 1 square kilometer. 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 reservs of ground water, which are extencively used for water supply and irrigation. The republic is reach with its sources of mineral waters. Thnks 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 (Table 3.1)

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. 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.

Table 3.1 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

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 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 km^3 by two rivers yearly

3.6 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:

i. National water resources include flow of the local rivers, underground and return water formed within one country; and

ii. 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 are given in (Table 3.2) 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 3.2 Available Water Resources (mill. m^3/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 per cent from total quantity of water consumption and 457 m^3 per 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.

3.7 Ground Water Resources

Total reserves of underground waters over Uzbekistan are 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 water intake from surface water and return flow (47.8 km^3) and underground water (6.4 km^3). 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 (104 million m^3) and fishery (368 million m^3) has made 6.8 km^3.

3.8 Land Resources

The available land of the country is 44.4 million ha of which about 11.8 million ha are potentially suitable for irrigation, including 4.3 million ha of existing irrigation area. The other 32.6 million ha is desert, pastures, mountains, sandy soils and etc. (Table 3.3) represents the Land Resources of Uzbekistan. By 1990, area of the irrigated lands has increased by 1.6 times, as much as the agriculture production has increased. The long-term cultivation of a monoculture crop (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 per cent. Lands with low and very low concentration of humus occupy about 40 per cent of all irrigated lands. More than 57 per cent 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 per cent falls to the soil of high-altitude zones.

Table 3.3 Land Resources of Uzbekistan (million ha)

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: Uzgi, 1992; Uzdaverloiykha, 2000

3.9 Modern Irrigation Technology for Improvement of Water Use Efficiency, Soil Erosion and Yield

After tests of Joyak (Zigzag) irrigation using various types of furrows, it is found that the most efficient and optimal productivity were observed on zigzag furrows having 2.8-3.0 width (Fig.3.2). The width of furrows depends upon on the degree of relief. However, the experimental result shows to minimize the difficulty of regulation of water flows and overall work width of the furrow should not be less than 2.0 m. For strongly intersected slopes, zigzag with 2.0 m and similarly 2.5-3.0 m to nearly parallel or parallel horizontal slopes. Spacing between the furrows 0.7-1.4 m across the slope, increases irrigation efficiency along the zigzag from 0.78 up to 0.87 against the control (traditional) of 0.7-0.75. The economy of irrigation water makes 400-878 m^3/ha for the whole cropping season. Infiltration of water increases as in 2.0m of furrows, permeability will be 0.0011-0.0039 m/hr, in 2.5 m of furrows permeability will be 0.0018-0.0045 m/hr, in 3.0 m of furrows permeability will be 0.0028-0.0048 m/hr on durum wheat (Fig.3.3).

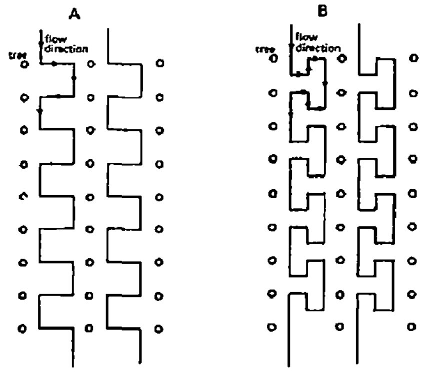


Fig.3.2 Schematic view of Zigzag furrows

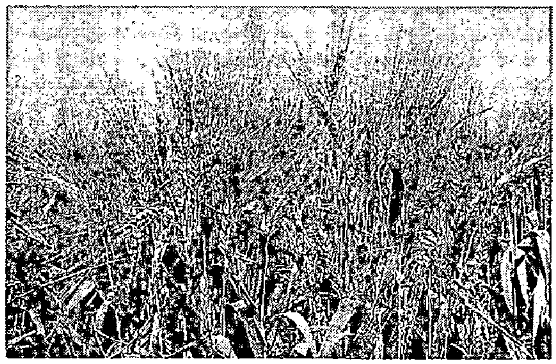


Fig.3.3 Durum wheat Irrigated by Zigzag irrigation

Soil erosion will also decrease from 0-0.52 ton/ha in a year compared with the control of 3.48 ton/ha 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 as compared to control. The water productivity increased from 211.3 -253.2 m3/ha (control) to 103.3-184.3 m3/ha. Inter-irrigation periods are shorter than that of control irrigation requiring over 4-5 days. Labor productivity varies from 0.83 ha/day (control) to 1.78-2.86 ha/day. Atmospheric precipitations effectively used in zigzag irrigation. All specific parameters of winter wheat irrigation are given in (Table 3.4).

As a whole, research of Joyak (Zigzag) irrigation of winter wheat showed high water-saving efficiency as well protection of soil from erosion. However, zigzag irrigation technology has its own limitations. During the period of harvesting, intersected furrows are made to be leveled so as avoid difficulty for the movement of tractor "combiner". And hence, it is necessary to develop mechanisms for cutting zigzag furrows.

Table 3.4 Results of research of improvement of irrigation technology of winter wheat in 2001-2002 years down

Parameters			Irrigation down the slope	Zigzag irrigation			
				2.0 m	2.5 m	2.8 m	3.0 m
No of irrigation			3	3	3	3	3
Irrigation timing and norm, (m^3/ha)	6.09	Gross	1200	1400	1185	1155	1100
		Net	850	1100	950	940	910
	19.09	Gross	1350	1170	1155	1050	1140
		Net	900	900	920	850	940
	26.04	Gross	850	700	800	850	650
		Net	750	550	640	690	530
Total		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			80-80-70	80-80-70	80-80-70	80-80-70	80-80-70
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

3.10 Experiments on Portable Polyethylene Chutes (PPCH-50) with Adjustable Apertures for Irrigation of an Early and Late 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 the (Fig.3.4), we can see the water productivity under spring and summer sown potatoes using the PPCh-50 and traditional irrigation practice

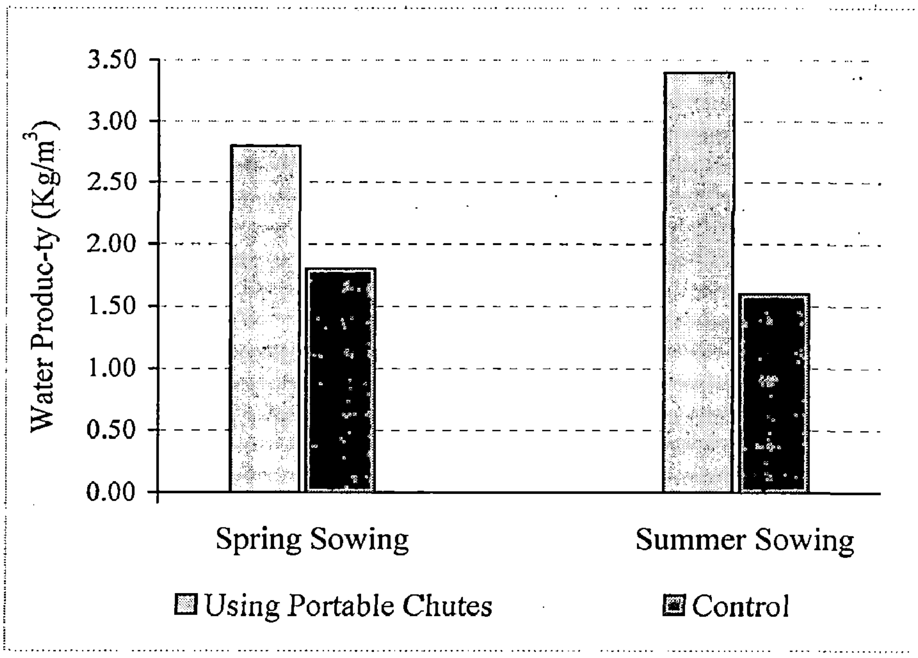


Fig.3.4 Water productivity under growing of summer sown Potatoes

After testing of PPCh-50 on various steepness of slope, their particular characteristics and parameters has been received in comparison with traditional irrigation, is given below (Table 3.5). For the application of PPCh-50, technical and operational parameters are necessary for its guidance.

In case if 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. Water-distributor is installed at intake point so that, water will flow into the first set of PPCh-50 and, the rest flows into the second set of PPCh-50 through polyethylene hoses. During research, at the Boykazon farm of Parkent district of Tashkent region, the key parameters, sizes, and operational parameters of PPCh-50 have been received. They are given in (Table 3.6).

Table 3.5 Results of research of improvement of irrigation technology of an early potato with the help of PPCh-50 in 2001

Parameters			Irrigation down the slope	PPCh-50
No of irrigation			10	10
Irrigation timing (days) and Irrigation norms (m^3/ha)	26.04	Gross	1076	839
		Net	710	733
	12.05	Gross	1148	1052
		Net	780	757
	25.05	Gross	1004	952
		Net	710	783
	1.06	Gross	2089	1043
		Net	757	783
	8.06	Gross	2071	1093
		Net	710	783
	16.06	Gross	2050	1084
		Net	705	783
	25.06	Gross	2085	924
		Net	710	828
	10.07	Gross	1648	924
		Net	686	783
	20.07	Gross	1941	950
		Net	828	783
	26.07	Gross	1220	1069
		Net	912	912
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	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 3.6 Main and 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)	15x50
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

Locally manufactured portable polyethylene chutes were installed at the heads of the field furrows that replaces inefficient ditches normally used to supply water (Fig.3.5 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.

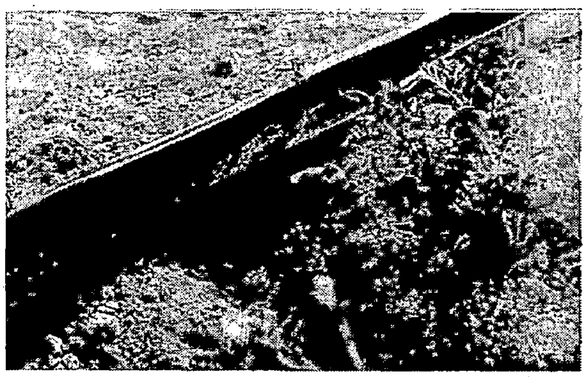


Fig 3.5 Potato irrigated by PPCh-50

Fig 3.6 Wheat irrigated by PPCh-50

3.11 Development of Self-pressurized Drip Irrigation System for Young Vineyards and Vegetables on Abrupt Biases

When there is an increasing in deficiency of water resources, drip irrigation system is necessary for cultivation of vineyards and vegetables in a foothill zone. The detaining facts of wide application of drip irrigation are their high expenses for the electric power and a long time of recovery of outlay of the capital expenses enclosed in system. 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 to vineyards on sloppy areas. Effective utilizing of bias areas within Uzbekistan is expected to be 214240 ha. For cultivation of vineyards and intermediate crops, and new design of drip irrigation system has been developed at SANIIRI, due to the pressure creates by sloppy land. The system is called as self-pressurized drip irrigation system.

A drip irrigation system was installed to provide irrigation water to vegetables such as tomatoes, peppers, melons, and cucumbers grown between the vine rows. (Fig.3.7, Fig.3.8). 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
Young vine irrigated by Drip Irrigation

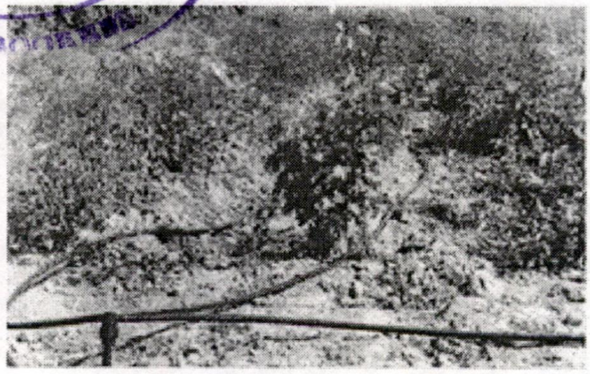


Fig.3.8
Combined vineyards with vegetables

In 2001, advanced drip irrigation technology tested at Boykozon site was found efficient for production of young vineyards, vegetables and melons grown in the inter-row spacing. Using this technology, farmers can be benefited from reduced irrigation rate (from 660 to 220 m3/ha) and secured profit from vegetables and melon during the first three unproductive years of vineyard establishment. Supervision of regime of irrigation and productivity of intermediate crops are given in (Table 3.7)

Table 3.7 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 conomy, %	Production, (quintal/ha)
							Drip irrigation	Traditional 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
Pepper	75	10	10	9	1.9	107	1070	5700	81.3	200
Water-melons	70	9	7	10	2.9	58	522	4300	87.9	675

Source: SANIIRI, 2001

Whole research experiments have shown economy of irrigation water by drip irrigation. For young vineyards, a water economy of 69.3% has been achieved. Whereas, for vegetables, it ranges from 81 to 83 per cent and an economy of water of 87.9% for watermelons. As a conclusion of the experiment, numbers of research indications have been drawn:

1. The new designed self-pressurized drip irrigation system, which has been constructed and installed on experimental field, is in normal condition and functions well during the irrigation period. It provides 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 with in a short period. A profit in the first year after land development plus 3-4 years vineyards start fructification, all expenses for construction of drip irrigation system can be recovered.
3. Economy of irrigation water for young vineyards has made 69%, for vegetables and inter-row crops from 81% to 87% in comparison with traditional 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.

3.12 Caring out Field Experience on Use of Marginal Waters 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 BC-1 is shown in (Fig.3.9). Irrigation-waste water in collector BC-1 from the point of view of its use for irrigation is more fertile than in irrigation canal (Table 3.8).

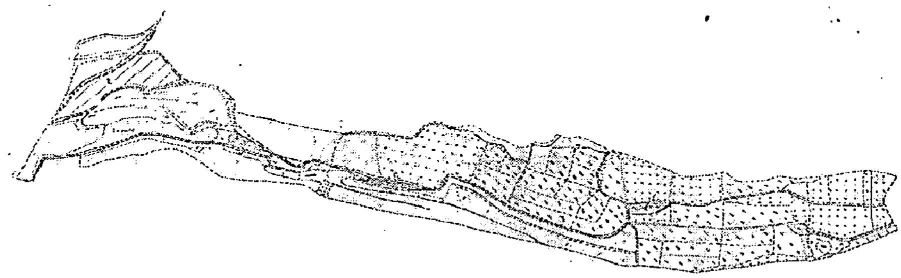


Fig.3.9 Scheme of fields on use of marginal waters

Table 3.8 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	29.06	0,025	0,15	2,04	120	0.85
irrigation	16.08	2,65	0	2,8	111	0,01
water	6.09	0,01	0	0,84	68	0
The end of	29.06	0,05	0,72	2,04	197	1759
Spillway BC-1	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

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.3.10)
2. Apple garden in inter-rows with Lucerne 0.6 ha (Fig.3.11)

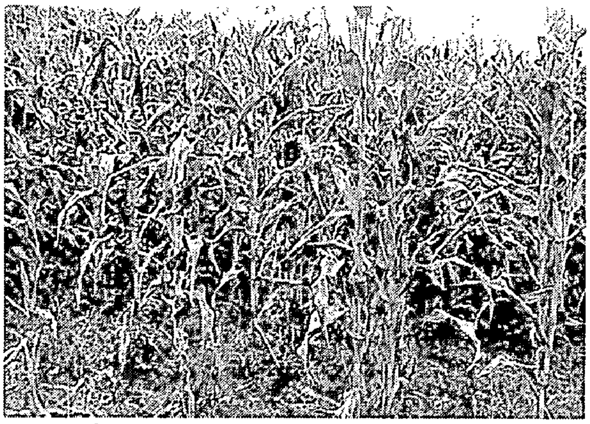


Fig.3.10 Maize irrigated with wastewater

Fig.3.11 Apple garden irrigated with wastewater

Within the theme of ICARDA, it has developed a new convenient technology for lifting and delivering wastewaters from the collector BC-1 to those farmers along the collector (Fig.3.12 and 3.13)

Fig.3.12 Waste water intake point

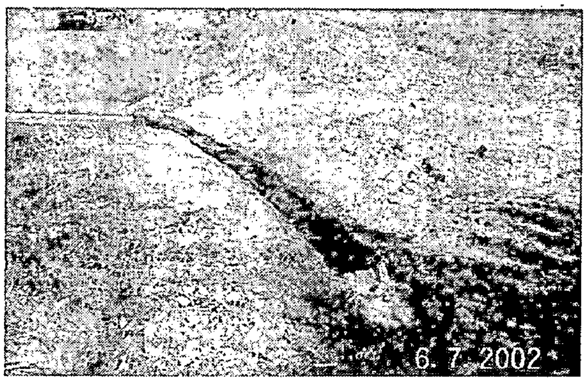


Fig.3.13 Waste water outlet

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.

Reuse of wastewaters on the irrigated areas with the raised biases has shown that it effectively increases soil fertility, allows irrigating inconvenient and earlier non-irrigable areas with smaller expenses of work. It also enables to receive more production as well to reduce water removal from irrigated territory.

3.13 Experiment of Goffered Hoses for Irrigation of Corn for a Silo

Researches were carried out in July-September, 2000. The Goffered hoses are used on very abrupt biases up to 0.02. The corn for silo has the same tendencies, as a winter wheat. On a bias of 0.08-0.14, the coefficient of irrigation efficiency increases from 0.79 at the primary discharge in usual conditions of irrigation up 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 70 m as usual irrigation.

Experiments of using Goffered hoses have shown their efficiency on irrigation of winter wheat and corn for silo (Fig.3.14). 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 (contról irrigation) of 0.78 (ha/day/person). Results of research of improvement of Goffred irrigation technology are given in (Table 3.9).

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.

Fig.3.14 Corn for a Silo Irrigated using the Goffered Hoses

Table 3.9 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
Irrigation timing and norms, (m3/ha)	5.07	Gross	1086	890
		Net	968	780
	16.08	Gross	1582	855
		Net	1113	750
	28.08	Gross	1580	860
		Net	1189	740
	6.09	Gross	1381	740
		Net	1290	735
	19.09	Gross	1480	840
		Net	1095	730
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	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

3.14 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 (Fig.3.15). Obvious 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. The increase in yield appeared to be equal to 14 t/ha. In 2001, the yield of beet on an experimental variant irrigation has made 97.8 t/ha compared with traditional irrigation 87.5 t/ha. The increase in yield was received at a rate of 9.8 t/ha.

Fig.3.15 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 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 is proved to have high efficiency and particularly for crops such as stock beet.

In 2002, this irrigation technology was tested on a cotton field (Fig.3.16) and maize (Fig.3.17) and at the Central Experimental Base of Institute of Cotton where salt concentration is high (new zone of Hungry steppe in Dzhizak province). Supervision over growth and development of irrigation practice in 2002 show that on all skilled sites, irrigation by shielded furrows, outstripping growth of plants was observed. 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 are obtained.

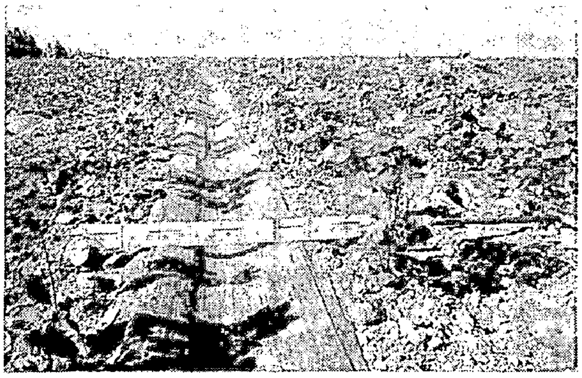


Fig.3.16 Cotton irrigated with Shielded polyethylene films

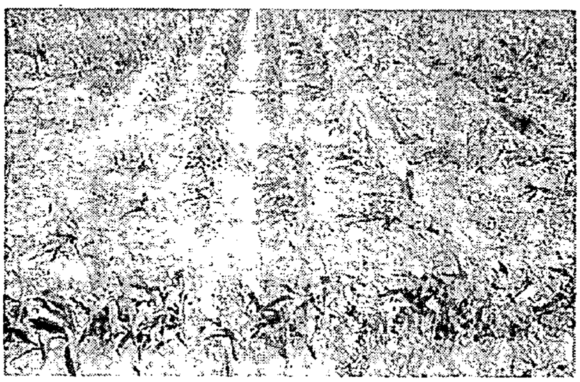


Fig.3.17 Maize irrigated with Shielded polyethylene films

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 what color and what thickness of films are most suitable for different crops. It is important to improve technology of water distribution and design of polyethylene films as well.

CHAPTER IV

FARM IRRIGATION AND WATER MANAGEMENT

4.1 Crop, Water and Irrigation Requirements: Main Concepts

The concept of crop water requirements is still diverse according to the discipline that approaches the question. However, an agreement on this concept is of essential importance since it is in the basis of irrigation planning, irrigation scheduling and water delivery scheduling, as well as water resources planning and management using farm irrigation water components (Fig.4.1) A well accepted concept was introduced by Doorenbos and Pruitt (FAO Irrig. & rain. Paper 24, 1977) who defined **Crop Water Requirements (CWR)** as the depth of water [mm] needed to meet the water loss through **Evapotranspiration (ETc)** from a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility, and achieving full production potential under the given growing environment.

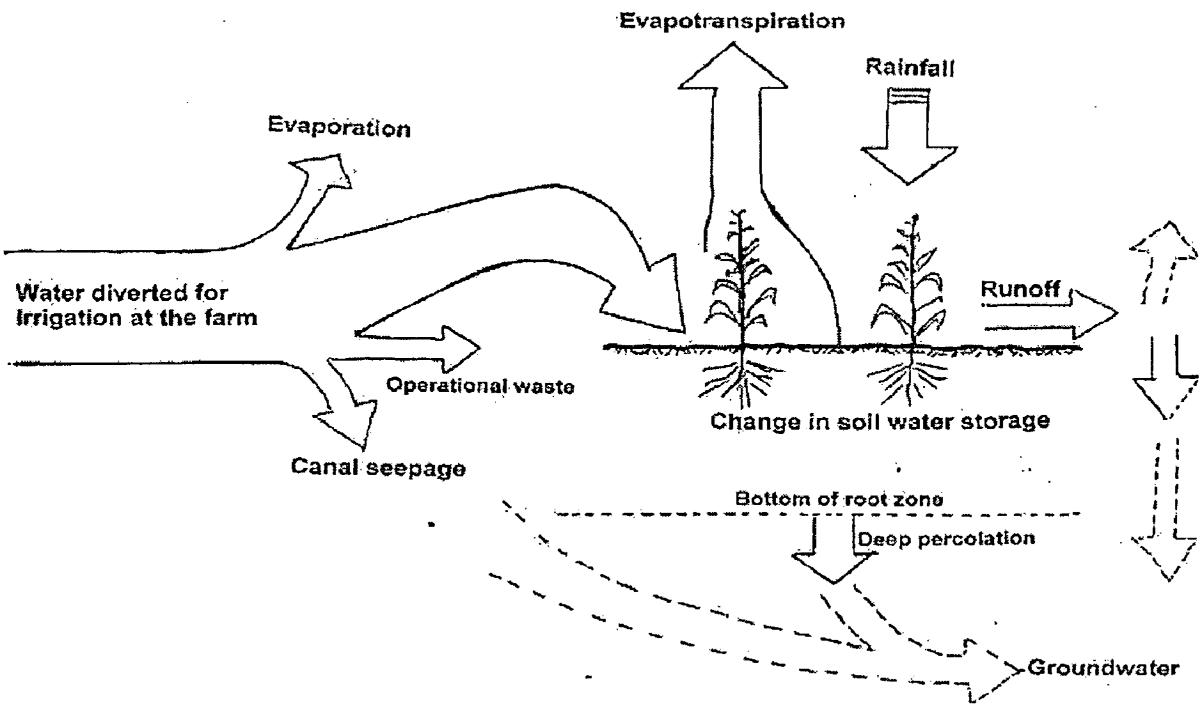


Fig.4.1 Typical Schematic Representation of Farm Irrigation Water Components

This concept accommodates all processes impacting the water use by a crop but excludes the influences of local advection, water stress, poor soil and fertility management or inappropriate farming conditions. Thus, a complementary concept is used when actual crop and field conditions are considered. This is the **Consumptive Crop Water Use (CWU)** defined as the depth of water [mm] utilized by a crop through evapotranspiration and cultivated under given farming conditions in a given growing environment. Therefore, when optimal cropping conditions are met **CWU = CWR**. Both **CWR** and **CWU** concepts apply to irrigated and rainfed crops. However, the first corresponds to potential yield production while the second relates to the real crop condition.

For irrigated crops, another main concept concerns the **Net Irrigation Water Requirement (NIWR)** defined as the net depth of water [mm] which is required to be applied to a crop to fully satisfy its specific crop water requirement. The **NIWR** is the fraction of **CWR** not satisfied by rainfall, soil water storage and groundwater contribution. When it is necessary to add a leaching fraction to assure appropriate leaching of salts in the soil profile, this depth of water is also included in **NIWR**.

When irrigated crops are grown under sub optimal conditions, particularly deficit irrigation, i.e. not achieving the full production potential, the net depth of water to be applied is then termed **Deficit Irrigation Water Requirement (DIWR),** which corresponds to the adoption of a given allowable deficit in the water supply to the crop.

Depending on the irrigation supply conditions, irrigation method, equipment utilized, irrigation scheduling adopted and ability of the irrigator, the amounts of water to be applied have to compensate for all application system losses and lack of efficiency. These include losses by evaporation, deep percolation (below crop root zone), and water runoff out of the farmer's field. Therefore, the **Gross Irrigation Water Requirement (GIWR)** corresponds to the gross depth of water (mm) to be applied (at the field's inlet) to a crop to fully satisfy its crop water requirements. **Diversion Irrigation Water Requirement (DIWR)** takes into account losses due to seepage or leakage in the conveyance and distribution systems, and management spills of excess water in canal systems. Thus,

GIWR = NIWR / E_a where **E_a** is the irrigation water application efficiency

DIWR = GIWR / E_c where **E_c** is the irrigation system conveyance efficiency

4.2 Farm Irrigation System Management and Yield

- Irrigation is the science and art of artificially supplying the plant root zone with the water necessary to create and maintain an environment favorable for crop growth and targeted production. Salt balance, microclimate modification, fertigation, pesticide application, etc… are all related to irrigation.
- Irrigation Comes At Cost!

  To convert from rainfed to irrigated agriculture, we are faced with the difficult and risky question:

  Would it pay to develop water supply source; select, buy, install, operate, and maintain irrigation facilities? All these are costly and risky business.

Concerns are distribution, application, and control of irrigation water on farm. It is the last stage in irrigation activities. Until recently engineers (civil or water resources) assume that they are not responsible for farm irrigation. Meanwhile agriculturists look at it as complicated (hydraulics, geometry, complicated equations, e. t.). However, during the last two decades, things have changed positively … though little late. Now, irrigation engineers, agriculturist, socio-economist and farmers are working altogether on how to use water more efficiently in agriculture.

Production of food is a highly water-consuming activity. In developing countries, agriculture accounts for 70-90% of available freshwater supplies. Huge volumes of water are transformed into vapour during the food production process. With prevailing land and water management practices, a balanced diet requires 1,200,000 litres of water per person per year (3300 litres per day) - 66 times more than the 50 litres per day used for an average household's domestic needs (see www.siwi.org).

Our goal is to resource our limited available amount of water as efficient as possible. The challenge is how to achieve/realize this goal?

Let us look and think about the following slogans and themes:

- Water - More crop per drop
- Water - More Nutrition per Drop

4.3 Impact of Uniformity, Adequacy and Efficiency on Total Crop Production of Field

After rainfed or supplemental irrigation depths of applying water are different in different spots of watering area. Such unbalanced water distribution generates a need of creating table of water depth of every chosen spots (Table 4.1) from where easy to draw a diagram, which can show minimum and maximum depths of irrigation.

Table 4.1 Water depth in every spots

Spot	Depth	% Area receiving equal to or greater than indicated
1	50	100
2	57	90
3	62	80
4	75	70
5	80	60
6	86	50
7	90	40
8	97	30
9	103	20
10	110	10
Σ	810	

To calculate average depth of saturated water in the root zone we need to draw figure depending upon percent area and depth in different spots of water distribution (Fig.4.2).

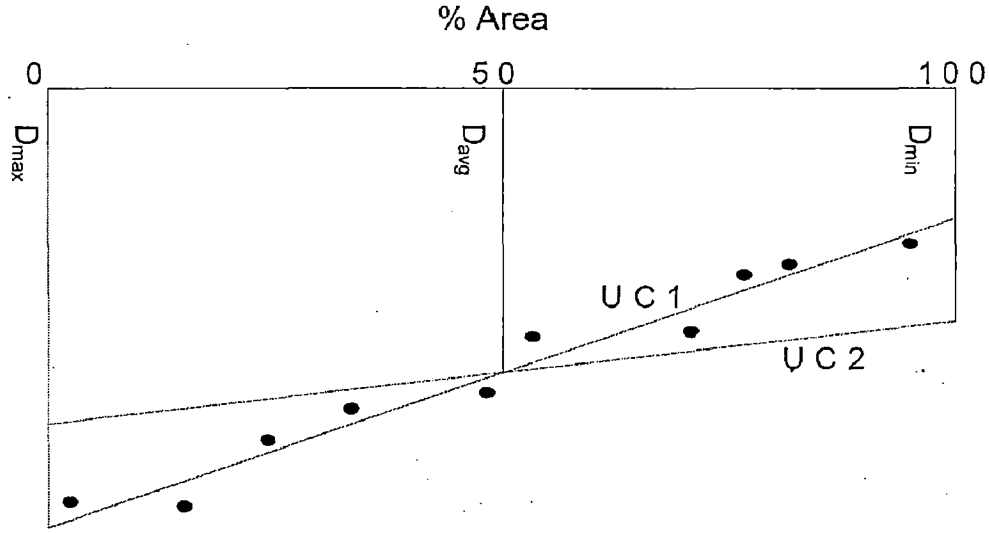


Fig.4.2 Depth in different spots

Value of yield is a main concept of crop water production. By that value many kind of crops differentiate by own specific varieties, where each crop can have particular maximum yield (Fig.4.3).

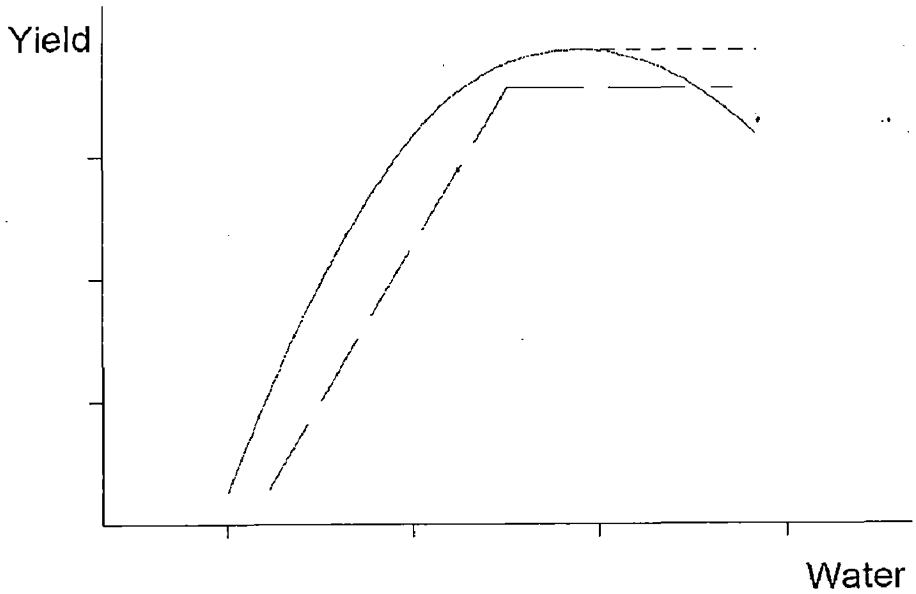


Fig.4.3 Possible Shape of Yield Production Function

By using following formulas we can find average depth in whole area of field, uniformity and coefficients are required to find out yield production:

$$D_{avg} = \frac{810}{10} = 81mm$$

$$UC = \left(1 - \frac{\Sigma X}{nm}\right) * 100\%$$

$$UC = (1 - 0.25b) * 100\% \quad \text{(linear)} \qquad UC = (1 - 0.8cv) * 100\% \quad \text{(normal)}$$

$$CV - \frac{SD}{m}; \quad m = D_{avg}$$

m or D_{avg} – average depth of water measured at all spots

X – ABS [Depth at any spot, m]

n – number of spots

$b = [\, D_{max} - D_{min}] \,/\, D_{avg}$

For linear distribution of irrigation water depths:

$SD = (D_{max} - D_{min}) \,/\, \sqrt{12}$

From the Fig.4.4 **Irrigation Efficiency** (at field application) = Area (abcef) / Area (abcd) = (Infiltrated water stored in RZD) / (Average depth of infiltrated water which is equal to average depth applied if there is no surface runoff running out of field).

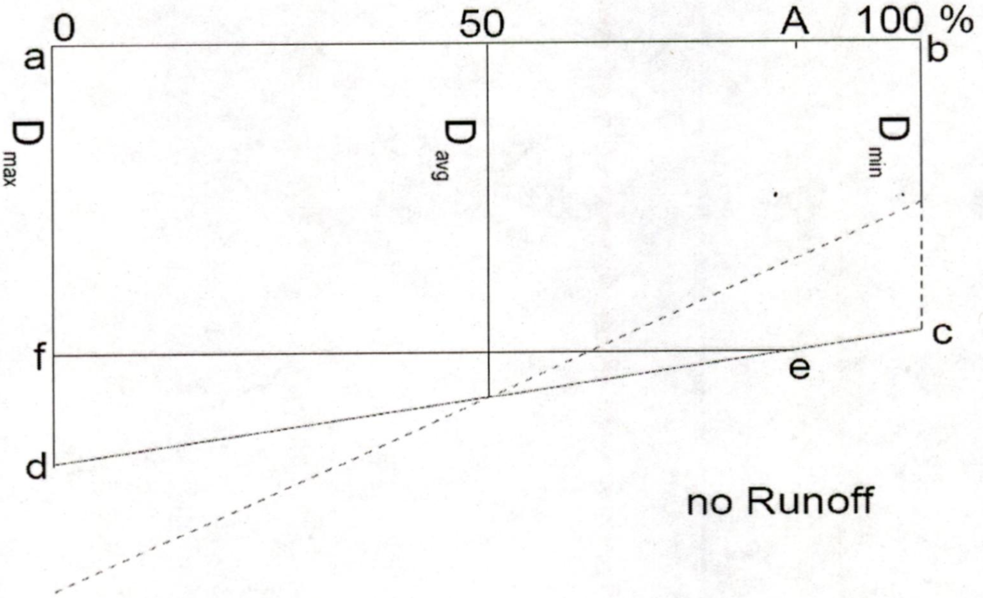


Fig.4.4 Spatial Water Distribution without Runoff

Note that (1-U) represents non-uniformity of irrigation.

In the above Figure, the vertical distance af represents the desired net depth of irrigation. Any spot in the field receiving less than af is considered in deficit (under-irrigated), whereas any spot receiving more than af is considered in surplus of water (over-irrigated). The point "e" in the above Figure exactly the desired net depth of irrigation. Therefore, the distance "fe" or "A in percentage" represents the Adequacy of irrigation (A). Thus, "A" represents the % area of the field that received the net depth of irrigation or more: i.e. % area adequately irrigated.

Uniformity (UC), Adequacy (A), and Water application efficiency at field level (Ea) are the key indices for evaluating the performance of Farm Irrigation Systems.

If the distribution of irrigation water depth applied versus accumulated area (form Fig.4.3) is linear, the following useful relation among these crucial indices holds:

$$E_a = 1 - 2\,(1 - UC)\,A^2$$

Example:

In an irrigation application by a sprinkler system, the UC was 75% and the % area of that was adequately irrigated 80%. Calculate or estimate the field water application efficiency for this irrigation.

Answer:

By direct application of the above equation, we get:

$E_a = 1 - 2\,(1 - 0.75)\,(0.8)2 = 0.68 = 68\%$

If the uniformity of water distribution by the sprinkler system were better, say 85%, then the water application efficiency will increase to:

$E_a = 1 - 2\,(1 - 0.85)\,(0.8)2 = 0.81 = 81\%$

So, improving water distribution uniformity by 10% has increased water application efficiency by 13%!

If the relation between crop yield and water is linear: Y= a + b W then uniformity has no effect on the crop production! How could this be? We can easily justify this, as below:

$$Y = totalyield = \sum_{i-1}^{n}(a + bW_i)$$

$$= \sum_{i-1}^{n} a + \sum_{i-1}^{n} bW_1 = na + \overline{y} = n(a + b\overline{W})$$

$$\frac{Y}{n} = y = a + b\overline{W}$$

$\overline{y}$ = average yield per unit

Thus, Y depends only on the average depth applied ($\overline{W}$)

If $\quad Y = a + bW + cW^2$ (Parabola)

$$\overline{Y} = a + b\overline{W} + c\overline{W}^2 + c\sigma^2$$

σ = average yield per unit area

Recall:

$Y = -6430 + 38W - 0.028W^2$ (yield of Bread Wheat in 1998, Boykozon (Fig.4.5)

W – Total Seasonal Irrigation (mm)

(Note: Drip irrigation system is used to irrigate wheat in the experiment. So Uniformity is very high and the experiment under control. No runoff, very little deep percolation…).

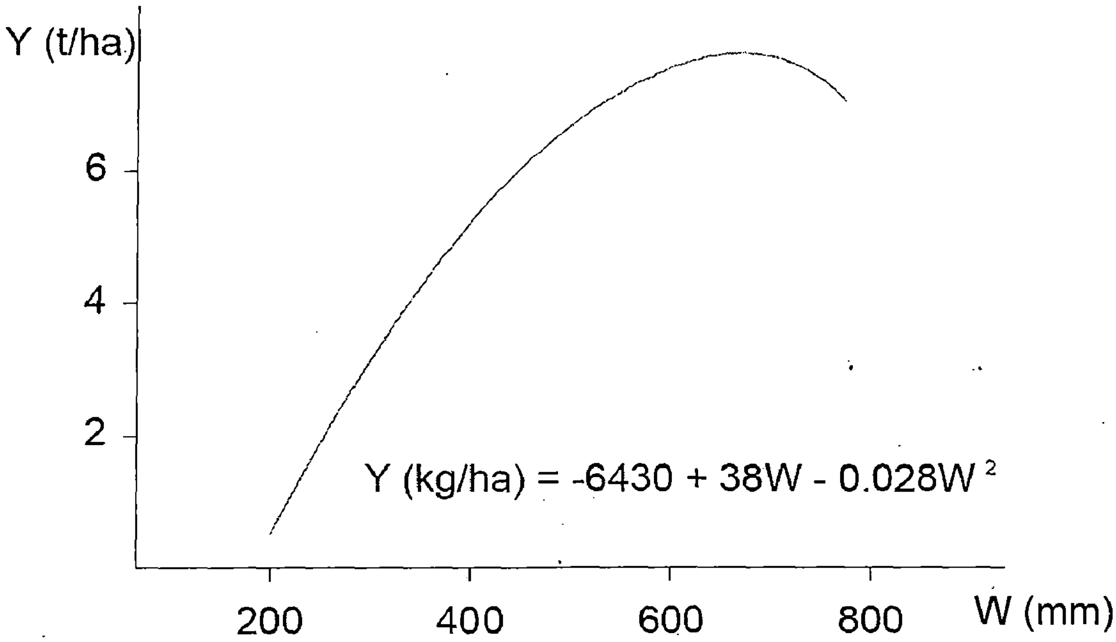


Fig.4.5 Yield of Bread Wheat, Boykozon, 1998

Y – Production of yield (t/ha);

W – Depth of water (mm)

Consider the following case where the same amount of water ($\overline{D}$ = 600 mm) has been applied under two different levels of uniformity (75 and 87.5 %). We would like to see the effect of uniformity of irrigation on the total farm yield.

For UC = 75%, which is found in example area of farm Boyqozon (Fig.4.6)

$$\sigma^2 = \frac{1}{12}(D_{max} - D_{min})^2$$

$$= \frac{1}{12}(900 - 300)^2$$

$$= (600)^2 / 12 = 50 \times 600$$

$$y = a + b\overline{w} + c\overline{w} + c\sigma^2$$

$$= -6430 + 38\ (600) - 0.028\ (600)^2 - 0.028 \times 50 \times 600$$

$$= 6290 - 210 = 6080 \text{ kg/ha}$$

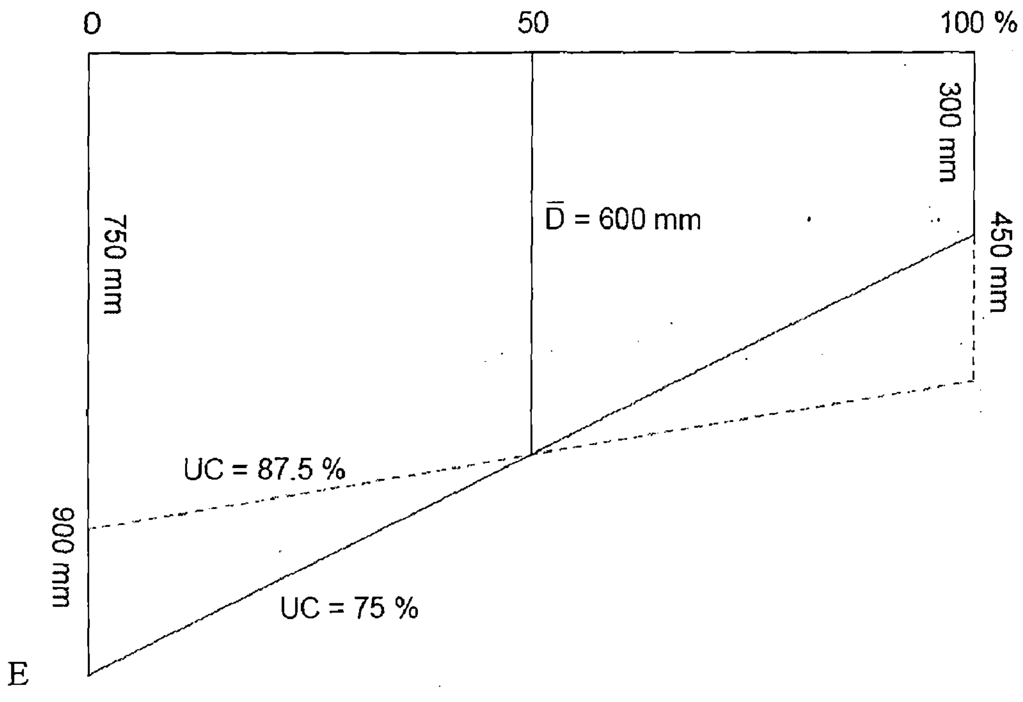


Fig.4.6 Spatial Water Distribution (Result of Example)

Note: the impact of uniformity is only reflected in the fourth term of the two equations!

- How can we improve irrigation uniformity (say from example from 75% to 87.5%)?
- Would this improvement come at cost?
- Where is the role of irrigation system management in this venture?

If Y – water (W) relation is quadratic (Parabola) then the optimal depth of water that gives maximum total farm crop production under non-uniform distribution of irrigation water (Fig.4.7).

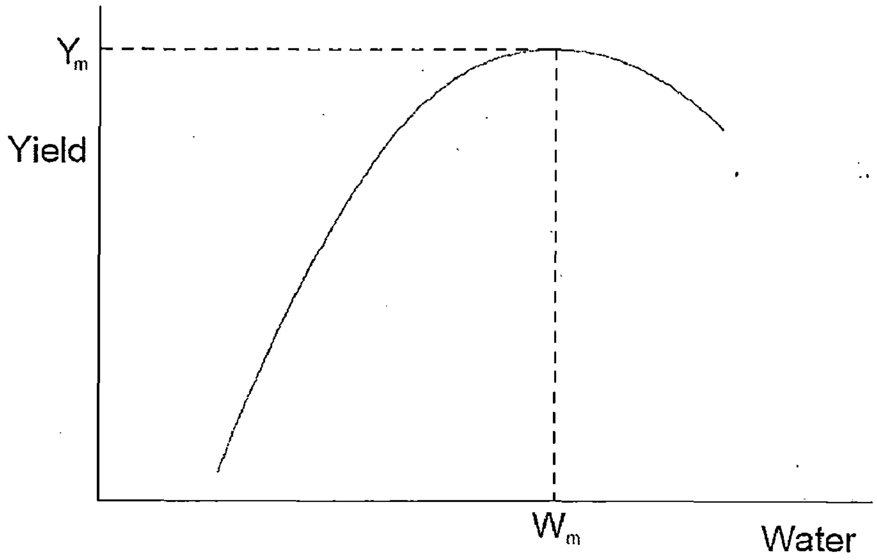


Fig.4.7 Yield – Water Relation under Non-uniform Distribution

$$\overline{W}^* = \left(\frac{1}{1+v^2}\right) w_m$$

v – Coefficient of variation of water depth in the field $= \frac{SD}{\overline{D}}$

Composite Crop Water Production Function (Fig.4.8) requires special mathematical treatment different than given here, which means that under non-uniform conditions of water distribution (which is usually the case in the field) the optimal average depth of irrigation should be less than W_m indicated in the Fig.4.7 to the right.

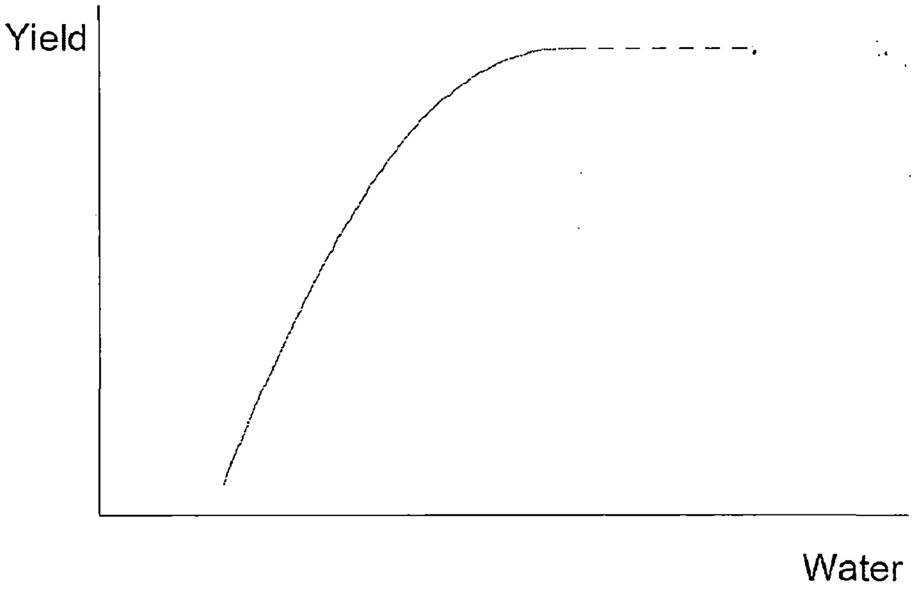


Fig.4.8 Composition of Crop Water Production Function

4.4 Non-uniformity in Surface Irrigation

Socio-Economical statistics give advantage to use Surface Irrigation under water availability condition. There are causes for non-uniformity are coming from (Fig.4.9):

1. Topography.
2. Soil non-uniformity.
3. Unequal infiltration opportunity time along the irrigation run.

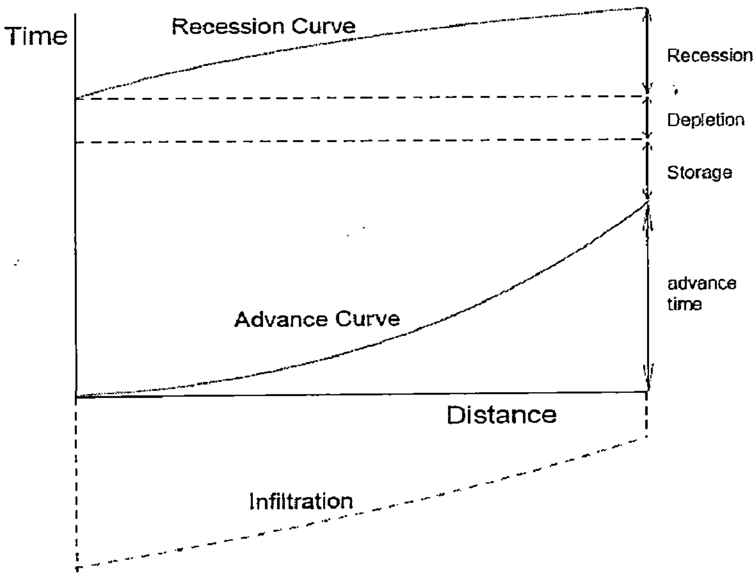


Fig.4.9 Non-uniformity in Surface Irrigation

Solutions:

1. Land grading: the most important factor for efficient surface irrigation.
2. Proper Q inflow (inflow rate (Fig.4.10).
3. Cut back irrigation and Re-use systems.
4. Optimal or proper length of run (furrow, border, basin ...) [affects, however, the following aspects to be taken into consideration: number of head ditches, labor requirements, deep percolation losses, agricultural mechanization, etc ...].
5. Surge / pulse irrigation.
6. Irrigation slope elimination for a certain length (around 10 m) at the up-stream and downstream ends of the run.

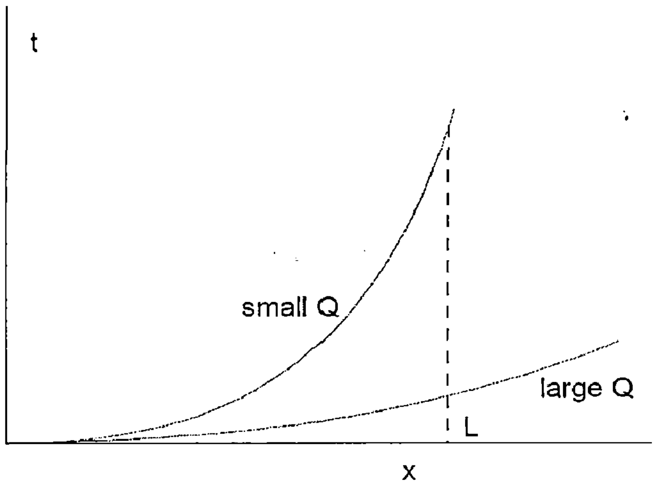
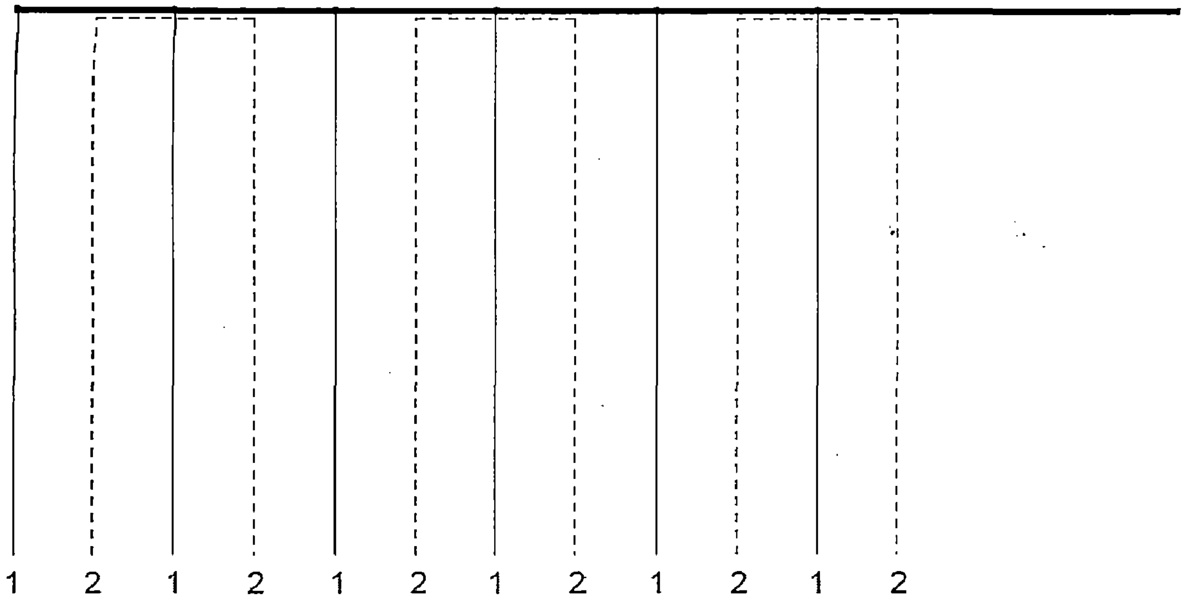


Fig.4.10 Inflow Distribution in Surface Irrigation under Non-uniformity

4.5 Non-uniformity in Sprinkler Irrigation

Causes for non-uniformity upon position in Sprinkler Irrigation (Fig.4.11):

1. Wind effects.
2. Improper pressure distribution.
3. Riser pipe height and stand.
4. Inadequate maintenance of sprinkler heads and Joints.
5. Improper pipelines alignment (for portable systems).



Remarks: (1) refers to the position of the portable sprinkler lateral line for the first, third, fifth etc. irrigation, (2) refers to the position of the portable sprinkler lateral line for the second, fourth, sixth, etc. irrigation.

Fig.4.11 Position of Portable Sprinkler Lateral Lines in Sprinkler Irrigation

Potential Improvement of sprinklers using through:

1. Avoid system operation during high wind speed periods.
2. Use square grid spacing (if possible) to completely eliminate the effect of wind direction on uniformity.
3. Continuous checks for sprinkler nozzles clogging, wear, and pipe Joints.
4. Use alternate setting of sprinkler lateral for portable systems as shown in the figure below. The improvement in UC may be estimated by the following relation:

$$UC_{alt} = 10\sqrt{UC}$$

If $UC - 80\%$ (without alternate setting)

$UC_{alt} \approx 90\%$ (with alternate setting)

4.6 Water Content Measurement

4.6.1 Gravimetric (Direct) Method

Dry soil sample in the Oven at 105°C until constant weight is attained (usually 24 hrs).

$$\omega_w = \omega_m = \frac{\text{Mass of Wet Soil - Mass of Dry Soil}}{\text{Mass of Dry Soil}} = \frac{\text{Wet Mass}}{\text{Dry Mass}} - 1$$

$$\omega_v = \omega_m * A_s$$

Use Cylindrical Core Sampler to get undisturbed Soil Sample:

$$A_s = \frac{\text{Mass of Dry Soil}}{\text{Volume of Core}} + \rho_{water}$$

- Water Content varies with Depth and Time

- A_s may vary with Depth

4.6.2 Neutron Probe Moisture Meter

A source of high energy or fast neutrons is lowered to the desired depth into a previous installed access tube. The fast neutrons gradually lose energy by collision with Hydrogen in the Soil. A detector that senses the number of neutrons reflected back. The count rate of the detector ratemeter is almost linearly related to soil water content (Fig.4.12):

- Surface layer (min 15cm)
- Layers
- Calibration (sol type, bulk, density, …)

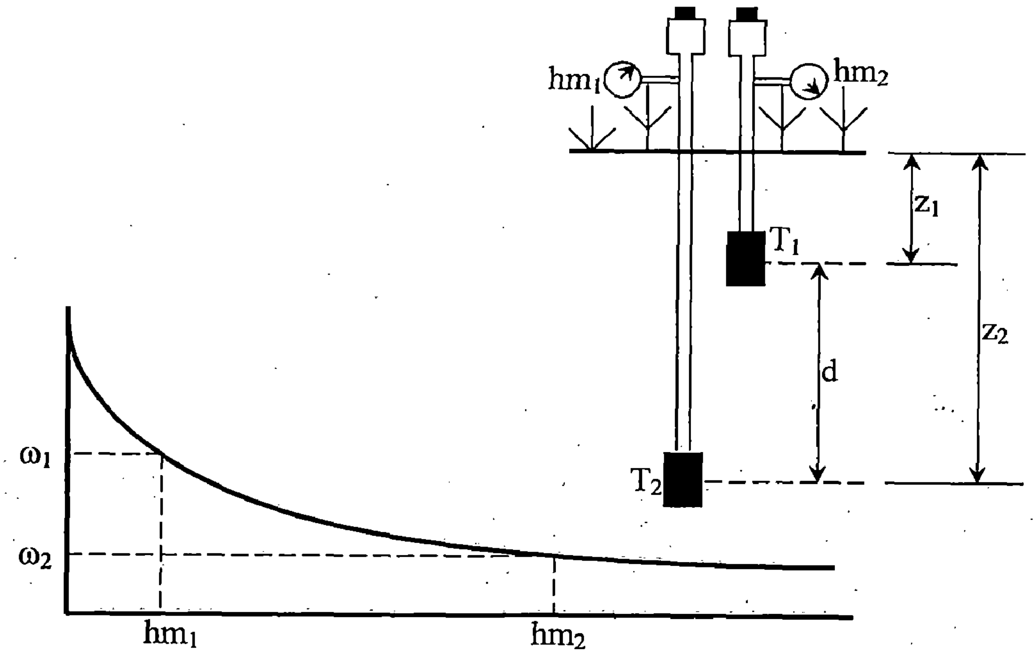


Fig.4.12 Measurement with Neutron Probe Moisture Meter

Available water = FC – WP (Fig.4.13)

Example: FC = 38% (by Volume)

WP = 18% (by Volume)

AW = 38-18=20% = 0.20 unit volume of water per one unit volume of soil

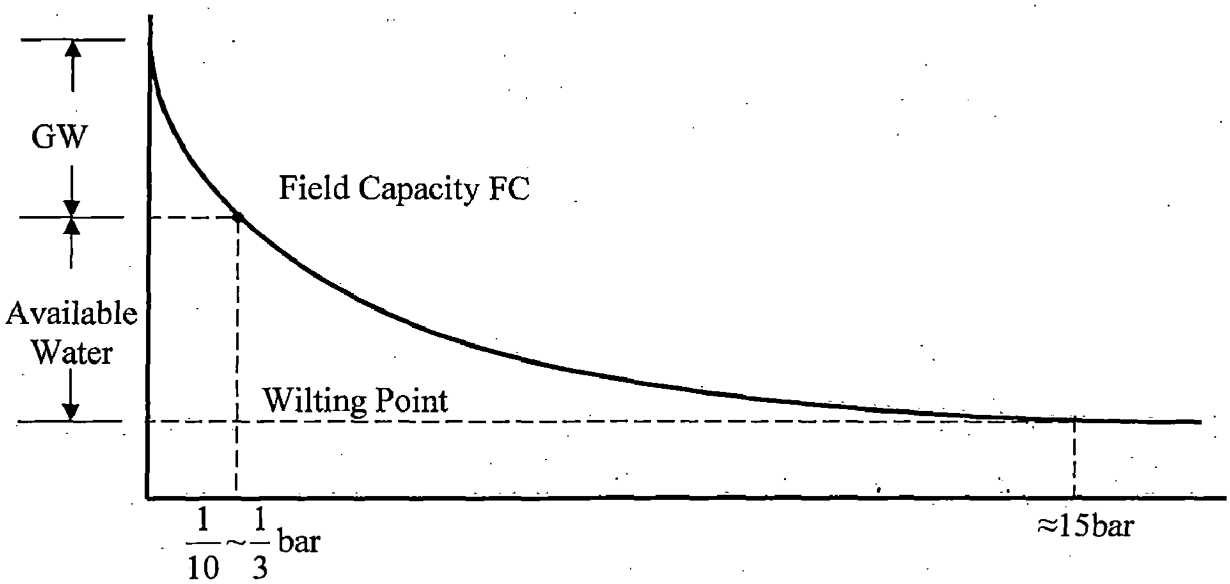


Fig.4.13 Available Water

Depth of $AW = \frac{AW * D * A}{A} = AW * D$

AW = 0.2m H_2O / 1m soil = 20cm / 1m = 2mm / 1cm

4.7 Infiltration Equations

In measurement of infiltration of specific field soil main role plays Rate of Infiltration, which is depends upon Depth of Infiltration and saturation timing (Fig.4.14):

$$I = \frac{dD}{dt}$$

$$D = c\,t^{m}$$

$$D = c\,t^{m} + P\,t$$

$$D = A\,t^{0.50} + B\,t$$

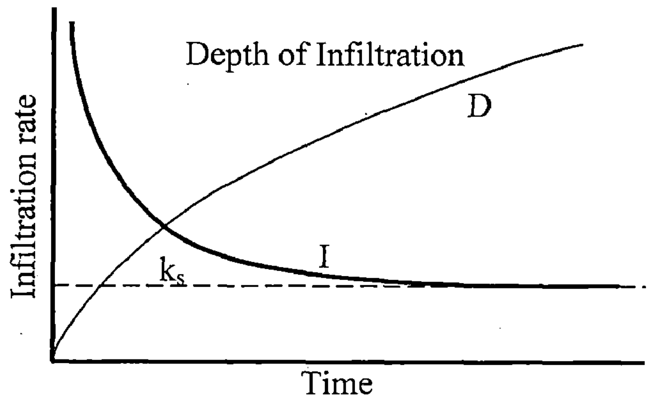


Fig.4.14 Diagram of Depth of Infiltration

Infiltration under rain conditions (Fig.4.15): I = Rain Rate, R(t)

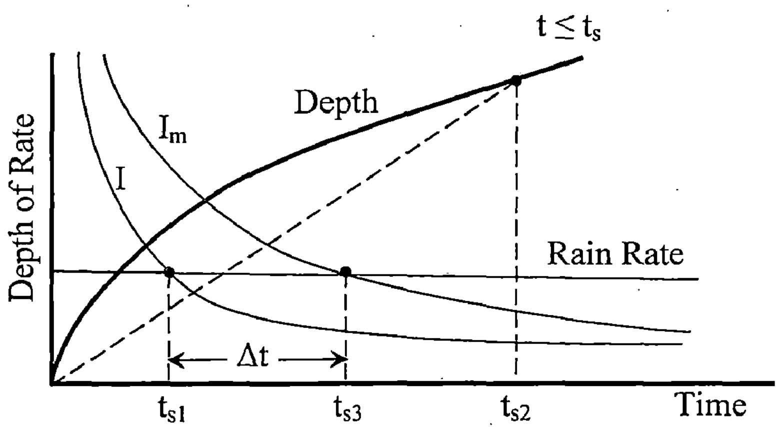


Fig.4.15 Diagram of Depth of Infiltration under rain conditions

$D = ct^{m}$

$I = cmt^{m-1} = kt^{n} = R$

- $t_{s1} = \left(\frac{R}{k}\right)^{1/n}$

$D = ct^{m} = R \cdot t$

- $t_{s2} = \left(\frac{R}{c}\right)^{1/n}$

$I_{m} = I\frac{ct^{m}}{Rt}$

$I_{m} = kt^{n}\frac{ct^{m}}{R*t} = R$

- $t_{s3} = \left(\frac{R}{\sqrt{kc}}\right)^{1/n}$

$I @ t > t_{s}$

$I = k(t - \Delta t)^{n}$

4.8 Water Productivity in Farmers' Fields of Tashkent Province

In 1999 experiment of farmers in Boykozon gives that diagram of water productivity is totally parabola under irrigated and rainfed conditions (Fig.4.16).

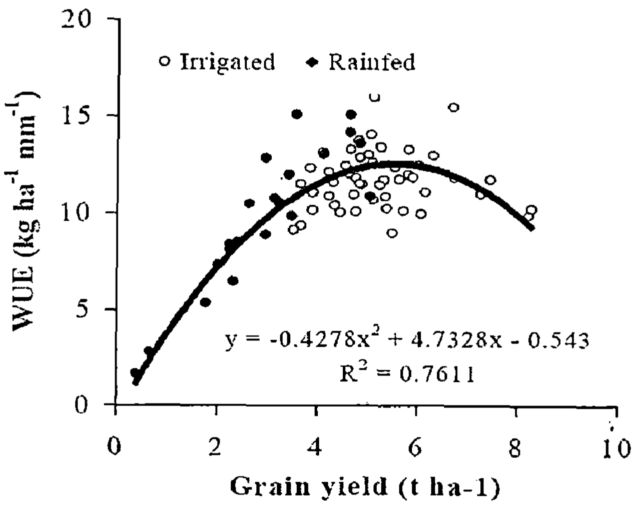


Fig.4.16 Relationship between water use efficiency and crop grain yield for durum wheat under supplemental irrigation in Boykozon, 1999

In Boykozon farm has been shown that applying only 50% of full SI requirements for wheat causes a yield reduction of only (10-15)%. Farmers tend to over irrigate their wheat fields, however, when there is no enough water to provide full irrigation to the whole farm, the farmer has two options: to irrigate part of the farm with full irrigation leaving the other part rainfed or to apply deficit SI to the whole farm. In areas where water is more limiting than land applying deficit irrigation increased the benefit by over 50% compared with that of the farmer's usual practice of overirrigation (Table 4.2).

Table 4.2 Wheat grain production scenarios for a Boykozon farm with various strategies of Supplemental Irrigation

Irrigation management strategy	Rainfed (342 mm)	Farmer's Practice	Applying full SI water	Applying 50% of full SI
SI water depth applied (mm)		298	222	111
Grain yield (t/ha)	1.8	4.18	4.46	4.15
Water productivity (kg/m^3)	0.53	0.70	1.06	1.85
Farm production (ton), water is not limiting	7.2	16.7	17.8	16.6
Farm production (ton) if only 50% of full irrigation requirements available	7.2	10.8	12.5	16.6
Per hectare average production (ton)	1.8	2.7	3.12	4.15
% increase compared to rainfed		50	73	131
% increase compared to farmer's practice			16	54
% increase compared to full SI				33

4.9 Improving Water Productivity and Use Efficiency

Water Productivity and Use efficiency directly depend upon particular crop. If consider that water management is big game, so plant, field, farm, project and basin are players of one whole natural system (Fig.4.17)

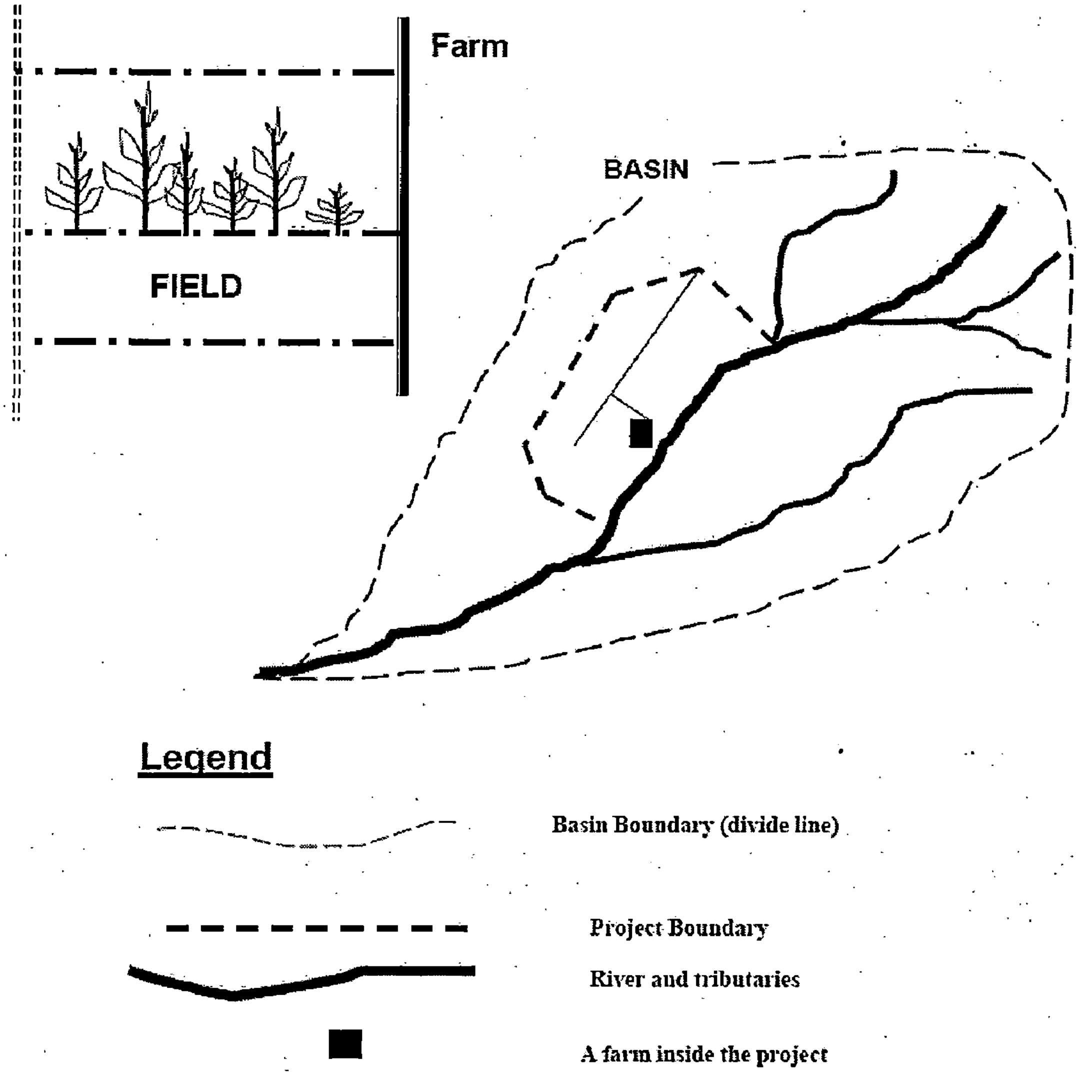


Fig.4.17 Typical Five-Level Presentation for Water Management: Plant – Field – Farm – Project – Basin

Efficiency of whole basin is ration between output and input components:

EFFICIENCY = Output / Input

Where:

Input: Land preparation, Seeds, Water, Fertilizers, Labor, Protection (Insects + Diseases), Weeding, Equipments, Energy, etc…

Output: Crop Production (Biomass, grain, economical Yield)

Water is the most critical input component (factor) limiting crop production in our region with big goal called "More Crop per a Drop!"

Therefore:

Water Productivity or Use Efficiency = Crop Yield / Water Used

Water Productivity = Crop yield / Water used

What do we mean by water used in crop production; which water?

Water Used:

- Transpiration (T)
- Evapotranspiration (ET) = T + E_s
- Irrigation water applied (I)

I = ET + Deep Percolation + Runoff (+ Spray Loss in sprinkler irrigation)

If T= 350 mm, ET= 500 mm, I= 800 mm

Yield (Y) = 5.6 ton / ha = 5600 kg / ha.

Then,

WP_T = 5600 / 350= 16 kg / ha / mm = 16 kg / 10 m3 = 1.6 kg / m^3

WP_{ET}= 5600 / 500= 11.2 kg / ha / mm = 1.12 kg / m^3

WP_I = 5600 / 800= 7 kg / ha / mm = 0.7 kg / m^3

NOTE: WP_{ET} is the one most widely used. Why?

4.10 Evapotranspiration Measurement

The most important role in Water Production process is playing Crop Evapotranspiration, which also evaluate Yield Production of particular crop (Fig.4.18).

Levels of WP Consideration :

Basin-wide Level

Project Level

Farm Level

Field Level

Plant/Crop Level

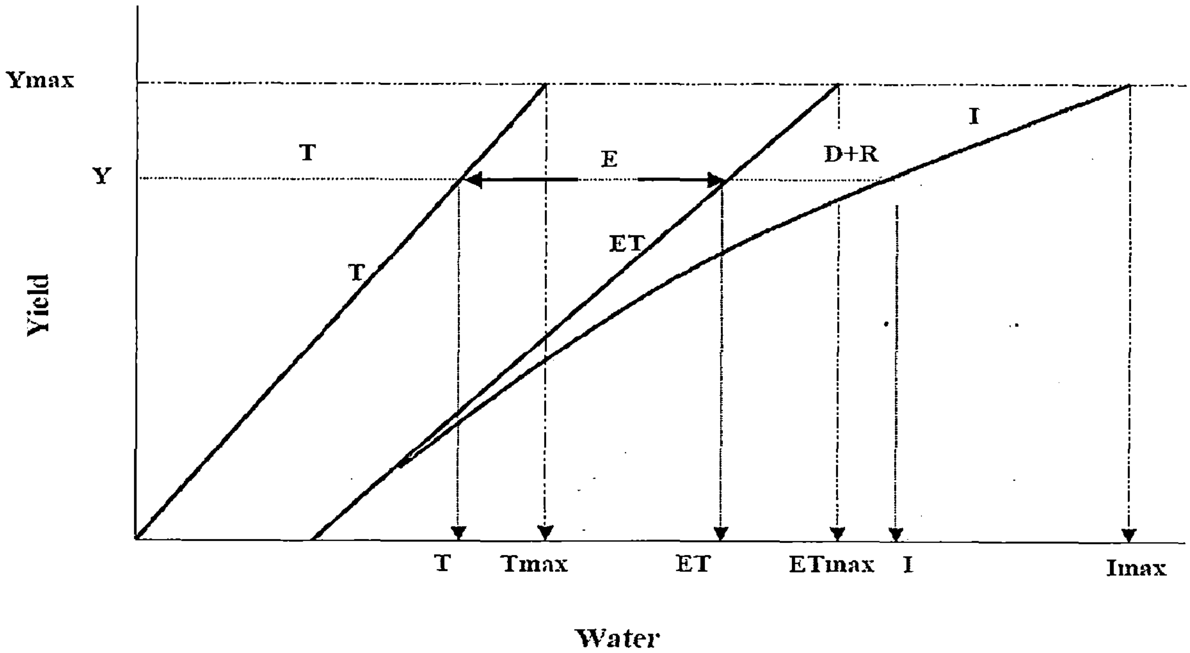


Fig.4.18 Water Productivity terms and components.

Where: T- transpiration,

E- evaporation,

I- irrigation,

ET- Evapotranspiration,

D- drainage (deep percolation), and

R- runoff

At Plant / Crop Level:

- Crop variety (Environment, Morphology, Root system)
- Crop rotation (Continuous, Fallowing, Legumes…)
- Tillage (Depth, Frequency, Timing…)
- Planting Date
- Planting Depth and Density
- Nutrient Availability (Type, Amount, Timing, Method)
- Weed Control
- Disease and Insect Control
- Irrigation Scheduling (Amount and Timing, Deficit Irrigation …)
- Water Quality (Tolerance, Leaching, Drainage …)
- Soil (Type, Depth, Salinity …)
- Management.

At Field Level:

- Land Grading
- Proper Length of Surface Irrigation Run
- Balance (Match) the Inflow rate, Application time, Soil type, Length of run and desired amount of irrigation.
- Uniformity of irrigation water distribution
- Efficiency of water application (Minimize runoff and unnecessary deep percolation below crop root zone)
- Use long irrigation interval if possible (Policy of water distribution among farms, 50-60% depletion of available water in the root zone, Minimize evaporation and seepage losses)
- Be careful when scheduling irrigation using saline water!?
- Human Capacity (Training, Pilot farms ...)

Deficit Irrigation means that the seasonal irrigation water (water infiltrated and stored in the root zone) is insufficient to attain the maximum yield (per unit area) and crops experience ET deficit (i.e. the crop water requirements will not be fully met).

Leaching of salts, Amount of irrigation water, Irrigation efficiency, Crop yield, and Water use efficiency?

Crop water production function:

$$Y(W) = b_0 + b_1\,(P+W) + b_2\,(P+W)^2 \quad (1)$$

Where: Y is grain yield (t ha^{-1}),

W is irrigation water (mm),

P is precipitation (mm) during the growth season,

b_0, b_1 and b_2 are regression coefficients.

A highly significant polynomial relationship existed between grain yield and the total applied water ($R_2 = 0.84$ for bread wheat and $R_2 = 0.87$ for durum wheat), with a minimum requirement of 203 mm water for initial grain yield for both crops.

The relationship between grain yield and the total applied water is useful for optimizing irrigation strategy. In order to derive the amount of water required under different rainfall conditions, one can fix the rainfall in Equation 1 and the response of yield to irrigation water can be found. The response of grain yield to irrigation water (W) can be described using the equation:

$$Y(W) = c_0 + c_1W + c_2W^2 \quad (2)$$

Where: $c_0 = b_0 + b_1P + b_2P^2$ and $c_2 = b_2$. Under rain-fed conditions ($W = 0$), grain yield of both bread and durum wheat increased from about 1.2 t ha^{-1} to 4–5 t ha^{-1} when rainfall increased from 250 mm to 450 mm. The response of grain yield to water applied decreased as rainfall increased, with the highest response for lowest rainfall.

4.11 Strategies for Supplemental Irrigation

In order to develop optimal irrigation management, it is necessary to develop a cost function in addition to the crop water production function. A linear cost function with increasing SI was derived from a farm survey as follows:

$$c(W) = a_1 + a_2W \quad (3)$$

where: $c(W)$ is the cost in sum (sum),

W is water in mm, a_1 and a_2 are fixed and variable costs of production, respectively. The values of a1 and a2 were estimated from the Uzbek National statistical book and are 315,429 sum and 610.7 sum, respectively (Table 4.3).

The net profit per hectare is a function of applied water:

$$R_n(W) = P_yY(W) - c(W) \quad (4)$$

where: $R_n(W)$ is the net profit,

$Y(W)$ is the crop production function,

P_y is the price per unit of grain yield of wheat. The level of water use for maximizing yield can be determined by taking the derivative of Eq. 2. The level of water use for maximizing the net profit under different constrained conditions can be determined by taking a partial derivative of Eq. 4 with respect to W.

The various levels of water use for different interests are as follows:

a) for maximizing yield, the amount of irrigation water (W_m) is:

$$W_m = c_1 / (-2c_2) \quad (5)$$

b) for maximizing the net profit under limited land resources, the amount of irrigation water (W_l) is:

$$W_l = (c_1 - a_2/P)/(-2c_2) \quad (6)$$

c) for maximizing the net profit under limited water resources conditions (English, 1990), the amount of irrigation water (W_w) is:

$$W_w = [(P_y c_0 - a_1)/(P_y b_2)]^{1/2} \quad (7)$$

where P is precipitation (mm) during the crop growing season;

d) the amount of irrigation water for a targeted yield (Y_t), W_t:

$$W_t = [-(c_1 + (c_1^2 - 4c_2(c_0 - Y_t))^{1/2}]/(-2c_1) \quad (8)$$

W_m - amount of water required for maximizing grain yield,

W_l - amount of water required for maximizing the profit under limited land resource,

W_w - amount of water required for maximizing the profit under limited water resources,

W_t - amount of water required for targeted yield of 4–5 t ha^{-1}.

The values of W_m, W_l, W_w, and Wt were determined for each crop using Eqs. 5–8 and the results are summarized in Table. To achieve the maximum grain yield for bread and durum wheat, the amount of water required (W_m) ranged from about 230–310 mm in a wet year with rainfall of 450 mm to 430–510 mm in a dry year with rainfall of 250 mm (Table 4.4). Water resources in WANA are scarce and therefore the strategy for maximizing grain yield is inappropriate because a large amount of water is needed. The cost per cubic meter of water in Tashkent Province plus corresponding increase resulting from additional investment (e.g. fertilizer, harvest, seed) is about 610.7 sum per mm water per hectare (Table 4.3).

The W_w strategy for maximizing profit under limited water resources conditions can save irrigation water by 40–73% with a grain yield loss of only 13% for bread wheat, and by 36–54% with a grain yield loss of only 12% for durum wheat. Hence the W_w strategy requires much less water with a considerable small loss of grain yield; and thus, it is more suitable for the water-scarce dry areas (Table 4.4). The W_t for achieving targeted 4–5 t ha^{-1} grain yield ranged from no irrigation in a wet year to 250 mm in a dry year (rainfall 250 mm). Compared with the irrigation scenario of maximizing grain yield, the Wt scenario, on average, saved 63% of water with a yield reduction of only 31% for bread wheat, and 84% of water with a yield reduction of 35% for durum wheat. On the other hand, the water saved from the Wt scenario can be applied to more than double the areas of the Wm scenario for maximizing yield. The overall production of the W_t scenario for the targeted yield can be more than double that of the W_m scenario for maximizing yield.

The analysis of crop sensitivity to water stress suggests the best time to apply irrigation water. However, the rainfall probability and the available soil moisture in the root zone need to be considered during the crop growing seasons. When rainfall is less than 300 mm, two to four irrigations and total 108–250 mm water are needed, and irrigation might be applied at stem elongation, booting, flowering and/or grain-filling stages. When rainfall is above 400 mm, only one or even no irrigation is needed; if irrigation is applied, the best time to apply it is at grainfilling stage. In a year with average rainfall of 330 mm in Tashkent Province, one to two irrigations are sufficient to stabilize crop yield.

Table 4.3 Production Costs for Wheat in Uzbekistan

Cost category	Costs* (sum ha^{-1})
Fixed costs (field machinery, tillage, planting and irrigation equipment, etc.)	114,150
Variable costs: rain-fed:	
Nitrogen at 50kg ha^{-1}	62,392
Seed	69,348
Harvest	69,537
Variable costs: irrigated at 250 mm	
Irrigation	47,160
Nitrogen at 100 kg ha-1	126,931
Seed	93,141
Harvest	88,990
Total costs	
Non-irrigated	315,429
Irrigated	468,251
Cost function	$c(W) = 315429 + 610.7W$

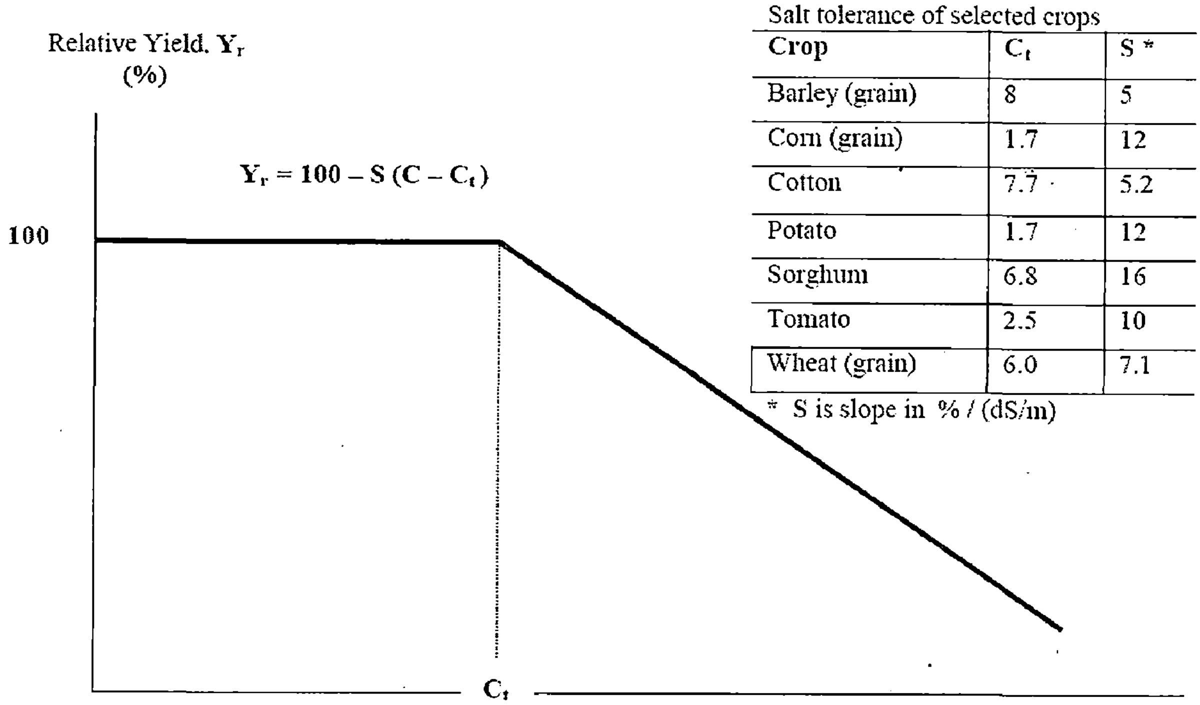
* Data are from Uzbek National annual statistical book in 1994

Table 4.4 Estimated amount (mm) and timing of supplemental irrigation for maximizing yield, maximizing the net profit and a targeted yield under different rainfall conditions

Rainfall	W_m	W_l	W_w	W_t	Time of irrigation
			Bread wheat		
250	430	336	260	158–254	Stem elongation, booting, flowering and grain filling
300	380	286	210	108–204	Stem elongation, flowering and/or grain filling
350	330	236	160	58–155	Flowering and/or grain filling
400	280	186	110	0–144	Grain filling
450	230	136	60	0–55	Grain filling
			Durum wheat		
250	510	454	314	144–207	Stem elongation, booting, flowering and grain filling
300	460	404	294	94–157	Stem elongation, flowering and/or grain filling
350	410	354	244	44–107	Flowering and/or grain filling
400	360	304	194	0–57	Grain filling
450	310	254	144	0	–

4.12 Salinity Management

During rotations of crops the condition of local soils can be changed. There is Soil salinity as one of important considering components of Yield Production shows that for produce especial crop has to be known the value of Electrical Conductivity of saturated soil extract. For each kind of crop the values can be different (Fig.4.19).



Salt tolerance of selected crops

Crop	C_t	S *
Barley (grain)	8	5
Corn (grain)	1.7	12
Cotton	7.7	5.2
Potato	1.7	12
Sorghum	6.8	16
Tomato	2.5	10
Wheat (grain)	6.0	7.1

* S is slope in % / (dS/m)

Fig.4.19 Electrical Conductivity of Saturated Soil Extract, C, dS/m

Relative Yield (Y_r) for selected crops as a function of soil salinity as EC in dS/m. C_t is salt tolerance threshold at initial yield decline

Example:

What will be the relative Yield (Y_r) of grain for wheat, barley, and corn in farm Boykozon if the soil salinity is 10 dS/m?

Answer:

For wheat: $Y_r = 100 - 7.1\ (10 - 6) = 100 - 28.4 = 71.6\%$ say 72%

For barley: $Y_r = 100 - 5\ (10 - 8) = 100 - 10 = 90\%$

For corn: $Y_r = 100 - 12\ (10 - 1.7) = 100 - 99.6 = 0.4\%$ say almost Zero yield

CHAPTER V

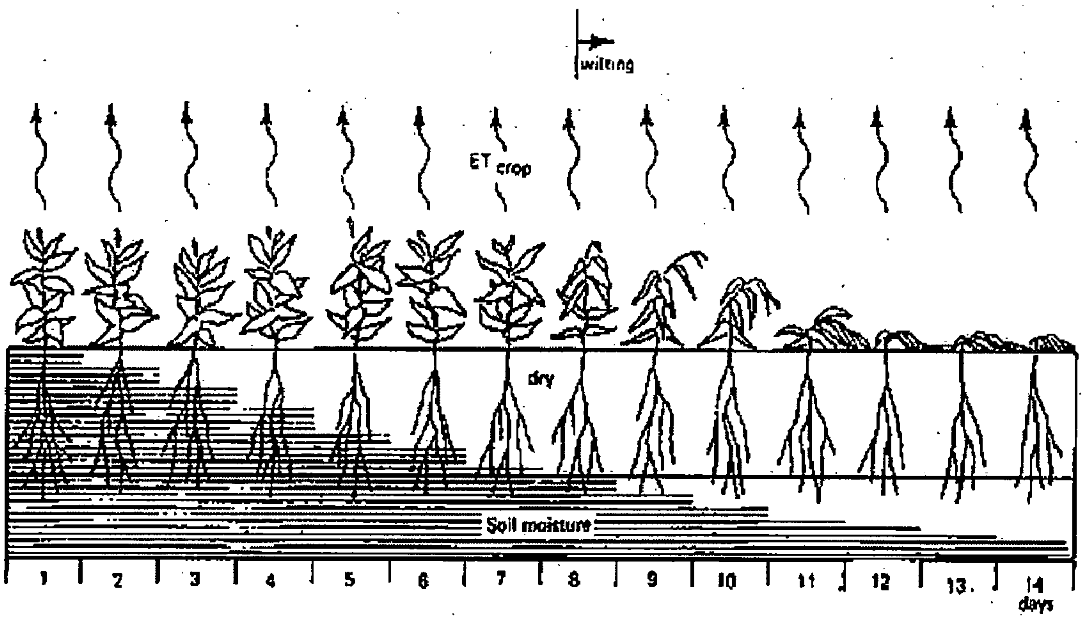
SUPPLEMENTAL IRRIGATION SCHEDULING

5.1 Main Concepts

The accurate determination of an irrigation schedule is a time-consuming and complicated process. The introduction of computer programs, however, has made it easier and it is possible to schedule the irrigation water supply exactly according to the water needs of the crops (Fig.5.1). Ideally, at the beginning of the growing season, the amount of water given per irrigation application, also called the irrigation depth, is small and given frequently. This is due to the low evapotranspiration of the young plants and their shallow root depth. During the mid season, the irrigation depth should be larger and given less frequently due to high evapotranspiration and maximum root depth. Thus, ideally, the irrigation depth and/or the irrigation interval (or frequency) varies with the crop development (Fig.5.2).

When sprinkler and drip irrigation methods are used, it may be possible and practical to vary both the irrigation depth and interval during the growing season. With these methods it is just a matter of turning on the tap longer/shorter or less/more frequently.

When surface irrigation methods are used, however, it is not very practical to vary the irrigation depth and frequency too much. With, in particular, surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change the schedule all the time. Therefore, it is often sufficient to estimate or roughly calculate the irrigation schedule and to fix the most suitable depth and interval; in other words, **to keep the irrigation depth and the interval constant over the growing season**. Three simple methods to determine the irrigation schedule are briefly described here: plant observation method, estimation method and simple calculation method. Some remarks are made about taking into account actual rainfall in irrigation scheduling.



In the absence of rainfall and if no irrigation water is applied, the plants eventually die. If irrigation water is applied regularly, the plants do not suffer from water shortage

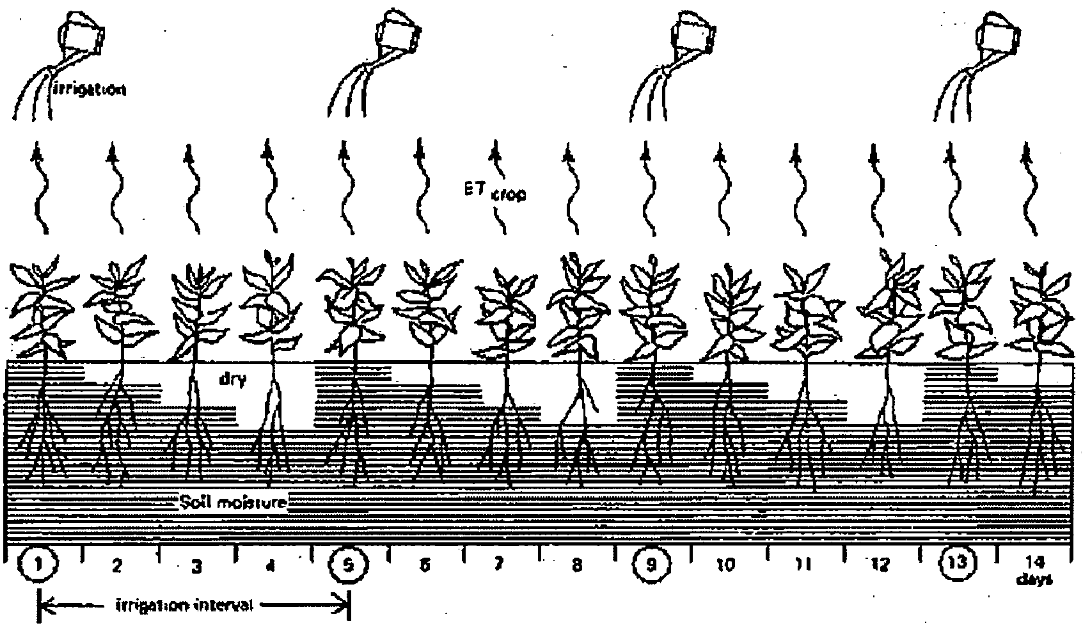


Fig.5.1 Need of Supplemental Irrigation

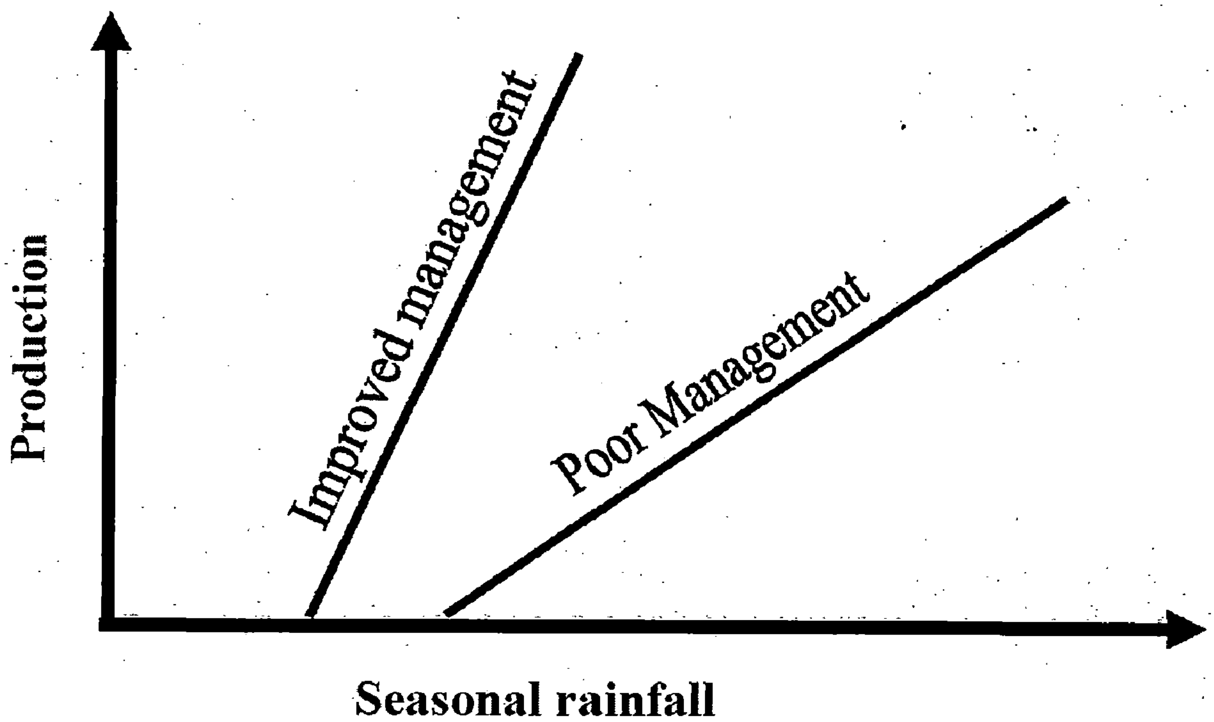


Fig.5.2 Effect of farm resources management on the relation between production and rainfall

5.2 The Plant Observation Method

It is the method which is normally used by farmers in the field to estimate "when" to irrigate. The method is based on observing changes in plant characteristics, such as changes in colour of the plants, curling of the leaves and ultimately plant wilting. The changes can often only be detected by looking at the crop as a whole rather than at the individual plants. When the crop comes under water stress the appearance changes from vigorous growth (many young leaves which are light green) too slow or even no growth (fewer young leaves, darker in colour, and sometimes rayish and dull). To use the plant observation method successfully, experience is required as well as a good knowledge of the local circumstances. A farmer will, for example, know where the sandy spots in the field are, which is where the plants will first show stress characteristics: the colour changes and wilting are more pronounced on the sandy spots. Why?

The disadvantage of the plant observation method is that by the time the symptoms are evident, the irrigation water has already been withheld too long for most crops and yield losses are already inevitable. It is important to note that it is not advisable to wait for the symptoms. Especially in the early stages of crop growth (the initial and crop development stages), irrigation water has to be applied before the symptoms are evident.

Another method used to determine the irrigation schedule involves soil moisture measurements in the field. When the soil moisture content has dropped to a certain critical level, irrigation water is applied. Instruments to measure the soil moisture include gypsum blocks, tensiometers and neutron probes. Their use, however, is beyond the farmer's capacity.

5.3 The Estimation Method

This method provides a table with irrigation schedules for the major field crops grown under various climatic, during the period of peak water demand. The schedules are given for three different soil types and three different climates. The table is based on calculated crop water needs and an estimated root depth for each of the crops under consideration. The table assumes that with the irrigation method used the maximum possible net application depth is 70 mm.

With respect to soil types, a distinction has been made between sand (coarse), loam (medium), and clay (fine), which have, respectively, a low, medium and high available water content. With respect to climate, a distinction is made between three different climates (Table 5.1).

Table 5.1 Soil Types and Climates

SOIL TYPES

Shallow and/or sandy soil	In a sandy soil or a shallow soil (with a hard pan or impermeable layer close to the soil surface), little water can be stored; irrigation will thus have to take place frequently but little water is given per application.
Loamy soil	In a loamy soil more water can be stored than in a sandy or shallow soil. Irrigation water is applied less frequently and more water is given per application.
Clayey soil	In a clayey soil even more water can be stored than in a medium soil. Irrigation water is applied even less frequently and again more water is given per application.

CLIMATES

Climate 1	Represents a situation where the reference crop evapotranspiration ETo = 4 - 5 mm/day.
Climate 2	Represents an ETo = 6 - 7 mm/day.
Climate 3	Represents an ETo = 8 - 9 mm/day.

An overview indicating in which climatic zones these ET_0 values can be found (Table 5.2).

Table 5.2 Reference Crop Evapotranspiration ET_0, (mm/day)

Climatic zone	**Mean daily temperature**		
	Low (less than 15°C)	**Medium (15-25°C)**	**High (more than 25°C)**
Desert/arid	4 - 6	7 - 8	9 - 10
Semi-arid	4 - 5	6 - 7	8 - 9
Sub-humid	3 - 4	5 - 6	7 - 8
Humid	1 - 2	3 - 4	5 - 6

It is important to note that the irrigation schedules given in Table 5.3 are based on the crop water needs in the **peak period.** It is further assumed that little or no rainfall occurs during the growing season. The use of Table 5.3 in the case of Boykozon farm is given below.

Table 5.3 Estimated Irrigation Scheduling for The Major Field Crops During Peak Water Use Periods

	Shallow and/or sandy soil				loamy soil				clayey soil			
	Interval (days)			Net irr. depth (mm)	Interval (days)			Net irr. depth (mm)	Interval (days)			Net irr. depth (mm)
Climate	1	2	3		1	2	3		1	2	3	
Alfalfa	9	6	5	40	13	9	7	60	16	11	8	70
Banana	5	3	2	25	7	5	4	40	10	7	5	55
Barley/Oats	8	6	4	40	11	8	6	55	14	10	7	70
Beans	6	4	3	30	8	6	4	40	10	7	5	50
Cacao	9	6	5	40	13	9	7	60	16	11	8	70
Carrot	6	4	3	25	7	5	4	35	11	8	6	50
Citrus	8	6	4	30	11	8	6	40	15	10	8	55
Coffee	9	6	5	40	13	9	7	60	16	11	8	70
Cotton	8	6	4	40	11	8	6	55	14	10	7	70
Cucumber	10	7	5	40	15	10	8	60	17	12	9	70
Crucifers*	3	2	2	15	4	3	2	20	7	5	4	30
Eggplant	6	4	3	30	8	6	4	40	10	7	5	50
Flax	8	6	4	40	11	8	6	55	14	10	7	70
Fruit trees	9	6	5	40	13	9	7	60	16	11	8	70
Grains, small	8	6	4	40	11	8	6	55	14	10	7	70
Grapes	11	8	6	40	15	11	8	55	19	13	10	70
Grass	9	6	5	40	13	9	7	60	16	11	8	70
Groundnuts	6	4	3	25	7	5	4	35	11	8	6	50
Lentils	6	4	3	30	8	6	4	40	10	7	5	50
Lettuce	3	2	2	15	4	3	2	20	7	5	4	30
Maize	8	6	4	40	11	8	6	55	14	10	7	70
Melons	9	6	5	40	13	9	7	60	16	11	8	70
Millet	8	6	4	40	11	8	6	55	14	10	7	70
Olives	11	8	6	40	15	11	8	55	19	13	10	70
Onions	3	2	2	15	4	3	2	20	7	5	4	30
Peas	6	4	3	30	8	6	4	40	10	7	5	50
Peppers	6	4	3	25	7	5	4	35	11	8	6	50
Potatoes	6	4	3	30	8	6	4	40	10	7	5	50
Radish	4	3	2	15	5	4	3	20	7	5	4	30
Safflower	8	6	4	40	11	8	6	55	14	10	7	70
Sorghum	8	6	6	40	11	8	6	55	16	10	7	70
Soybeans	8	6	4	40	11	8	6	55	14	10	7	70
Spinach	3	2	2	15	4	3	2	20	7	5	4	30
Squash	10	7	5	40	15	10	8	60	17	12	9	70
Sugarbeet	8	6	4	40	11	8	6	55	14	10	7	70
Sugarcane	7	5	4	40	10	7	5	55	13	9	7	70
Sunflower	8	6	4	40	11	8	6	55	14	10	7	70
Tea	9	6	5	40	13	9	7	60	16	11	8	70
Tobacco	6	4	3	30	8	6	4	40	10	7	5	50
Tomatoes	6	4	3	30	8	6	4	40	10	7	5	50
Wheat	8	6	4	40	11	8	6	55	14	10	7	70

* cabbage, cauliflower, etc.

Data from FAO "Crops and Drops" Advanced addition, 2000

5.4 Adjusting the Irrigation Schedule

5.4.1 Adjustments for the Non-peak Periods

The irrigation schedule, which is obtained using Table 5.3, is valid for the peak period; in other words, for the mid-season stage of the crop.

During the early growth stages, when the plants are small, the crop water need is less than during the mid-season stage. Therefore, it may be possible to irrigate during the early stages of crop growth, with the same frequency as during the mid-season, but with smaller irrigation applications. It is risky to give the same irrigation application as during the mid-season, but less frequently; the young plants may suffer from water shortage as their roots are not able to take up water from the lower layers of the root zone.

In summary, in order to save water, it may be feasible to irrigate, during the early stages of the crop development, with smaller irrigation applications than during the peak period. During the late season stage it may be feasible to irrigate less frequently, in particular if the crop is harvested dry.

When adjusting the irrigation schedule for the non-peak periods, it should always be kept in mind that the irrigation schedules must be simple, in particular in surface irrigation schemes where many farmers are involved. It will often be necessary to discuss with the farmers, before implementing the irrigation schedule, the various alternatives and come to an agreement which best satisfies all parties involved.

5.4.2 Adjustment for Climates with Considerable Rainfall Daring the Growing Season

The schedules obtained from Table 3 are based on the assumption that little or no rainfall occurs during the growing season. If the contribution from the rainfall is considerable during the growing season, the schedules need to be adjusted: usually by making the interval longer. It may also be possible to reduce the net irrigation depth.

It is difficult to estimate to which values the interval and the irrigation depth should be adjusted. It is therefore suggested to use the simple calculation method (which will be discussed), instead of the estimation method, in the case of significant rainfall during the growing season. Alternatively it is possible to adjust the irrigation schedule to the actual rainfall (to be also discussed).

5.4.3 Adjustment for Local Irrigation Practices or Irrigation Method Used

It may happen that the net irrigation depth obtained from Table 5.3 is not suitable for the local conditions. It may not be possible, for example, to infiltrate 70 mm with the irrigation method used locally. Tests may have shown that it is only possible to infiltrate some 50 mm per application.

In such cases, both the net irrigation depth and the interval must be adjusted simultaneously. For example, suppose that maize is grown on a clayey soil in a moderately warm climate. According to Table 5.3, the interval is 10 days and the net irrigation depth is 70 mm. This corresponds to an irrigation water need of 70/10 = 7 mm/day.

Instead of giving 70 mm every 10 days, it is also possible to give 63 mm every 9 days; 56 mm every 8 days; 49 mm every 7 days; or even 42 mm every 6 days. This means that in the above example an interval of seven days is chosen with a net application depth of 49 mm.

5.4.4 Adjustment for Shallow Soils

A shallow soil can only store a little water, even if the soil is clayey. For shallow soils - sandy, loamy or clayey - the column "shallow and/or sandy soil" of Tab.6.3 should be used.

5.5 The Simple Calculation Method

The simple calculation method to determine the irrigation schedule is based on the estimated depth (in mm) of the irrigation applications, and the calculated irrigation water need of the crop over the growing season.

Unlike the estimation method, the simple calculation method is based on calculated irrigation water needs. Thus, the influence of the climate, i.e. temperature and rainfall, is more accurately taken into account. The result of the simple calculation method will therefore be more accurate than the result of the estimation method.

The simple calculation method to determine the irrigation schedule involves the following steps that are explained in detail below:

– Estimate the net and gross irrigation depth (d) in mm

– Calculate the irrigation water need (IN) in mm, over the total growing season

– Calculate the number of irrigation applications over the total growing season

– Calculate the irrigation interval in days

Step 1 – Estimate the net and gross irrigation depth (d) in mm

The net irrigation depth is best determined locally by checking how much water is given per irrigation application with the local irrigation method and practice. If no local data are easily available, Table 5.4 can be used to estimate the net irrigation depth (d net), in mm. As can be seen from the table, the net irrigation depth is assumed to depend only on the root depth of the crop and on the soil type. It must be noted that the d net values in the table are approximate values only. Also the root depth is best determined locally. If no data are available, Table 5.5 can be used which gives an indication of the root depth of the major field crops.

Table 5.4 Approximate Net Irrigation Depth, IN, mm

	Shallow rooting crops	**Medium rooting crops**	**Deep rooting crops**
Shallow and/or sandy soil	15	30	40
Loamy soil	20	40	60
Clayey soil	30	50	70

Table 5.5 Approximate Root Depth of the Major Field Crops

Shallow rooting crops (30-60 cm):	Crucifers (cabbage, cauliflower, etc.), celery, lettuce, onions, pineapple, potatoes, spinach, other vegetables except beets, carrots, cucumber.
Medium rooting crops (50-100 cm):	Bananas, beans, beets, carrots, clover, cacao, cucumber, groundnuts, palm trees, peas, pepper, sisal, soybeans, sugarbeet, sunflower, tobacco, tomatoes.
Deep rooting crops (90-150 cm):	Alfalfa, barley, citrus, cotton, dates, deciduous orchards, flax, grapes, maize, melons, oats, olives, safflower, sorghum, sugarcane, sweet potatoes, wheat.

Not all water which is applied to the field can indeed be used by the plants. Part of the water is lost through deep percolation and runoff. To reflect this water loss from the irrigated field, the field application efficiency (ea) is used. The gross irrigation depth (d gross), in mm, takes into account the water loss during the irrigation application and is determined using the following formula:

$$d_{gross} = \frac{100 \bullet d_{net}}{e_a}$$

d_{gross} – gross irrigation depth,

d_{net} – net irrigation depth,

e_a – field application efficiency in percent

As example we can take values for field application efficiency from Boykozon farm for different Irrigation methods, where:

Surface irrigation = 60%,

Sprinkler irrigation = 75%,

Drip irrigation = 90%.

If, for example, tomatoes are grown on a loamy soil, Tab.6.4 and Tab.6.5 show that the estimated net irrigation depth is 40 mm. If furrow irrigation is used, the field application efficiency is 60% and the gross irrigation depth is determined as follows:

$$d_{gross} = \frac{100 \bullet 40}{60} = 67 \text{ mm} = \text{rounded } 65 \text{ mm}$$

Step 2 – Calculate the irrigation water need (IN) in – over the total growing season

This has been discussed in detail in FAO I&D Paper No. 56. Assume that the irrigation water need (IN, mm/month) for tomatoes, planted 1 February and harvested 30 June, is as follows:

February = 67

March = 110

April = 166

May = 195

The irrigation water need of tomatoes for the total growing season (Feb-June) is thus (67 + 110 + 166 + 195 + 180 =) 718 mm. This means that over the total growing season a net water layer of 718 mm has to be brought onto the field.

If no data on irrigation water needs are available, the estimation method should be used.

Step 3 – Calculate the number of irrigation applications over the total growing season

The number of irrigation applications over the total growing season can be obtained by dividing the irrigation water need over the growing season (Step 2) by the net irrigation depth per application (Step 1).

If the net depth of each irrigation application is 40 mm (d net = 40 mm; Step 1), and the irrigation water need over the growing season is 718 mm (Step 2), then a total of (718/40 =) 18 applications are required.

Step 4 – Calculate the irrigation interval (INT) in days

Thus a total of 18 applications is required. The total growing season for tomatoes is 5 months (Feb-June) or 5 x 30 = 150 days. Eighteen applications in 150 days corresponds to one application every 150/18 = 8.3 days.

In other words, the interval between two irrigation applications is 8 days. To be on the safe side, the interval is always rounded off to the lower whole figure: for example 7.6 days becomes 7 days; 3.2 days becomes 3 days.

In this example, the irrigation schedule for tomatoes is as follows:

d_{net} = 40 mm

d_{gross} = 65 mm

interval= 8 days

5.6 Adjusting the Simple Calculation Method for the Peak Period

When using the simple calculation method to determine the irrigation schedule, it is advisable to ensure that the crop does not suffer from undue water shortage in the months of peak irrigation water need.

For instance, in the above example the interval is 8 days, while the net irrigation depth is 40 mm. Thus every 30 days (or each month): 30/8 x 40 mm = 150 mm water is applied. The amount of water given during each month (d net) should be compared with the amount of irrigation water needed during that month (IN).

The result is shown below (Table 5.6). The "IN" values represent the irrigation water needs, while the "d_{net}" values represent the amount of water applied. The "d_{net} - IN" values show whether too much or too little water has been applied:

Table 5.6 Calculation of "d_{net} – IN" values

	Feb	Mar	Apr	May	June	Total
IN (mm/month), needed	87	110	166	195	180	718
d net (mm/month), (Fixed amount	150	150	150	150	150	750
d net - IN (mm/month)	+83	+40	-16	-45	-30	+32

The total net amount of irrigation water applied (750 mm) is more than sufficient to cover the total irrigation water need (718 mm). However, in February and March too much water has been applied, while in April, May and June, too little water has been applied.

Care should be taken with under-irrigation (too little irrigation) in the peak period as this period normally coincides with the growth stages of the crops that are most sensitive to water shortages.

To overcome the risk of water shortages in the peak months, it is possible to refine the simple calculation method by looking only at the months of peak irrigation water need and basing the determination of the interval on the peak period only.

In the example given above for tomatoes, this means looking at the months April, May and June:

April	= 166 mm/day
May	= 195 mm/day
June	= 180 mm/day
Sub-total	= 541 mm/day

The total irrigation water need from April to June (90 days) is 541 mm, while the net irrigation depth is 40 mm. Thus 541/40 = 13.5 (rounded 14) applications are needed. Fourteen applications in 90 days means one application every 6.4 (rounded 6) days.

Calculated this way the irrigation schedule for the tomatoes would be:

d_{net} = 40 mm

d_{gross} = 65 mm

interval = 6 days

Over the total growing period of 150 days, this means 150/6 = 25 applications, each 40 mm net and thus in total 25 x 40 = 1000 mm.

In summary:

Feb-March : d_{net} = 40 mm; d_{gross} = 65 mm; Interval = 8 days

April-May-June : d_{net} = 40 mm; d_{gross} = 65 mm; Interval = 6 days

Adjusting the irrigation schedule to actual rainfall is given below (Table 5.7)

Table 5.7 Result of adjusting the irrigation schedule to the months of peak irrigation water demand

	Feb	Mar	Apr	May	June	Total
IN (mm/month)	67	110	166	195	180	718
d net (mm/month)	200	200	200	200	200	1000
d net - IN (mm/month)	+133	+90	+34	+5	+20	+282

The estimation method to determine the irrigation schedule can only be used when no significant rainfall occurs during the growing season. The simple calculation method is based on the average irrigation water need of the crop which is the average crop water need minus the average effective rainfall. This method is used when designing and implementing an irrigation system with a **"rotational"** water supply: each field receives a certain amount of water on dates that are already fixed in advance. The rotational supply takes into account the average rainfall only and thus does not take into account the actual rainfall; this results in over-irrigation in wetter than average years and under-irrigation in drier than average years. In surface irrigation systems the rotational water supply method is most commonly used.

There are also water supply methods that allow the irrigation water to be distributed "on demand". The farmer can take water whenever necessary. In this case it is possible to take the actual rainfall into account and thus give the correct amount of irrigation water even in drier or wetter years. With this delivery system of irrigation water, however, the rainfall has to be measured on a daily basis. The net irrigation depth (d net) has to be determined in accordance with the irrigation method used. In addition, the crop water need has to be known on a daily basis for each month of the growing season. As soon as the accumulated water deficit exceeds the value of the net irrigation depth, irrigation water is supplied.

An example is given below for a situation with a crop water need (CWN) of 8 am/day and a net irrigation depth (d_{net}) of 45 mm. As soon as the accumulated deficit exceeds the d_{net} (= 45 mm), irrigation water is supplied. Note that the "deficit" can never be positive; maximum zero (Table 5.8).

Table 5.8 Situation with a Crop Water Need

day	CWN (mm/day)	Rain (mm)	Irrigationd net (mm)	Calculations	Accumulated deficit (mm)
1	8	-	-		-8
2	8	-	-	(-8-8)	-16
3	8	-	-	(-16-8)	-24
4	8	-	-	(-24-8)	-32
5	8	-	-	(-32-8)	-40
6	8	-	45	(-40-8+45)	-3
7	8	-	-	(-3-8)	-11
8	8	12	-	(-11-8+12)	-7
9	8	24	-	(-7-8+24)	0
10	8	-	-	(0-8)	-8
11	8	-	-	(-8-8)	-16
12	8	-	-	(-16-8)	-24
13	8	4	-	(-24-8+4)	-28
14	8	-	-	(-28-8)	-36
15	8	-	-	(-36-8)	-44
16	8	-	45	(-44-8+45)	-7
17	8	-	-	(-7-8)	-15
etc.					

In the above example of adjusting the irrigation schedule to the actual rainfall, irrigation takes place on day 6, on day 16, etc. with on each occasion a net irrigation depth of 45 mm.

Six keys to improving irrigation efficiency

- Reduce evaporation by avoiding mid-day irrigation and using under-canopy rather than overhead sprinkling;
- Avoid over-irrigation;
- Control weeds on inter-row strips and keep them dry;
- Plant and harvest at optimal times; and
- Irrigate frequently with just the right amount of water to avoid crop distress.
- Reduce seepage losses in channels by lining them or using closed conduits;

5.7 Irrigation Scheduling Tables

It is necessary to measure Moisture Volume Fraction in appropriate field to defined equation with Count Ratio (Fig.5.3).

C.R	M.V.F
0.531	0.32
0.542	0.332
0.56	0.374
0.567	0.399
0.581	0.408
0.583	0.418
0.511	0.315
0.495	0.295
0.5	0.287
0.36	0.229
0.409	0.279
0.437	0.29
0.498	0.301
0.511	0.342
0.541	0.373
0.518	0.358
0.41	0.267
0.431	0.281
0.445	0.304
0.484	0.334
0.51	0.355
0.549	0.376
0.473	0.34
0.523	0.34
0.564	0.37
0.593	0.392
0.422	0.237
0.451	0.272
0.476	0.309

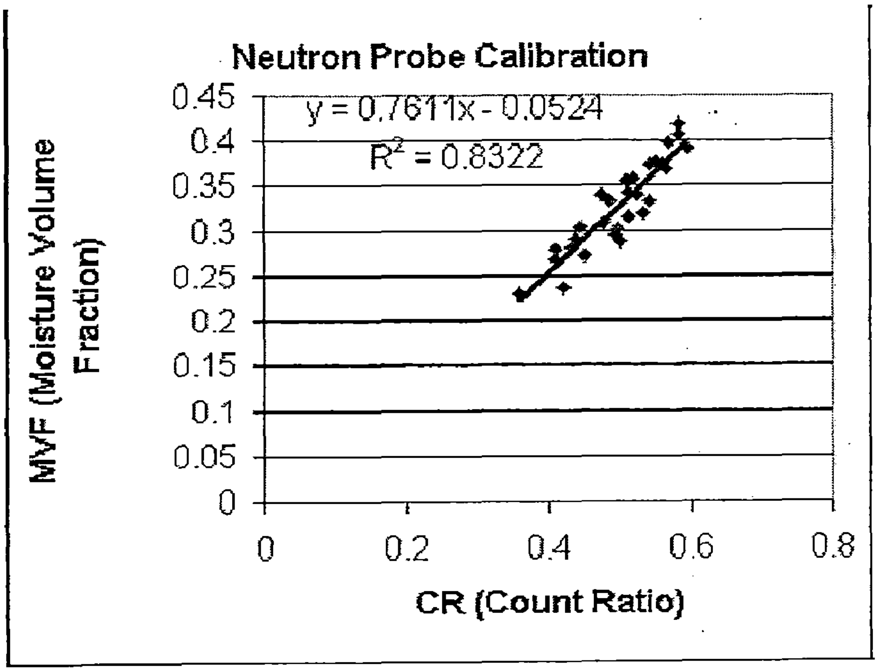


Fig.5.3 Neutron Probe Calibration, Boykozon, 1996

To calculate Total Water in Profile it has to be taken data from Moisture Volume fraction, Count Ratio, Applied water Depth in each period of irrigation, which is belong to particular soil layer (Table 5.9).

Precipitation and Crop Evaporation are needed to calculate using Modern Supplemental Irrigation Scheduling to calculate them average in every irrigating period (Table 5.10).

Finally is getting seasonal summary of water content in each soil layer depth in particular area. By using them total values are fining out next important values in Boykozon farm (Table 5.11).

et(interval) = (Total water in the soil profile at the beginning of the interval– Total water in the soil profile at the end of the interval)+ total rain during the interval + total irrigation during the interaval

et(interval) = (water beginning – water end) + rain + irrigation

Where:

et – evapotranspiration;

et (interval) – et during a given time (in days) interval, (mm);

et per day – et(interval) divided by time interval, (mm/day);

eo – Class-A pan evaporation;

eo(interval) – eo during a given time (in days) interval, (mm)

Table 5.9 The Irrigation Data for Durum Wheat in Boykozon Farm

Site: Boykozon, Tashkent Province, Uzbekistan

Trial: Supplemental Irrigation

Treatment: N50 W0 (rainfed) Tube no: 49

Replicate: Durum Wheat Date 1

M.V.F = (0.76 * count/st.water) – 0.052

H_2O (mm) in each layer = M.V.F.* 150

CR = count/st. water reading

Probe No.6 St. water reading = 928

Soil layer	Depth (cm)	1/11/95				3/12/95				31/12/1995				27/1/1996			
		COUNT	CR	M.V.F	H2O mm	COUNT	CR	M.V.F	H2O mm	COUNT	CR	M.V.F	H2O mm	COUNT	CR	M.V.F	H2O mm
0-15	7.5	Direct			13.4	Direct			40.9	Direct			40.3	Direct			44.9
15-30	22.0	166.0			12.6	220.0			19.2	320.0			31.5	423.0			44.2
30-45	37.5	258.0			23.9	254.0			23.4	272.0			25.6	423.0			44.2
45-60	52.5	310.0			30.3	307.0			29.9	307.0			29.9	330.0			32.7
60-75	67.5	356.0			35.9	350.0			35.2	349.0			35.1	347.0			34.8
75-90	82.5	369.0			37.5	373.0			38.0	372.0			37.9	367.0			37.3
90-105	97.5	391.0			40.2	393.0			40.5	394.0			40.6	391.0			40.2
105-120	112.5	399.0			41.2	405.0			42.0	399.0			41.2	396.0			40.8
120-135	127.5	414.0			43.1	413.0			42.9	410.0			42.6	408.0			42.3
135-150	142.5	409.0			42.4	408.0			42.3	407.0			42.2	409.0			42.4
150-165	157.5	419.0			43.7	414.0			43.1	416.0			43.3	414.0			43.1
165-180	172.5	425.0			44.4	424.0			44.3	422.0			44.0	425.0			44.4
Total water in profile (mm)					**408.6**				**441.7**				**454.2**				**491.3**
Precipitation in pirods, mm					0.0				59.1				31.0				71.3
EfT, Total ET (mm)					0.0				26.0				18.5				34.1
Et, mean daily (mm/day)					0.0				0.8				0.7				1.3
Evaporation, Eo (mm)					0.0				2.2				1.1				1.3
Et/Eo ratio					0.0				0.4				0.6				1.0
Cumulative Rainfall (mm)					0.0				59.1				90.1				161.4
Cumulative Eo (mm)					0.0				69.3				100.5				135.6
Cumulative Et (mm)					0.0				26.0				44.5				78.6
Days in period (days)					0.0				32 days				28 days				27 days

Table 5.10 Supplemental Irrigation Scheduling, Durum Wheat, Boykozon, 1995-96

Site: Boykozon

Trial: Supplemental Irrigation

Treatment: N50 W0 Tube no: 49

[(0.76 * count/st.water) – 0.052] * 150 = H_2O mm in layer

Replicate: Durum Date1

	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
DATE	1/11/95	3/12/95	31/12/1995	27/1/1996	3/3/96	6/4/96	24/4/1996	2/5/96	7/5/96	12/5/96	15/5/1996	29/5/1996	6/6/96	7/7/96	7/8/96
0-15	13.4	40.9	40.3	44.9	47.5	40.5	43.8	32.9	25.9	22.4	21.5	19.9	18.5	14.6	16.2
15-30	166	220	320	423	402	411	338	300	257	236	241	224	221	220	218
30-45	258	254	272	423	403	446	382	349	328	313	311	313	313	312	314
45-60	310	307	307	330	355	495	460	456	438	424	417	405	391	395	400
60-75	356	350	349	347	348	525	512	506	500	490	484	489	489	483	432
75-90	369	373	372	367	372	521	513	511	511	509	496	502	493	494	476
90-105	391	393	394	391	386	497	482	482	483	474	483	480	485	471	469
105-120	399	405	399	396	401	405	412	408	410	414	420	417	417	415	417
120-135	414	413	410	408	405	405	406	402	400	411	411	413	419	420	415
135-150	409	408	407	409	405	411	407	410	408	407	405	406	411	411	421
150-165	419	414	416	414	420	418	417	409	408	410	410	409	415	417	408
165-180	425	424	422	425	424	420	414	424	424	418	421	425	419	416	414
Precipitation	0	59.1	31	71.3	60	133.2	26	0.7	0	0	0	4.5	0	0	0
Evaporation	0	69.3	31.2	35.1	69.5	78.9	60.6	41.8	36.3	45.5	25.5	135.3	86.8	423.2	449.3

Table 5.11 Seasonal summary for 1995-96, Water Content (mm/soil layer)

Site: Boykozon | Trial: Durum Wheat Supplemental Irrigation | Treatment1: Durum Wheat 0 (Rainfed) N50

Soil layer (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1995					1996					1996			1996	
	1/11	3/12	31/12	27/ 1	3/ 3	6/ 4	24/ 4	2/ 5	7/ 5	12/ 5	15/5	29/5	6/6	7/7	7/8
0- 15	13.4	40.9	40.3	44.9	47.5	40.5	43.8	32.9	25.9	22.4	21.5	19.9	18.5	14.6	16.2
15- 30	12.6	19.2	31.5	44.2	41.6	42.7	33.7	29.1	23.8	21.2	21.8	19.7	19.3	19.2	19.0
30- 45	23.9	23.4	25.6	44.2	41.7	47.0	39.1	35.1	32.5	30.7	30.4	29.4	30.7	30.5	30.8
45- 60	30.3	29.9	29.9	32.7	35.8	53.0	48.7	48.2	46.1	44.3	43.4	42.0	40.2	40.7	41.3
60- 75	35.9	35.2	35.1	34.8	35.0	56.7	55.1	54.4	53.6	52.4	51.7	52.3	52.3	51.5	51.4
75- 90	37.5	38.0	37.9	37.3	37.9	56.2	55.2	55.0	55.0	54.7	53.1	53.9	52.8	52.9	50.7
90-105	40.2	40.5	40.6	40.2	39.6	53.3	51.4	51.4	51.5	50.4	51.5	51.2	51.8	50.1	47.4
105-120	41.2	42.0	41.2	40.8	41.5	42.0	42.8	42.3	42.6	43.1	43.8	43.4	43.4	43.2	43.4
120-135	43.1	42.9	42.6	42.3	42.0	42.0	42.1	41.6	41.3	42.7	42.7	42.9	43.7	43.8	43.2
135-150	42.4	42.3	42.2	42.4	42.0	42.7	42.2	42.6	42.3	42.2	42.0	42.1	42.7	42.7	43.9
150-165	43.7	43.1	43.3	43.1	43.8	43.5	43.4	42.4	42.3	42.6	42.6	42.4	43.2	43.4	42.3
165-180	44.4	44.3	44.0	44.4	44.3	43.8	43.1	44.3	44.3	43.5	43.9	44.4	43.5	43.3	43.1
Total	408.7	441.7	454.2	491.4	492.5	563.3	540.7	519.2	501.3	490.1	488.4	483.6	482.1	476.0	472.6

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Rain	0.0	59.1	31.0	71.3	60.0	133.2	26.0	0.7	0.0	0.0	0.0	4.5	0.0	0.0	0.0
et(interval)	0.0	26.0	18.5	34.1	58.8	62.6	48.7	22.1	18.0	11.1	1.8	9.3	1.5	6.1	3.3
et per day	0.00	0.81	0.66	1.26	1.63	1.84	2.71	2.76	3.61	2.21	0.61	0.67	0.19	0.20	0.11
eo(interval)	0.0	2.2	1.1	1.3	1.9	2.3	3.4	5.2	7.3	9.1	8.5	9.7	10.9	13.7	14.5
et/eo	0.00	0.38	0.59	0.97	0.85	0.79	0.80	0.53	0.50	0.24	0.07	0.07	0.02	0.01	0.01
cum rain	0.0	59.1	90.1	161.4	221.4	354.6	380.6	381.3	381.3	381.3	381.3	385.8	385.8	385.8	385.8
cum eo	0.0	69.3	100.5	135.6	205.1	284.0	344.6	386.4	422.7	468.2	493.7	629.0	715.8	1139.0	1588.3
cum et	0.0	26.0	44.5	78.6	137.4	200.0	248.7	270.8	288.8	299.9	301.7	311.0	312.5	318.6	321.9

CHAPTER VI

CONCLUSIONS AND SUGGESTIONS

Irrigation is one of the important strategies in the economy of Uzbekistan. Due to the arid climate of the region crops must be irrigated in most areas. According to the source of "Uzdaverloiykha, 2000" the total irrigated cropland is 4.277 million ha, including 1.625 million ha grain (38%), 1.496 million ha cotton (35%), 0.256 million ha orchard (6%) and, 0.898 million ha vineyards and other crops.

The water and land resources of Uzbekistan are the major natural factors of the sustained social and economic development of the Republic. However, these resources remain under continued anthropogenious stress. Being on the verge of depletion, they are still used inefficiently and in a wasteful manner. This negatively effects on the natural and economic resources of the Republic.

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.

Some 10-12 years back irrigation area expanded by factors of Amu-Darya (150%) and Syr-Darya (130%) river basin respectively. This required the diversion of ever increasing quantities of water. Uzbekistan's annual intake of water grew from 35 km^3 to 60-63 km^3. Water was continuously to be used highly inefficiently. This caused to lead waterlogging, soil salinization, decline of water quality and also have resulted by the aggravation of the Aral Sea status. 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.

There are six keys to improving irrigation efficiency:

- Reduce evaporation by avoiding mid-day irrigation and using under-canopy rather than overhead sprinkling;
- Avoid over-irrigation;
- Control weeds on inter-row strips and keep them dry;
- Plant and harvest at optimal times;
- Irrigate frequently with just the right amount of water to avoid crop distress;
- Reduce seepage losses in channels by lining them or using closed conduits

Our goal is to resource our limited available amount of water as efficient as possible. It means increase productivity of use of water by condition like "More crop per drop". Control of all production input components coupled with good management of the on-farm natural resources is the key to produce "More crop per drop". When water is not limited, the emphasis is to maximize production per unit of land. When water is limited, the emphasis shifts to maximizing production per unit of water. The optimal (most economical) irrigation level lies between these two productivity limits.

In this Dissertation the study involves critical review of irrigation practices in the country and also improves upon the yield from irrigated agriculture as well as the entire degradation of soil and environment. Overuse of irrigation water at the farm level, although partly recoverable at the basin level, involves substantial losses both in evaporation, water quality, and aquifer sustainability. This is a major problem that involves both technical and socio-economical dimensions.

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