ENVIRONMENTAL IMPACT OF IRRIGATED AGRICULTURE IN UZBEKISTAN

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree
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IRRIGATION WATER MANAGEMENT

By

QAHRAMON JUMABOEV

WATER RESOURCES DEVELOPMENT TRAINING CENTRE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)
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CANDIDATES DECLARATION

I hereby certify that the work which is being presented in this dissertation entitled **" ENVIRONMENTAL IMPACT OF IRRIGATED AGRICULTURE"**, in my partial fulfillment of the requirement for the award of the degree of Master of Techmology in IRRIGATION WATER MANAGEMENT (IWM), submitted in the department of Water Resources Development Training Center (WRDTC), Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from June 2003 to June 2004 under the supervision of **Professor Raj Pal Singh**, ***Professor WRDTC*** and **Dr. Deepak Khare**, ***Associate Professor WRDTC, Indian Institute of Technology, Roorkee.***

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

June, 2004 QAHRAMON JUMABOEV

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

PROFESSOR RAJ PAL SINGH,
PROFESSOR, WRDTC,
INDIAN INSTITUTE OF TECHNOLOGY,
ROORKEE

DR. DEEPAK KHARE,
ASSOCIATE PROFESSOR WRDTC,
INDIAN INSTITUTE OF TECHNOLOGY,
ROORKEE

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Qahramon Jumaboev

Abstract

Land and water are the most important natural resources and are regarded as the permanent assets in the service of mankind. It is important that these resources must be used wisely so that benefits from them are as far as possible, left undiminished for long periods. Accordingly irrigation, drainage and reclamation projects must be planned to achieve sustained high productive irrigated agriculture.

In arid and semi-arid regions, irrigation provides the main source of water for agriculture. But as the essence of successful irrigated agriculture is the maintenance of favorable balance of moisture and salts for plant growth in the soil root zone, water table should not as a result of irrigation be permitted to rise and remain in the root-zone for long periods and adversely affect agricultural production. Drainage is therefore an essential component of irrigation, which can remove excess irrigation water and salts for the root zone and thereby can create conditions favorable to plant growth.

Irrigation plays an important role in the economy of Uzbekistan. Owing to the arid climate of the region, crops must be irrigated in most areas. Total irrigated cropland is 4.274 Mha, which includes 1.624 Mha (38%) grain, 1.495 Mha. (35%) cotton, 256440 ha. (6%) orchard and vineyards, 897540 ha. (21%) others. All irrigation is full control irrigation, mainly using surface water. Main irrigation method is furrow irrigation. Pressurized irrigation systems only used in experiment fields and greenhouses.

During 1970-1989 irrigated area expanded by factors of (150%) and (130%) in the Amudarya and Syrdarya 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, in general water has been used inefficiently. In Uzbekistan, farmers withdraw an average of 14,000 m^3 of water per hectare for irrigation, whereas rates in countries such as Egypt and Pakistan for efficient irrigation average around 9000-10000 m^3.

Excessive emphasis on the extension of irrigation systems and construction of many medium and small-scale reservoirs have created problems for both the environment and system efficiency; in particular substantial water losses and surplus of irrigation caused by implementation of misappropriate irrigation technologies, have led to water logging, soil salinization, 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 3.722 Mha, out of which 1.080 Mha is the land of medium and highly salinized.

The present salinization and water logging tendencies have been damaging crops and the yield is reducing rapidly. All the above-mentioned facts are consequence of using misappropriate irrigation practices in the country.

In the dissertation entitled "Environmental Impact of Irrigated Agriculture in Uzbekistan" an attempt has been made to discuss main causes of waterlogging and salinization in the country. Irrigation practices of semi arid and arid countries reviewed withdraw lessons to Uzbekistan. Preventive/remedial measures such as surface drainage, subsurface drainage, mole drainage, physical and mechanical methods recommended to improve salt affected areas.

CROPWAT software has been used to calculate crop water requirement for the main crops of the Country. Also Water and Salt Balance Model has been applied to cotton growing field of Syr-Darya region to simulate daily salt and water balance in the root zone.

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LIST OF ABBREVIATIONS

GEF	Global Ecological Fund
MAWR	Ministry of Agriculture and Water Resources
IFAS	International Fund of Aral Sea
RWG	Regional Working Group
NWG	National Working Group
BVO Syr-Darya	Basin Water Management Organization for Syr-Darya
BVO Amu-Darya	Basin Water Management Organization for Amu-Darya
ICO Energy	Incorporated Control Office of the Central Asia
SDPS/GRES	State District Power Station
ME	Ministry of Energy of Republic of Uzbekistan
MF	Ministry of Finance of Republic of Uzbekistan
MLI	Meliorative Land Improvement
RIL	Rehabilitation of Irrigated Land
NPAEP-2000	National Plan of Actions on Environmental Protection of Republic of Uzbekistan
UzNIIHI	Uzbek Scientific Research Cotton Growing Institute
Uzgipromeliovodkhoz	Uzbek State Design and Survey Research Institute on designing meliorative, water management objects, development of large irrigation areas and Aral Seaside objects, named after A.A.Sarkisov
FAO CROPWAT	Program of Crops Requirement Calculation
WARMAP	TACIS Project: Agriculture and Water Resources Management in Central Asian Republics
OD KMC	Operating Department of Karshi Main Canal
ICWC	International Coordination Water Commission

TASIC	EU Program on Technical Assistance
FSK	Former state and collective farm (kolkhoz and sovkhoz)
I&D	Irrigation and Drainage
NPV	Net Present Value
O&M	Operation and Maintenance
RESP	Rural Enterprise Support Project, Uzbekistan
WUA	Water Users' Association
Ruz	Republic of Uzbekistan

CHAPTER-1

INTRODUCTION

1.1 General

The importance of environmental protection and conservation measures has been increasingly recognized during the past two decades. It is now generally accepted that economic development strategies must be compatible with environmental goals. This requires the incorporation of environmental dimensions into the process of development. It is important to make choices and decisions that will eventually promote sound development by understanding the environment functions. Protection of the Quality and Supply of Freshwater, underscored the importance of environmental protection and conservation of the natural resource base in the context of water resources development for agriculture and rural development.

Much of the land currently under agriculture is deteriorating due to inappropriate planning, implementation and management. Natural resources, particularly soil and water, are being seriously affected. Soil erosion, desertification, salinization and waterlogging reduce productivity and jeopardize long-term sustainability. Agricultural expansion programs have often encompassed marginal land in many parts of the world. Wise management of the environment requires an ability to forecast, monitor, measure and analyze environmental trends and assess the capabilities of land and water at different levels, ranging from a small irrigated plot to a catchments. Adoption of environmental impact assessments (EIAs) will enable countries to plan water and land use in an integrated manner, avoiding irreversible environmental damage. Contrary to common perceptions, this would lead to higher economic benefits and sustainable resource use.

Irrigation and drainage projects invariably result in many far-reaching ecological changes. Some of these benefit human population, while others threaten the long-term productivity of the irrigation and drainage projects themselves as well as the natural resource base. The undesirable changes are not solely restricted to increasing pollution or loss of habitat for native plants and animals; they cover the entire range of environmental components, such as soil, water, air, energy, and the socioeconomic system.

1.2 Effects of water logging and soil salinity in Agriculture

Land and water are the most important natural resources and are regarded as the permanent assets in the service of the mankind. It is important that these resources must be used judiciously so that benefits from them are as far as possible, left undiminished for long periods. Accordingly, irrigation, drainage and reclamation projects must be planned to achieve sustained high productive irrigated agriculture.

In arid and semi arid regions, irrigation provides the main source of water for crops. But as the essence of successful irrigated agriculture is the maintenance of a favourable balance of moisture and salts for plant growth in the soil root zone, water table should not as a result of irrigation be permitted to rise and remain in the root zone for long periods and adversely affect agricultural production. Drainage is therefore an essential compliment to irrigation so that it can remove excess irrigation water and salts for the root zone and thereby can create conditions favourable to plant growth.

An agricultural land is said to be waterlogged when high water table affects its productivity of fertility. When the water table is within 1.5m to 2.1m below the ground level, the land is considered as waterlogged. The effects of water logging in agriculture are narrated below

- Difficulty in cultivation

- Growth of wild aquatic plants

- Reduction maturity period

- Adverse effect on community health due to damp climate

- Rise of salt due to upward flow of water.

The harmful salts are shifted from inside of the earth to the surface. This salinity reduces the fertility of soil.

Salt is saver of foods but the scour age of agriculture, when in excess it kills growing plants. Soluble salt contamination of soil has caused problems primarily in the semi arid regions of the world, which have inadequate rainfall means little or no more chance for excess salt to be leached from the soil. The effect of salt devastation is apparent in many areas and becoming increasingly prevalent and serious as land use intensifies and water becomes more limiting and increasingly polluted with soluble salts intensive agriculture and expansion into arid lands means more irrigation with water of increasing salt content. Modern population densities make it important to use or reclaim salty lands and to avoid any further salt damage land now in use.

Salt soils affected have been given descriptive and even colourful names like white alkali, black alkali, Red, etc. These names come from the land surface appearances as soils become salt contaminated virtually eliminating all plant growth as salt concentrations increase.

Soluble salts as referred to in soil science, are those inorganic chemicals that are more soluble than gypsum, which has a solubility of 0.241/10ml. Water at 0 c. Most soluble salts in soils are composed of cautions viz Na +, Ca++, Mg++ anions viz Cl*, SO4 and HCO. Usually smaller quantities of K+, NH4+, NO3 and CO3 also occur. The cations and anions that form soluble salts come from dissolved minerals as they weather. If in the area precipitation is too low to provide leaching water (<15) annually, most or all the salts remain in soil. Now incoming water brings more dissolved salts to add to the accumulation as the newly added water, in turn, evaporates. After many years of salt additions soils with high salt concentration develop, because a high rate of precipitation on permeable soil removes soluble salts by leaching, most salty soils occur in arid regions and poorly drained soils of sub humid regions.

Many salt accumulated in parent materials million of years ago. Salt layers are frequently observed in shale, which are sedimentary rock developed from clay deposits in ocean and seas now exposed as land surfaces some farming salty soils. Salt in other soils are currently increasing where seepage waters do not runoff but evaporate and where irrigation is done with minimal water and no leaching occurs.

1.3 Need of Study

There is a great need in an integrated, holistic approach to conserve water and prevent soil salinization and waterlogging while protecting the environment and ecology.

Firstly, source control through the implementation of more efficient irrigation system and practices should be undertaken to minimize water application and reduce deep percolation. Unavoidable drainage water should be intercepted, isolated and reused to irrigate a succession of crops of increasing salt tolerance, possibly including eucalyptus and halophyte species, so as to reduce drainage water volumes further to conserve water and minimize pollution while producing useful biomass. Conjunctive use of saline groundwater and surface water should also be undertaken to aid in lowering water table elevations; hence to reduce the need for drainage and its disposal, and to conserve water.

To achieve these goals, new technologies and management practices must be developed and implemented. Efficiency of Irrigation must be increased by the adoption of appropriate management strategies, systems and practices and through education and training. Existing Computer software and models should be broadly used to simulate water and salt balance in irrigated agriculture in order to make wise decision for further action.

1.4 Objective and scope of study

Republic of Uzbekistan has been chosen to study Environmental Impacts of Irrigated Agriculture. Agriculture is backbone of Uzbek economy and more than 60% of total population depends on irrigated Agriculture. Since the collapse of the Soviet Union, both government budgets and farm incomes have fallen dramatically in the country. Water management institutions have weakened and infrastructure maintenance has in many places came to standstill irrigation and drainage is beginning fall part.

Problem with irrigation infrastructure have compounded such problems by prejudicing soil quality. Land have become salinized and waterlogged after deterioration of irrigation and drainage infrastructure. In Uzbekistan land subjected to salinization is 3.722 Mha. of 4.277 Mha. of existing irrigation area. Salinization and water logging processes have irreversible damage to the crop production losses estimated in millions of tons. Moreover aggravated the Aral Sea area.

Until 1960 the Aral Sea covered an area of about 66000 km^2 with a volume of more than 1,000 billion cubic meters (BCMs). Inflow from the Amu-darya and Syr-darya rivers amounted to about 120 BCMs annually with precipitation about 6 BCMs and groundwater 5 BCMs. Annual evaporation from the Aral Sea was stable at about 50-53m.

Extensive irrigation schemes developed over 30 years (1960-90), which doubled total irrigated area, led to an increase in water diverted from the Amu-darya and Syr-darya rivers 63 BCMs to 117 BCMs reducing the inflow to the Aral Sea to only about 9-12 BCMs by 1990. Consequently sea level dropped 17m to its current level of about 36m and its surface area halved by about 50 %.

This large increase in irrigated areas also created serious environmental problems especially increased salinity of land and water. Increased basin – wide soil and water salinity, the disappearance of fresh water lakes and biodiversity, salt storms, desertification, poor quality drinking water and loss of fisheries. Moreover it created health problems such as deceases like anemia, cancer and tuberculosis and allergies.

The main underlying causes of the Aral Sea disaster namely the unsustainable use of land and water. Inefficient management of irrigation and drainage and insufficient investment in maintenance and rehabilitation of the infrastructure especially since 1990 have resulted in increased soil and water salinity and water logging throughout the basin. The main objectives of study include

(1) Determination of the extent waterlogged and salt affected soils in the country to address the absolute sense need for water and salt management in irrigated agriculture.
(2) Estimate the crop water requirement for effective development of irrigation.
(3) Study the various remedial measures on management of waterlogging and salinization taken elsewhere and recommend the most feasible ones.
(4) Simulation of daily water balance and soil salinity in the root zone with the help of computer models.

1. 5 Organization of the Thesis

The study is organized to achieve its objective in eight chapters.

Chapter-1 is an Introduction. It gives general information about Environmental Impact of Irrigated Agriculture such as effect of soil salinity and waterlogging on crop yields. Also it deals with the problem definition and objective of present study. Chapter-2 is Literature review, which deals water logging and salinity development in Irrigated agriculture especially in arid and semi-arid countries. Chapter-3 gives general information about study area. Chapter-4 is Data acquisition, which describes study area in detail. Chapter-5 deals with crop water requirement, methodology to calculate evaportanspiration and application of CROPWAT software to study area. Chapter- 6 is Water and Salt Balance Model (WASIM), methodology to use and simulation of daily salt and water in cotton growing field of Syr-Darya region of Uzbekistan. Chapter-7 Conclusion and recommendations.

CHAPTER 2
LITERATURE REVIEW

2.1 General

In a number of countries, irrigated agriculture has resulted in major environmental disturbances such as waterlogging and salinization, depletion and pollution of water supplies, especially groundwater, and increased health risks. The recreational, aesthetic and habitat values of many water systems and agricultural landscapes have also been degraded by improper irrigation development and practices.

Most of the problems of waterlogging and secondary salinization prevalent in irrigated lands and of associated water pollution have resulted from the excessive use of water for irrigation as a consequence of inefficient irrigation distribution systems and poor on-farm management practices and inappropriate drainage management

2.2 Water logging

When water tables rise, soils become waterlogged. This reduces yields, places a greater load on plowing and traction machinery, and compacts the subsoil. Waterlogging also contaminates drinking water sources with bacteria, salts, and agrochemicals. When drainage systems fail, water tables rise, and polluted drainage and irrigation water often mixes with shallow and even deep aquifers that supply household drinking water. Where piped water supply systems are available, they are in poor enough condition to be susceptible to infiltration from groundwater and bacteria from latrines. Many villagers use irrigation or drainage water for drinking. When irrigation water becomes scarce, it becomes more stagnant and salts more concentrated, thus affecting drinking water supplies.

2.3 Soil Salinity

A salinity problem exists if salt accumulates in the crop root zone to a concentration that causes a loss in yield. In irrigated areas, these salts often originate from a saline, high water table or from salts in the applied water. Yield reductions occur when the salts accumulate in the root zone to such an extent that the crop is no longer able to extract sufficient water from the salty soil solution, resulting in a water stress for a significant period of time. If water uptake is appreciably reduced, the plant slows its rate of growth. The plant symptoms are similar in appearance to those of drought, such as wilting, or a darker, bluish-green color and sometimes thicker, waxier leaves. Symptoms vary with the growth stage, being more noticeable if the salts affect the plant during the early stages of growth. In some cases, mild salt effects may go entirely unnoticed because of a uniform reduction in growth across an entire field.

Salts that contribute to a salinity problem are water soluble and readily transported by water. A portion of the salts that accumulate from prior irrigations can be moved (leached) below the rooting depth if more irrigation water infiltrates the soil than is used by the crop during the crop season. Leaching is the key to controlling a water quality-related salinity problem. Over a period of time, salt removal by leaching must equal or exceed the salt additions from the applied water to prevent salt building up to a damaging concentration. The amount of leaching required is dependent upon the irrigation water quality and the salinity tolerance of the crop grown.

Salt content of the root zone varies with depth. It varies from approximately that of the irrigation water near the soil surface to many times that of the applied water at the bottom of the rooting depth. Salt concentration increases with depth due to plants extracting water but leaving salts behind in a greatly reduced volume of soil water. Each subsequent irrigation pushes (leaches) the salts deeper into the root zone where they continue to accumulate until leached. The lower rooting depth salinity will depend upon the leaching that has occurred.

Following irrigation, the most readily available water is in the upper root zone a low salinity area. As the crop uses water, the upper root zone becomes depleted and the zone of most readily available water changes toward the deeper parts as the time interval between irrigations is extended. These lower depths are usually saltier. The crop does not respond to the extremes of low or high salinity in the rooting depth but integrates water availability and takes water from wherever it is most readily available. Irrigation timing is thus important in maintaining a high soil-water availability and reducing the problems caused when the crop must draw a significant portion of its water from the less available, higher salinity soil-water deeper in the root zone. For good crop production, equal importance must be given to maintaining amount of total soluble salts in a soil. To measure a soil conductivity a weighed soil sample is mixed with water to farm a saturated paste; the liquid is then removed by suction, filtrations and the conductivity of extract is measured in mmhos/cm. If the value is termed non-salty the concentration of salt with Ec value is calculated by the following formula (2.1):

$$\% \text{ Soluble salt} = 0.64 \times Ecs \qquad (2.1)$$

Exchangeable sodium percentage requires a laboratory measurement off all exchangeable cations and then a calculation of the percentage of them that are sodium by formula (2.2)

$$ESP = (\text{Exchangeable Sodium ion} / \text{Total exchangeable cation}) \times 100 \qquad (2.2)$$

2.3.1 Salt balance

The salt balance, equalling outgoing salt to incoming salt equal, is a part of handling salty land. Since salts are continuously added in applied water especially irrigation water, some leaching must be caused by addition of more water than needed just to wet the plant root zone of the soil to maintain the salt balance. This additional water needed for leaching, over that water needed to wet the profile, is called the leaching requirement (LR). LR formula (2.3) is given below

$$LR = Eciw / Ecdw \qquad (2.3)$$

Where,

Eciw – Electrical conductivity of the irrigation water,

Ecdw - Electrical conductivity of the saturation extract at which a 50% decrease in yield is obtained in uniformly saline soils.

2.3.2 Mode of formation of Saline Soils

Salinity of irrigation water can cause a build-up of salts in the root zone, particularly if the internal drainage of soils is restricted and leaching, either due to rainfall or applied irrigation, is inadequate.

- Saline seeps are the result of excessive leaching that result from reduced evaportanspiration after a change in land use from natural forest vegetation to cereal grain crop farms, or after a shift in the cropping pattern such as the introduction of a fallow season in grain farming system.

- Salinity problems are also caused by the ingress of seawater through tidal waves, underground aquifers or through wind transport of salt spray.

- In every river basin, prior to the introduction of irrigation, there exists a water balance between the rainfall on the one hand and the steam flow, groundwater level and evaporation and transpiration on the other hand. This balance is disturbed when large additional quantities are artificially spread on the land for agriculture. Moreover, evaporation from the groundwater through the soil surface will raise the salinity of soil surface and root zone. Such salinization problems can be more severe when the salinity of groundwater is high, as is usually the case in arid region. In addition, the same trend with the depth of water table, once the water is within 1 to 2 meter from the soil surface, can contribute significantly to evaporation from the soil surface and therefore to the root zone salinization.

2.3.3 Anthropogenic Causes

Man, through poor soil and water management and agronomic practices, encourages soil degradation. Some of these practices are listed below:

- Excessive application of irrigation water;
- Irrigation with poor quality water;
- Poor leveling;
- Use of heavy farm machinery that leads to soil compaction and poor drainability;
- Excessive leaching during faulty reclamation techniques; and
- Adherence to improper cropping pattern and rotation.

2.3.4 Effect of Salinity on Crop Yields.

Reduced productivity due to presence of excessive salts in root zone is a worldwide phenomenon in arid and semi-arid regions. Irrigation induced salinization and water logging processes and their influences crop yields has been studied in many countries. In India K.Kdetta (ICAR) and C De.Jong (ILRI) have carried study out Northwest region of Haryana. In Northwest India, a considerable recharge to the groundwater leads to water logging and salinization. In several sub-areas groundwater is mined, water tables fall and salts are added to the root zone because a high proportion of Irrigation water is derived from pumped groundwater of poor quality. Out of 1 million hectares of irrigation induced waterlogged saline area in Northwest India, approximately half a million hectares are in the state of Haryana. Crop yields decreased in area due to salinization and water logging, net present value of the damage in Haryana is about Rs.23900/ha. Drainage requirement with the aim of facilitating the leaching of excess salts from the root zone and of providing protection to the reclaimed/good lands in Haryana. It was concluded that drain spacing of 65 to 75 m with drain depth of 1.4 to 1.75 m for the semi-arid parts of the state and drain spacing of as wide as 100m with a drain depth of 1.75m for the arid parts can provide sufficient drainage.

The chambal command area, Rajasthan is located in the subtropical and semi arid zone. It represents an area of 3.85.000 ha out of which 2.29.000 ha are irrigated. Irrigation was introduced in the year 1960. The annual rainfall in the CCA ranges from 600 to 1400mm with an average 850mm.Approximately 90 % of rainfall occurs during monsoon season (July to September). Waterlogging and soil salinity occurs as scattered patches in different parts in CCA. The severity of salinity varies from place to place and it effects on agriculture production vary with the crop. There are areas, which have gone out of cultivation due to severe salinity problems. Important crops grown in the area include: mustard, wheat, maize, paddy, sugarcane, pulses and soybean. Crop yield has been hampered because of salinity and waterlogging. The Rajasthan Agriculture Drainage Research Project (RAJAD) was introduced in the year 1992 to control the problem of salinity and waterlogging in the Chambal command area. Subsurface drainage has been adopted as the principal technology to improve and control the salinity and waterlogging.

Ahmed Gehad (EALIP) project reported in Egypt land subjected salinization because of poor soil and water management practices. The majority of salt effected soils in Egypt are located in the Northern-Central part of the Nile delta ant on its Eastern and Western sides. Nine hundred thousand ha suffer from salinization problems in cultivated irrigated areas. In some coastal areas the extraction of groundwater has proceeded to the point where intrusion of saline seawater into aquifers has degraded the quality of these resources. Continued irrigation with low quality groundwater has contributed to the expansion of land salinization. It seriously affected crop yields. Salt effected soil has been leached continuously and intermittently in Egypt to get target salinity level.

Dryland Salinity management project reported that in Australia irrigated agriculture also affected by salinization and water logging problems. Murray is one of most important river basin in Australia. Current farming systems, even when implemented with best practice, cannot control salinity.

DFID Plant and Sciences research program reported that in Pakistan, losses from the Canal system, which constitute about 60% of the canal diversion, added a new increment of groundwater recharge, which gradually raised the groundwater levels. This trend of rising water table and generally poor drainage conditions led to progressive water logging and salinization of the soil.

James E.Ayars (US Department of Agriculture) reported that two field studies were conducted on the west side of San Joaquin Valley of California to demonstrate potential for integrated management of irrigation and drainage systems. The first study was used modified crop coefficient to calculate the irrigation schedule controlling the operation of subsurface drip system irrigating cotton in an area with saline groundwater at a depth of 1.5m. Use of the coefficient resulted in 40% of the crop water requirement coming from the groundwater without a loss in lint yield. The second study evaluated the impact of the installation of controls on a subsurface drainage system installed on a 65-hectare field. As a result of the drainage controls, 140 mm less water was applied to the tomato crop without a yield loss. A smaller relative weight of tomatoes classified as limited use, was found in the areas with the water table closest to the soil surface.

K. Lamsal, Guna N. Paudyal, M. Saeed (Water Engineering and Management Program, AIT) applied model for assessing impact of salinity on soil water availability and crop yields. The salinity condition in the rootzone hinders moisture extraction from soil by plants, because of osmotic potential development in soil water due to presence of salts, which ultimately decreases transpiration of plants and thereby affects crop yield. Therefore, an effort was made to quantify the impact of salinity on soil water availability to plants. The movement of salts under irrigation and evaportanspiration regimes in rootzone of soil profile was studied throughout the growing season of wheat crop with adopting exponential pattern of water uptake. A model was developed to analyze soil water balance to find out moisture deficit because of salinity. A non-linear relationship was formulated between moisture content and salt concentration for simultaneous prediction. The Cranc-Nicolson method to finite differencing was used to solve the differential equations of soil water and solute transport. The effect of various salt concentrations on transpiration and relative yield. Relationship among salt concentration, matric potential, moisture deficit and actual transpiration were also established to provide better understanding about impact of salinization and to provide guidelines for obtaining better crop yields in saline soils.

2.4 Management of salt affected and waterlogged lands.

Since there is usually no single way to control salinity and sodicity, several practices should be combined into systems that function satisfactory. This means that development of a technological package, which consists of individual practices, is to be implemented as a package. This package should be field tested under farmer conditions.

The management practices and human aspects related to the reclamation and sustainable use of salt affected soils can be summarized as follows:

2.4.1 Hydro technical methods

Methods adopted to remove excess salts from root zone include:

- Remove salt accumulation on the soil surface by mechanical means.
- Leaching by application of excess water allowing it to pass downward to leach salts from root zone.

2.4.2 Leaching methods

Continues maintained water at depth of 10cm by frequent additions of water to replace amounts lost by evaporation and drainage.

Intermittent added in quantities sufficient to dissolve soluble salts. In heavy clay soils with low k (hydraulic conductivity) values, using intermittent leaching after deep ploughing and sub soiling is mainly due to clay swelling and water logging conditions thus leaching at different intervals lead to drying soils thus increase k values relatively.

2.4.3 Surface drainage

Surface drainage should be considered as an option where ever circumstances cause the water table to rise to the surface during a critical time of the year. If the hydraulic conductivity of the soil is so low (<0.01 m/day) that no subsurface drainage with economically justifiable is possible, one should use a surface drainage system of furrows and small ditches of 40-45 cm, possible combined with bedding of the soil. The bedding system can be used to grow vegetables or tree crops. Beds are mostly made manually. In this soil, water begins to accumulate at the surface when the irrigation exceeds the ability of the soils to accept water. The law hydraulic conductivity and infiltration rate of most clay makes that this situation is rather common. The types of surface drainage are bedding, furrow and ditch systems.

2.4.4 Subsurface drainage

Subsurface drainage is usually based upon system of buried perforated pipes that control the ground water level. Buried pipes have the advantage of not interrupted mechanized farming. Further they require less maintenance than open ditches and do not lead to loss of land. When the hydraulic conductivity is more than 0.1 m/day, the soils are highly responsive to conventional pipe drainage. The major problem of pipe drainage of heavy clay soils with hydraulic conductivity less than 0.1 m/day is that, to be effective, the spacing usually needs to be narrow, which may be uneconomic. In practice, the spacing is often determined using local experience, and it varies between 10 and 20m in heavy clay soils of medium hydraulic conductivity (> 0.1 m/day). If the layer with higher hydraulic conductivity is at a great depth (>2m) and the top layer is of very law hydraulic conductivity, the drainage problem could be solved by vertical drainage.

2.4.5 Mole drainage

Mole drainage is the construction of an underground channel without digging a trench and without using tubes. Mole drainage is unlined circular soil channels, which function like pipe drains. It is used mainly in soils with dense, impervious, fine textured subsoil in undulating areas. The problem is not the control of a ground water table (which may be very deep), but the removed of excess water from the field surface or from the topsoil. Mole drainage therefore, can be considered an intermediate system between surface drainage and subsurface drainage.

Moling combined with open field drains can be highly recommended as an auxiliary drainage treatment in low level clay salty soils with a saline water table to raise soil productivity.

2.4.6 Physical methods

Several mechanical methods have been used to improve infiltration and permeability in the surface and root zone and thus to control saline and sodic conditions.

Land leveling makes possible for a more uniform application of water for better leaching and salinity control. For coarse leveling, simple scrapers of levelers may be used, while for fine leveling, use of laser guidance has recently been adopted which is more effective (precision 1/ to 3 cm). Land leveling causes a significant amount of soil compaction by the weight of heavy equipment and it is advisable to follow this operation with sub soiling, chiseling or ploughing to break up the compact layers and restore or improve water infiltration.

Tillage is another mechanical operation that is usually carried out for seedbed preparation, breaking up surface crusts and soil permeability improvement, but if improperly executed might form a plough layer or bring a saline layer closer to the surface. Heavy machinery traffic and wet soil condition should be avoided.

Deep ploughing is most beneficial on stratified soils having an impermeable layer. It loosens the soil, improves the physical condition of this layer and increases air space and hydraulic conductivity. Deep ploughing in sodic soils should be carried out after preliminary correcting the sodicity; otherwise the mechanical disturbance may cause collapse of the soil structure. Sub soiling opens channels to improve soil permeability. The shape of the subsoiler's shanks and the space between shanks depend to a large extent on the depth, thickness, hardness and continuity of the impervious layer. Sub soiling leaves salts or grooves or cracks in the compacted layers, which help air and water movement.

2.4.6.1 Sub soiling

Soil compaction is one of the major soil constraints affecting crop production. The main purpose for sub soiling is to decrease the degree of compaction and enhance drainage and filtration.

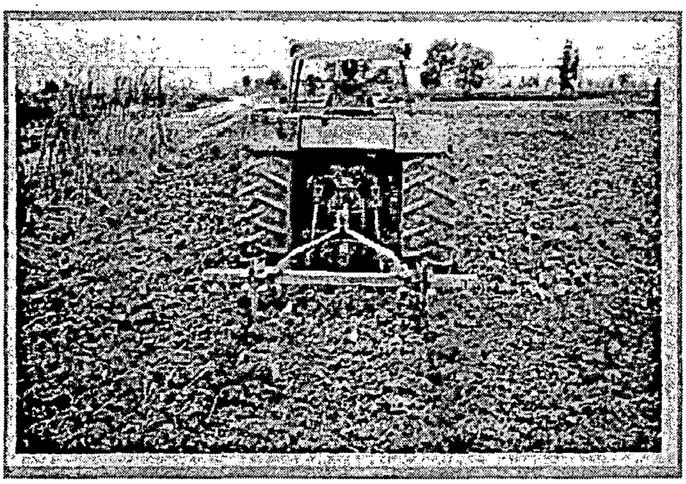


Figure 2.4.6.1 Sub soiling

2.4.6.2 Gypsum application

The common treatment for saline soils is to apply calcium ions in the form of gypsum. The physical and chemical properties of the soils are improved directly in the root zone as well as the biological improvement of the soil.

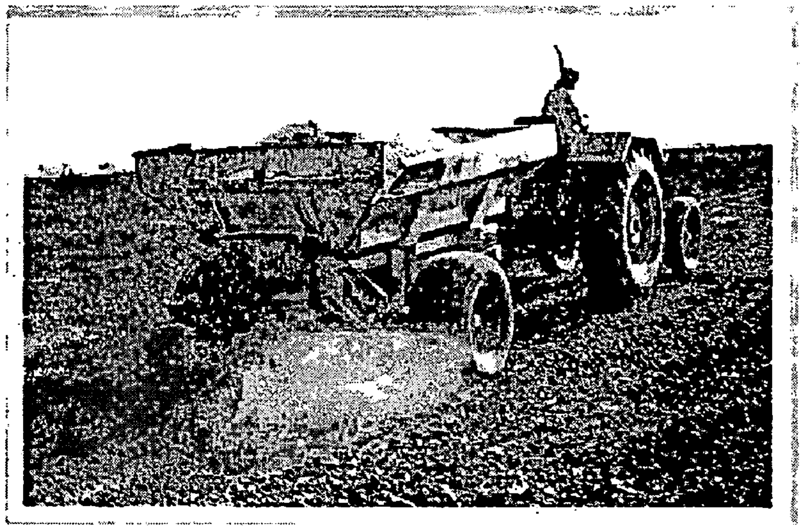


Figure2.4.6.2 Gypsum application

2.4.6.3 Reshaping of field drains

The aim of reshaping of field drains is to lower the water table level, consequently optimizing soil physical environment.

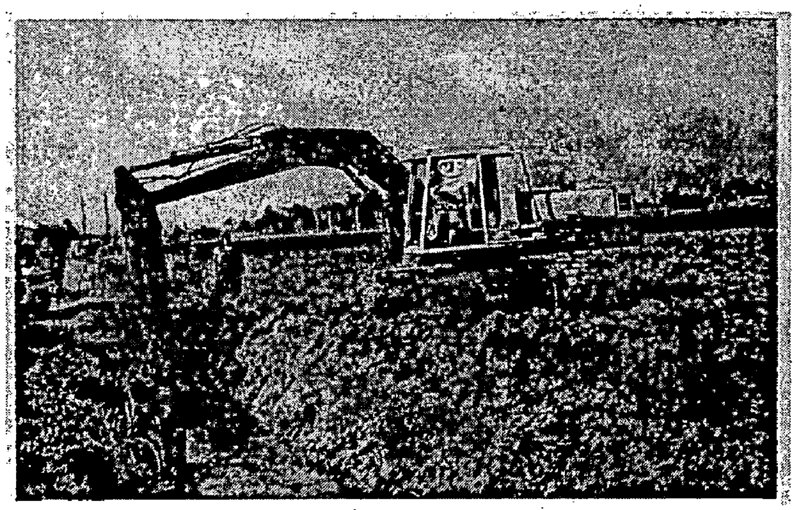


Figure 2.4.6.3 Reshaping of field drains

2.4.6.4 Land leveling

Precision land leveling is recommended to produce an ideal land surface. Proper leveled fields compared to non leveled fields results in a yield increase between 10 and 25%, a reduction of irrigation time of 25 - 50% and a cropping intensity up to 15 % or higher.

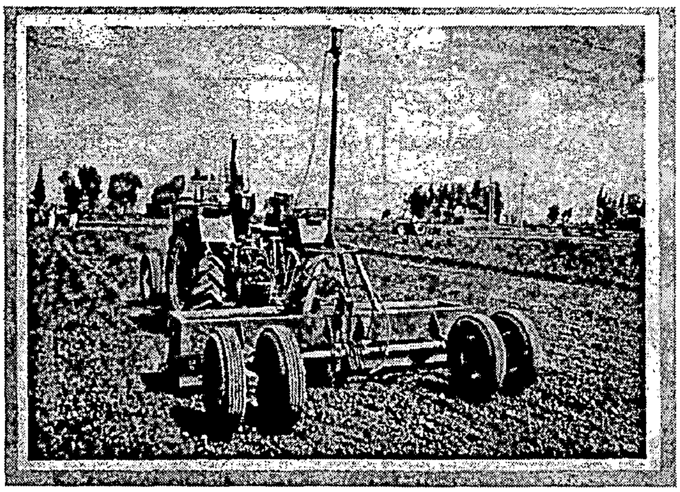


Figure 2.4.6.4 Land leveling

CHAPTER 3

STUDY AREA

3.1 Country background

Territory:

"A territory is the space of the Earth, internal and coastal waters, including air space over them with the definite borders".
V.Lopatin, L.Lopatina "Russian definition dictionary"

Uzbekistan is located in Central Asia, geographic coordinates: 41 00 N, 64 00 E. Total area: 447.400 sq km, including water 22,000 sq km and land 425, 000 sq km. Area slightly larger than California. Land boundaries are total: 6,221 km. Uzbekistan borders with Afghanistan 137 km, Kazakhstan 2,203 km, Kyrgyztan 1,099 km, Tajikistan 1,161 km and Turkmenistan 1,621 km. Uzbekistan includes the southern portion of the Aral Sea with a 420 km shoreline. Political map of Uzbekistan is given in Figure 3.1

The majority of Uzbekistan is desert steppe broken by fertile oases along the banks of two great rivers, the Amu-darya and Syr-darya. Uzbekistan has dry winters and no more than eight inches of rainfall per year, but its hot, dry summers extending from May to October, and water for irrigation produce excellent growing conditions for crops such as cotton, tobacco, fruits, and vegetables.

The fertile Ferghana Valley boasts 6 million people, including large minorities of ethnic Kyrgyz, Tajiks, and Russians. The Ferghana Valley is split between three countries: Uzbekistan, Kyrgyzstan and Tajikistan, and is home to a very diverse ethnic mix. The Ferghana Valley produces a major share of the country's cotton and grain crops and contains numerous manufacturing plants, as well as natural gas and oil fields.

Uzbekistan's central region consists mostly of desert, broken by the oases of the Zarafshan River, Qarshi Steppe, and Surkhandarya River. This region is best known for the ancient Silk Road cities of Samarkand and Bukhara, which together claim more than 600,000 inhabitants and comprise the heart of Uzbekistan's tourism industry. Central Uzbekistan is also home to the mining center of Navoi and contains the majority of Uzbekistan's gold and other mineral deposits, as well as the largest natural gas and oil fields. Irrigation along the Zarafshan and other rivers provides a basis for agriculture. The ecologically damaged Aral Sea and the vast deserts surrounding it characterize western Uzbekistan and the autonomous Republic of Karakalpakstan. Over use of the rivers that feed the Aral Sea have led to a severe reduction in the sea's size, destroying the traditional fishing culture of the region. The salt and sand that the receding sea has left behind makes the surrounding land useless for agriculture as well.

Fig 3.1 Political map of Uzbekistan

A combination of plains and mountains characterizes the country's landscape. The Plateau Ustyurt, the lower reaches of the Amudarya and the Kyzylkum Desert form the plains of the southwest and northwest. An old bed of the River Amudarya follows along the western edge of the plain. The southern outskirts of the Kyzylkum, or Sundukli sands, the Karshy Steppe and the eastern part of the Hungry Steppe are a kind of a transitional zone to the hilly areas. Approximately a third of the Republic's territory consists of mountains and foothills to the east and southeast, where they merge with the mountain ranges of neighboring Kyrgyzstan and Tajikistan. The Urgam, Pskem, Chatkal, Turkestan, Zarafshan and Gissar Mountain Ranges close to each other in the country. They form a cluster of mountain chains, gradually diminishing in size to the northwest and southwest. The mountains of Uzbekistan form part of the Western Tien Shan and Gissaro-Alay Ranges. The highest point reaches 4,643 meters.

Rather large depressions are located between the mountains, for instance, the basins and hollows of Sanzaro - Nuratin, Samarkand, Kashkadarya, Surkhandarya, Ferghana, as well as the Tashkent and Hungry Steppe Plain. The largest of them is the Ferghana Basin, more widely known as the Ferghana Valley (370 km long and 190 km wide). From three sides it is surrounded by mountains and is open in the west.

The Ferghana Valley lies between the Kuramin and Chatkal Ranges in the north and northwest, and the Alay and Turkestan ranges in the south. In the northeast, the Ferghana Range limits it. Toward the furthest eastern point it becomes much more narrow and joins a hilly depression of the Hungry Steppe.

The Ustyurt Plateau, the lower reaches of the Amudarya, and the Kyzylkum Desert make up the plains of Uzbekistan. The prevailing monotony of the plains landscape is disrupted in the Kyzylkum Desert by much small upland, a particular characteristic of the area. In the center and southwest, there are the higher uplands of Bukantau, Altintau and Kok-patas.

A high degree of seismic activity, up to 8-9 points on the Richter scale, is typical of the country. Among the most destructive earthquakes that ever struck the country were those in Ferghana (1823), Andijan (1889 and 1902) and Tashkent (1866 and 1868). The capital of the Republic also lies in a seismically active zone. The highly destructive earthquake of April 26, 1966 caused damage to many districts, and particularly to the center of the city. 700 tremors were recorded in Tashkent within the year of 1966.

3.2 Population

In the beginning of 2000, the population of Uzbekistan was 24.5 million people, which was twice the size of the population 25 years ago. The natural and climatic conditions of the republic account for the concentration of the population chiefly in the oases. Among the densely populated regions are the Ferghana Valley, the Khorezm region and the Tashkent region. The most highly populated area is the Andijan region, where the population density was 484 people per km^2. In 1996 the average population density was 52.7 people per km^2.

3.3 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:

- National water resources include flow of the local rivers, underground and return water formed within one country;
- Transboundary water resources are water (river, underground, return) located on the territory of two or more countries, or deposits connected hydraulically with Transboundary Rivers, and also resources of artificial/anthropogenic reservoirs.

The main sources of surface flow are the rivers Amu-Darya and Syr-Darya, their tributaries and the rivers Kashkadarya and Zarafshan. Map of the region are given in appendix 2.

3.4 Land Resources

"With intensive use of land there is a necessity to think not only of how to take from it more, but simultaneously take care of its fertility".
Bogolyubov S. "Ecology".

The available land of the republic is 44.410 Mha of which about 12.000 Mha are potentially suitable for irrigation, including 4.277 Mha of existing irrigation area. The other 30.9 Mha is desert pastures, mountains, sandy soils, etc. More than 57% of the currently irrigated area is concentrated in the desert and semi desert zones in naturally undrained land, which is subject to natural and secondary salinization. Remaining 43% falls to the soil of high-altitude zones.
The major part of the irrigated area of the republic is subject to degradation processes among which the most spread categories are as follows:

- Secondary salinization over the area 2.111Mha due to inadequate drainage, inefficient water use, etc.
- Gypsum of the soil over the area of 0.377mha;
- Low humus content land occupying more than 40% of total irrigated area;

- Eroded soil of piedmonts and low mountains (up to 8% of the total area) and deflation of desert land (more than 2.0 Mha). Polluted soil of irrigated areas adjoining to industrial cities. Moreover, aerosol transport of salt and dust from the dried bed of Aral Sea is a serious problem.

Current trend of soil degradation cause further loss of organic substance, and, therefore, soil fertility and destruction of natural tools regulating irrigated land productivity.

3.5 Irrigation

The history of irrigation started more than 2500 years ago in the seven natural oases in Uzbekistan: (1) Tashkent valley in the northeast of the country; (2) Fergana valley in the east; (3) Zeravshan valley in the east-central part; (4) Kashkadarya valley in the southeast; (5) Surkhandarya in the southeast; (6) Khorezm in the west-central part; (7) Karakalpakstan in the northwest.

At the beginning of twentieth century, about 1.2 Mha were irrigated in Uzbekistan. Large-scale development started in the late 1950s, when the Soviet Union decided to specialize Uzbekistan in the production of cotton. Modern irrigation techniques were then developed in the Hunger steppe in the central part of the country, in the Syr Darya basin, and in the Karshi steppe in the southeast of the country in the Amu Darya basin. In 1994, irrigation covered almost 4.3 Mha or about 82% of the cultivated land.

3.6 Waterlogging, salinity and drainage development

The two major land quality problems in the country are the interrelated issues of salinity and waterlogging caused by high groundwater levels. In 1994, only 50% of the irrigated land was classed as non-saline by Central Asian standards (toxic ions represent less than 0.5% of total soil weight). In the upper reaches of the Amu Darya and Syr Darya basins, less than 10% of the land is saline or highly saline, while downstream (especially in Karakalpakstan) about 95% of the land is saline, highly saline or very highly saline. Salinity is closely related to drainage conditions. Moreover, since 1990, a reduction in the quantity of water allocated to each farm, lower water quality, and the decay of companies responsible for maintaining the drainage network have resulted in increased salinization. Though loss of crop production due to soil salinization is important, salinized land is generally still cultivated.

About 3.3 Mha of irrigated land would require man-made drainage. Only 2.8 Mha are currently equipped with drainage infrastructure. Most of the drainage systems are open drains. Vertical pumping drainage is carried out on 401 000 ha, mainly on clay soils. In the newly reclaimed areas (Hunger and Djizak steppes in the Syr Darya basin, Surkhan-Sherabad and Karshi steppes in the Amu Darya basin), drainage is mainly subsurface drainage. The total length of main and inter-farm collectors is about 30 000 km, while the on-farm collector-drainage network extends for about 110 000 km.

CHAPTER-4

DATA ACQUISITION

4.1 Climate

The climate of Uzbekistan is extreme continental, arid and with abundance of solar radiation, slight cloudiness, and poor precipitation. Mean annual amount of precipitation in the valley ranges from 100-150 mm (desert) to 200-400 mm (foothills). Total annual evaporation varies from 900 mm in the Aral Sea coastal area, up to 1200 – 1500 mm/year in the south of the republic. Annual precipitation map is given in appendix-2. Being located far from ocean, it also has a strongly continental climate. High temperatures characterize the climate in summer (abs. max. 42-47° C in the plains and 25 – 30° C in the mountainous zone in July) and low mean temperatures in winter (- 11° C in the north and to +2 or – 3 ° C in the south on January). Climate data from 1980 to 2001 is given in appendix-3. This continental climate, with its contrasts and dryness, places the south of Uzbekistan area in the Asian-continent subtropics climate zone. In Uzbekistan, some 2500 to 3060 hours per year of sunshine is typical. In terms of duration of sunshine from May to October, Uzbekistan significantly surpasses the Mediterranean area and California.

4.2 Available Water Resources and Potential To Use

In strategy of water resources use, the main interest is available water resources which not only take into account the natural re-regulated flow in reservoirs, but return and underground water as well. Present level of estimated available water resources in provinces of Uzbekistan is given in the table 4.1

On the whole limit of Uzbekistan for basins of Amu-Darya and Syr-Darya under present flow regulation is 63.02km^3, including 53.59km^3 of river water and 9.43km^3 for use of underground and drainage water. Estimated limits of water use and possibility of irrigation development in Uzbekistan to be determined by the Schemes in oblasts are shown in Tables 4.2 and 4.3 Estimated value of available water resources for Uzbekistan was specified in 63.02km^3, but as it was previously stated, actually at present it doesn't exceed 59.2km^3.In high water years Uzbekistan uses to 63km^3 including 59km^3 for irrigation. In low water years these are reduced to 54.2km^3 . 49.0km^3, respectively, which is both much lower the limit specified by the schemes, and limit adjusted to the real situation in water use.

Table 4.1 Present Level of Estimated Available Water Resources in Provinces of Uzbekistan, M m³/year

River basin	Abstraction from rivers			Underground water use	CDW flow	Available water resources
	Stem stream	Small rivers	Total			
Syr-Darya Basin						
Andijan	950	1580	2530	170	450	3150
Namangan	2260	450	2710	120	970	3800
Ferghana	1200	2450	3560	440	860	4950
Syr-Darya	3260	-	3260	100	680	4040
Dzhizzak	2460	300	2760	70	500	3330
Tashkent	360	4420	4780	690	750	6220
TOTAL	**10490**	**9200**	**19690**	**1590**	**4210**	**25490**
Amu-Darya Basin						
Surkhandarya	946	3659	4605	205	-	4810
Kashkadarya	4566	1739	6305	157	313	6775
Bukhara	4521	-	4521	11	708	5240
Samarkand	-	4029	4029	298	-	4327
Navoi	437	986	1423	186	171	1780
Dzhizzak	-	225	225	18	-	243
Khorezm	3395	-	3395	54	490	3939
Karakalpakstan	9398	-	9398	75	945	10418
TOTAL	**23263**	**10638**	**33901**	**1004**	**2627**	**37532**
Total for Uzbekistan	**33753**	**19838**	**53591**	**2594**	**6837**	**63022**

Source: MAWR, Uzbekistan, 2000

Table 4.2 Development of Water Management in Oblasts of Uzbekistan

River basin, Oblast	Irrigated area '000 ha	Irrigation water use Mm³/year	Municipal & industrial water use M.m³/year	Total water use M.m³/year
Syr-Darya Basin				
Andijan	281	2860	290	3150
Namangan	265	3330	470	3800
Ferghana	335	4250	700	4950
Syr-Darya	322	3890	150	4040
Dzhizzak	308,6	3200	130	3330
Tashkent	380,4	3830	2390	6220
TOTAL	**1892**	**21360**	**4130**	**25490**
Amu-Darya Basin				
Surkhandarya	298	4403	407	4810
Kashkadarya	483	6221	554	6775
Bukhara	251	4778	462	5240
Samarkand	344	3539	788	4327
Navoi	111	1478	302	1780
Dzhizzak	18	199	44	243
Khorezm	223	3522	417	3939
Karakalpakstan	451	8481	1937	10418
TOTAL	**2179**	**32621**	**4911**	**37532**
Total for Uzbekistan	**4071**	**53981**	**9041**	**63022**

Source: MAWR, Uzbekistan,2000

Table 4.4 Water Mineralization in the Rivers, (g/l)

River – Gauge Station	Min	Max
Amu-Darya Basin		
Amu-Darya – Termez	0.30	0.98
Surkhandarya (upstream stations)	0.20	0.55
Sherabad – Sherabad	0.80	3.0
Kashkadarya (upstream stations)	0.20	0.52
Guzadarya – Yartepa	0.90	2.20
Zarafshan – Dupuli	0.17	0.34
Syr-Darya Basin		
Naryn – Uchkurgan	0.22	0.48
Kashkadarya – Kampyrravat	0.23	0.36
Small rivers of Ferghana Valley	0.22	0.48
Midstream rivers	0.28	0.51
Chirchik – 0.3 km upstream of Gazalkent	0.14	0.43
Akhangaran – Turk	0.10	0.29

Source: NWG RUz by Glavgidromet data, 2001

Table 4.5 River Flow Mineralization Trend at Stages of Irrigation, (g/l)

River, section	Irrigation Stages					
	1932-50	1951-60	1961-70	1971-80	1981-90	1991-99
Amu-Darya Basin						
Surkhandarya – Zhdanov – Manguzar	0.3-0.57	0.32-0.6	0.35-0.88	0.38-1.08	0.40-1.2	0.42-1.2
Amu-Darya – Kerki – Samanbai	0.5-0.51	0.51-0.52	0.57-0.64	0.59-0.75	0.57-1.2	0.57-1.2
Kashkadarya – Varganza – Karatikon	0.26-0.38	0.27-0.49	0.28-1.01	0.3-1.82	0.31-2.57	0.35-2.57
Zarafshan – Dupuli – Navoi	0.22-0.3	0.23-0.55	0.24-0.73	0.24-0.88	0.24-1.22	0.25-1.22
Syr-Darya Basin						
Naryn – Toktogul - Uchkurgan	0.24-0.28	0.24-0.29	0.25-0.29	0.25-0.3	0.26-0.3	0.26-0.3
Karadarya – Kampyrravat – Uchtepe	0.3-0.48	0.31-0.49	0.32-0.5	0.35-0.52	0.40-0.53	0.42-0.53
Chirchik – Khodjikent – Chinaz	0.17-0.34	0.18-0.4	0.18-0.44	0.19-0.65	0.23-0.72	0.25-0.72
Angren – Turk – Soldatskoie	0.12-0.32	0.13-0.33	0.13-0.44	0.13-0.68	0.13-0.85	0.13-0.85
Syr-Darya – Kal – Kyzylkishlak	0.4-0.42	0.45-0.59	0.62-1.03	1.04-1.2	1.1-1.25	1.12-1.26

Source: NWG RUz by Glavgidromet data, 2001.

4.2.2 Water Resources Management: Legal, Institutional and Financial Aspects

Legal aspects of water resources management in the Republic of Uzbekistan consist of publication and application of legislative acts and legal regulations directed to protect water from pollution, contamination, desiccation, organization of water resources rational use to meet the demands of socio-economic infrastructure in zones of planning and water management sources.

Objects to be protected include surface sources (rivers, lakes, reservoirs, canals, collectors) and ground water.

Development of the system for nature protection and water legislation of the country is inseparably linked with formation of new economic relations in Uzbekistan. Laws "On Nature Protection" of 09.12.1992, "On Water and Water Use" of 06.05.1993, "On deposits" of 23.03.1994 as well as a number of legal regulations on water relations, as a whole, meets the international standards on protection and use of water resources as an object of natural environment. Overwhelming impact of irrigated agriculture on socio-economic aspects of water resources use and formation of new economic relations between subjects of water use are taken into account. In future it will be possible to specify some legislative and standard acts on land reclamation and irrigation/drainage systems in Uzbekistan.

In the country, institutional water resources management is carried out by the relatively advanced national MAWR infrastructure, which is organizationally developed and technically equipped. In its central staff there are divisions of direct management of water resources complex such as Water Management Department, State Nature Protection Committee, State Committee on Geology and Mineral Resources and Central Administrative Board on Hydrometeorology with the appropriate divisions at the local level between which the appropriate authorities are specified according to existing legislation acts and legal norms.

According to the law 'On Water and Water Use' the right of distribution of surface water resources is given to MAWR bodies, and underground water to Goskomgeologia which set water intake limits at all water-distribution levels, which are obligatory for execution by all water users, irrespective of their departmental subordination.

Besides, MAWR is assigned to participate in the regional water management organizations of the Central Asia countries.

The regional (interstate) level of cooperation and coordination in institutional management is allocated to the Interstate Coordination Water Management Commission (ICWMC) acting under aegis of the International Fund of Aral Sea.

In ICWMC structure there are Basin Water Management Associations (BVO) "*Amu-Darya*" and BVO "*Syr-Darya*".

The following hierarchy of management represents the system of planning and water distribution limitation:

- National level - zones of planning (Republic of Karakalpakistan and Oblasts)
- Local level (area, object).

However, at present the idea of transition to structure of water resources management by the hydrographic principle is being supported, the idea more completely combines branch, territorial (basin) and administrative aspects of water use.

Management and operation of water management objects of the national, interregional, interdistrict and interfarm value which are being in a structure of water management organizations of MAWR is carried out using state budget financings.

In connection with a common problem of maintenance costs under financing there is natural reduction of the funds to be allocated for operational costs to provide administrative structures of all levels with information, and to monitor water consumption and water abstraction.

In the past years an increased use of computers in administrative water management structures at a national level, in zones of planning and other divisions is observed. However, their use and software available at present are not quite effective, which is explained in some cases due to inexperience of both management structures and administrative staff.

Moreover, the available software not always meets usual natural and economic, technical and technological features of local water management systems

4.3.2 Suitability and Land Use

Total area of agricultural land in Uzbekistan is 26.754 Mha of which arable land is 3.757 Mha perennial plantings 0.353 Mha and remaining 22.263 Mha are occupied by hayfields and pastures. Land use in 2000 is illustrated in Figures 4.1 and 4.2

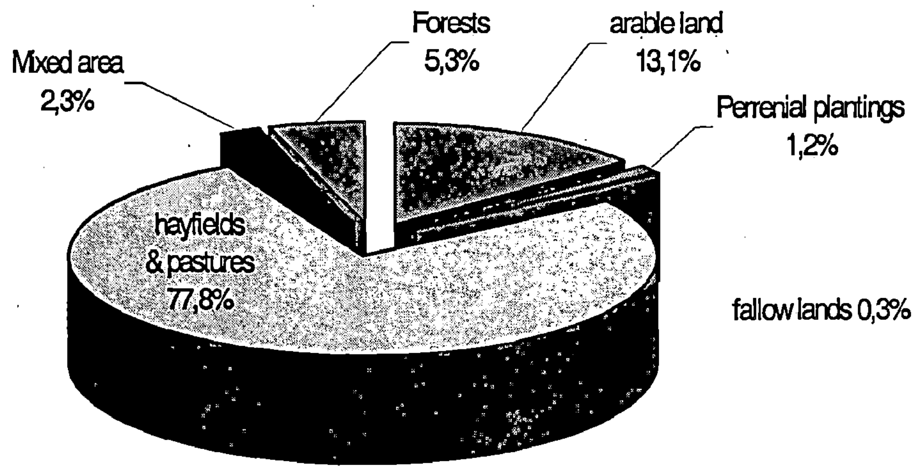


Figure 4.1 Ratio of Areas According to Land Use Type

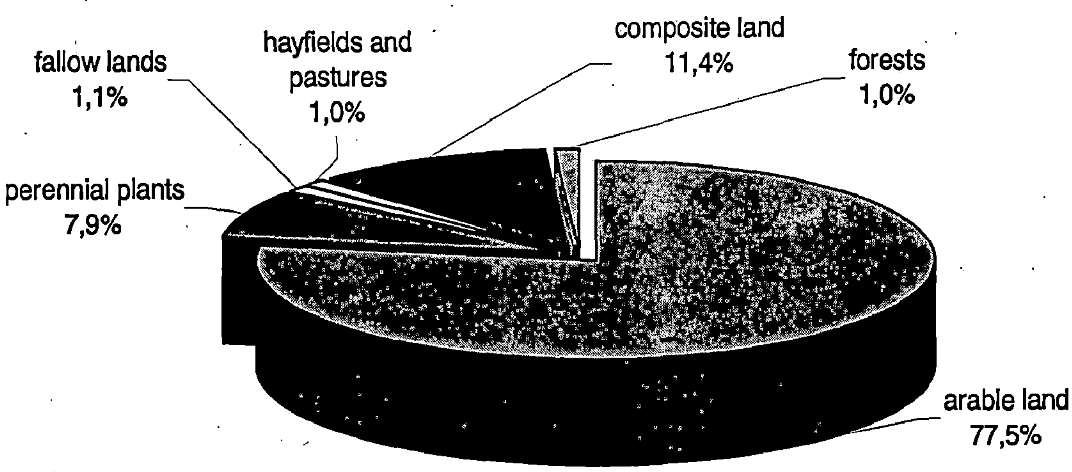


Figure 4.2 Ratio of Irrigated Areas by Land Use Types

4.4.1 Soil Types by FAO

On the territory of Uzbekistan 12 main FAO soil groups are identified. The most widespread FAO soil group is Calcisols. It occupies more than 5.3 Mha or up to 11.85% of the total area. The second greatest soil group is Solonchaks 5.211 Mha (or 11.6%) including 3.6% of Calcisol and Arenosols. Cambisol covers more than 5.068 Mha (11.33%). About 12% of the territory (5.366 Mha) is occupied by Solonetz of Ustyurt, etc. Arenosols and Regosols cover 2.063 Mha. and 2.270 Mha respectively. Four main groups of soil (Fluvisol, Gleysols, Kastanozem and Anthrosols cover jointly 2.475 Mha or about 5.53% of the area. More than 34.5% (14.528 Mha) of the area is occupied by sand. Soil map of Central Asia is given in appendix 2.

4.4.2 Classifying major soil groups according to World Reference Base for Soil Resources

Based on the World Reference Base for Soil Resources, the main Uzbekistan major soil groups are given in Table 4.8 Major soils are: Arenosols (AR), Calcisols (CL) interfered with Gypsisols (GY), Calcisols (CL), Fluvisols (FL), Leptosolos (LP), Regosols (RG), Solonchaks (SC) and Vertisolos (VR)

Table 4.8 Major Soil groups in Uzbekistan

MAJOR SOIL GROUPS AND LAND COVERS UNITS	AREA mha.
ARENOLS (AR)	2.063
CALCISOLS (CL)	5300
CAMBISOLS (CM)	5.068
FLUVISOLS (FL)	2.475
SOLONETS (SN)	5.366
SAND	14.528
REGOSOLS (RG)	2.270
SOLONCHAKS (SC)	5.211

ARENOSOLS (AR)

Soils having:

1- A texture which is loamy sand or coarser either to a depth of at least 100 cm from the soil surface, or to a *plinthic, petroplinthic* or *salic* horizon between 50 and 100 cm from the soil surface; *and*

2- Less than 35 percent (by volume) of rock fragments or other coarse fragments within 100 cm from the soil surface; *and*

3- No diagnostic horizon other than an *ochric, yermic* or *albic* horizon, or a *plinthic, petroplinthic* or *salic* horizon below 50 cm from the soil surface, or an *argic* or *spodic* horizon below 200 cm depth.

CALCISOLS (CL)

Other soils having:

1- A *calcic* or *petrocalcic* horizon within 100 cm of the surface; *and*

2- No diagnostic horizons other than an *ochric* or *cambic* horizon, an *agric* horizon, which is calcareous, a *vertic* horizon, or a *gypsic* horizon underlying a *petrocalcic* horizon.

CAMBISOLS (CM)

Other soils having

1. A texture which is loamy sand or coarser either to a depth of at least 100 cm from the soil surface, or to a *plinthic, petroplinthic* or *salic* horizon between 50 and 100 cm from the soil surface; and

2. Less than 35 percent (by volume) of rock fragments or other coarse fragments within 100 cm from the soil surface; and

3. No diagnostic horizons other than an *ochric, yermic* or *albic* horizon, or a *plinthic, petroplinthic* or *salic* horizon below 50 cm from the soil surface, or an *argic* or *spodic* horizon below 200 cm depth.

FLUVISOLS (FL)

Other soils having:

1- *fluvic* soil material starting within 25 cm from the soil surface and continuing to a depth of at least 50 cm from the soil surface; *and*

2- No diagnostic horizons other than a *histic, mollic, ochric, takyric, umbric, yermic, salic* or *sulfuric* horizon.

SOLONETZ (SN)

Other soils having

1. An eluvial horizon, the lower boundary of which is marked, within 100 cm from the soil surface, by an *abrupt textural change* associated with *stagnic* properties above that boundary; and
2. No albeluvic tonguing

SOLONCHAKS (SC)

Other soils having:

1- A *salic* horizon starting within 50 cm from the soil surface; *and*

2- No diagnostic horizons other than a *histic, mollic, ochric, takyric, yermic, calcic, cambic, duric, gypsic* or *vertic* horizon.

4.5 Major causes and processes of soil salinization in the country

4.5.1 Natural Causes

Climate:

Climate of Uzbekistan is extreme continental, arid and with abundance of solar radiation, small cloudiness, and poor precipitation. Mean annual amount of precipitation in a flat part ranges from 100-150 mm (desert) to 200-400 mm (foothills). Total yearly evaporation varies from 900 mm in the Aral Sea coastal area, up to 1200 – 1500 mm/year in the south of the republic. Being located far from any ocean, it also has a strongly continental climate. High temperatures characterize the climate in summer (abs. max. 42-47° C in the plains and 25 – 30° C in the mountainous zone in July) and low mean temperatures in winter (- 11° C in the north and to +2 or – 3 ° C in the south on January). This continental climate, with its contrasts and dryness, places the south of Uzbekistan area in the Asian-continent subtropics climate zone. In Uzbekistan, 2500 to 3060 hours per year of sunshine is typical. In terms of duration of sunshine from May to October, Uzbekistan significantly surpasses the Mediterranean area and California.

Relief and Hydrogeology:

Relief and hydrogeology peculiar features make a possible to identify three provinces: i) low accumulative plains, including coastal, alluvial and alluvial-proluvial lowlands; ii) high plains, plateaus and mountain area of denudation highlands; iii) mountain setting, presented by zones of denudation and geochemical runoff. Transition and accumulation of geochemical flows characterize low plains. There are areas, suffering from surface salt accumulation, recent hydromorphic landscapes with close groundwater table (<3 m) as well as areas, for which soil salinization at a high depth is especially characteristic. In high plains and plateaus salt affected soils and the soils with gypsum are dominant. They are stable in their salinity or subjected to slow salt removal.

Climate aridity, relief, hydro morphology and geological formations of the Pamir and Gissaro – Alay Mountains and the development history of Turan province are the natural cause of relictive and modern hydrogen salt accumulation and rivers salinisation. Mountain ranges are rocky and comprise granite, schist, and limestone. Since these are mainly insoluble formations, mineral content is relatively low and the quality of water in the headwaters is suitable for most possible uses. In the valleys, where more soluble deposits are found, sulfates and chlorides enrich water.

4.5.2 Anthropogenic Causes of Formation of Salt-Affected Soils

4.5.2.1 Land Mismanagement

The productivity of Uzbekistan croplands is influenced by the salt load and by soil organic matter content (SOM). The loss of SOM lead to reduction of the soil fertility and deterioration of agro-physical, biological and other activities.

At present content of the humus in the soil has decreased by 30-40%. Soils with the very low humus content (0.4-1%) are occupying about 40% of total irrigated area, and low productivity soils cover more than 1.0 million hectares (WEMP Sc-A1, 2001).

The main causes of the deterioration of soil fertility are the extensive agriculture development with monoculture of cotton, using high levels of fertilizer and pesticide to achieve the required yields and water mismanagement that caused loss of humus, exhaustion of the soil and its physical and chemical qualities, and general degradation of land. Abandoned land in Jizzakh province of Uzbekistan is given in figure 4.3 The newly developed agricultural land incorporated saline and low-productivity lands as part of the irrigation programs. It has resulted in degradation of natural regulating mechanisms, transformation of land from complex ecological system to substratum for transmission of mineral combinations to roots of plants that has resulted in decrease of efficiency of irrigated lands.

Figure 4.3 Abandoned land in Jizzakh steppe, 2001

The second factor causing the current low productivity of soils is thought to include poor soil treatment and land preparation, weak crop husbandry and harvesting difficulties. These have arisen because of difficulties over machinery and equipment usage, low seeding rates, low fertility application rates, shortfalls in the amount of irrigation water applied, inefficient pest control, and undesirable crop rotations. During last years the amendment of use of the cultivation areas has been done. The soil structures in Kashkadarya, Bukhara, Samarkand and Tashkent regions approach to environmental optimum.

After independence the agro-chemicals usage has declined appreciably. The state has stopped the subsidizing of mineral fertilizers production, due to realization of market reforms in the industry. Physical use of mineral fertilizers is accordingly reduced, especially in farmer and dehkans farms and due to replacement with local organic fertilizers. Inorganic fertilizer rate of cotton has declined by 69% (N) and 23% (P_2O_5) in 1995. Other crops show similar patterns in fertilizer application (MMTU, 1998). Increase of macro-nutritious vegetative products quality and content of nitrates is marked. The main factor for this decline in usage is that farmers do not have sufficient money to purchase the chemicals and shortage of such products in the market. This is especially true of imported products.

The soil characteristics conditions (slightly alkaline reaction of soils, irrigated agriculture) and arid climate in Uzbekistan promote decomposition and migration of chlorine-organic pesticides. Though since 1983 DDT residuals is prohibited, the exceeding its maximum admitted concentration are observed more than in a half of soil samples. However soil pollution from total DDT is practically at the same level, but it exceeds the maximum admitted concentration 2-5 times (Environment, 2001).

The soil pollution from herbicides such as dalapon, cotoran, and trefman exceeding normal acceptable standard is extremely rare occurred and such preparations as metafos, phosalone, tiodan occur in soil in the form of traces due to their instability in dry climate (Environment in CAR, 2001).

Local soil pollution from toxic chemicals in the areas near the former agriculture spray plane airfield storage and pesticides deposits causes the special alarm. At the same time, the agriculture cannot develop without application of organic and mineral fertilizers and chemical control. In this context, it is necessary to establish only a sure rate corresponding with geographical conditions of the republic. Last years the ways to solve the problem for utilization of old pesticides were founded (SPUSH, 2001).

4.5.2.2. Water Mismanagement

The intensive development of irrigated agriculture in Uzbekistan resulted in the establishment of an extensive network of channels and structures designed for the collection and disposal of collector-drainage water (CDW). Disposal of CDW to the rivers has caused deterioration of the river water quality, reduction in yields of crops using the river as a source of irrigation water and deterioration of the ecological environment in lower reaches.

After the collapse of Soviet Union, the irrigation sector has inherited huge network of reservoirs, dams, pumping stations, canals and other structures, also number of problems connected with all of them (I&D Strategy, 2001).

The infrastructure of the irrigation and drainage is operated more than 30 years without modernization and rehabilitation. Last twelve years due to economic problems in the country, amount of funding reduced drastically. Because of the exploitation difficulties, many existing drainage systems are malfunctioning or lose its carrying capacity, and approximately 50% of the vertical drainage is not operating at all. An insufficient of maintaining the drainage networks have resulted in increase of salt mobilization from deep aquifers. The mass of salts from upstream completely in the irrigated areas of downstream are accumulated.

Such intensity of salt removal from irrigated area is also connected with natural salinisation of soil-ground and high mineralization deep ground waters, intercepted with drainage system. On some sections collectors in Kashkadarya region pass on salt containing rocks and their mineralization in some months exceeds 8 g/l (MMTU, 1998).

The average efficiency of water distribution to the fields is equal 55-58% Water application efficiency in the fields composes 55-63%. Overall water use efficiency is 32-39%. In 1998, surface irrigation was practiced on 98% of total area, mainly furrow. Other methods of irrigation (sprinkler, drip, etc) are not popular use. Widely used method leaching of saline soils on basin is characterized with a high water requirement and labour. Some important problems are used for leaching in parts of mid and lower stream of the Amu-darya basin are return flows with a poor quality. It is resulted in crop capacity decrease, slow development, low export income and adverse impact on general living standard of the population. At present the coastal and delta plains of the Pre Aral are the main crisis zones (Khasankhanova, 2001).

Worsening of water quality is the most important environmental issues in Uzbekistan and significantly impact biodiversity. The current average mid and downstream salinity level in the rivers is 0.7-0.9 g/l, but annually in the dry season (October to April) and during dry years the salinity can rise to 2.2-4.0 g/l. The salt load in drainage water of the rivers is, an average, 5.5 times that of irrigation water (WARMAP, 1999).

The requirement to maintain agricultural output in Uzbekistan has less considered the negative effects of diffuse (non-point) sources of contamination including irrigated areas, cattle-breeding farms, oil products storage, aerodromes, small settlements and other facilities, which represent serious threats to human health, food, and the environment. Based on observations, more than 60% of the total volumes of contaminated water in catchments areas are the direct result of diffuse (non-point) sources of contamination. It is a serious threat to the development of food policy reforms, health and environmental safety (MMTU, 1998).

Degree of land degradation due to land water mismanagement according digital Uzbekistan map and the two regional maps is summarised in Table 4.9 and Figure 4.4 (a, b, c)

Table 4.9 Degree of land degradation due to land and water mismanagement

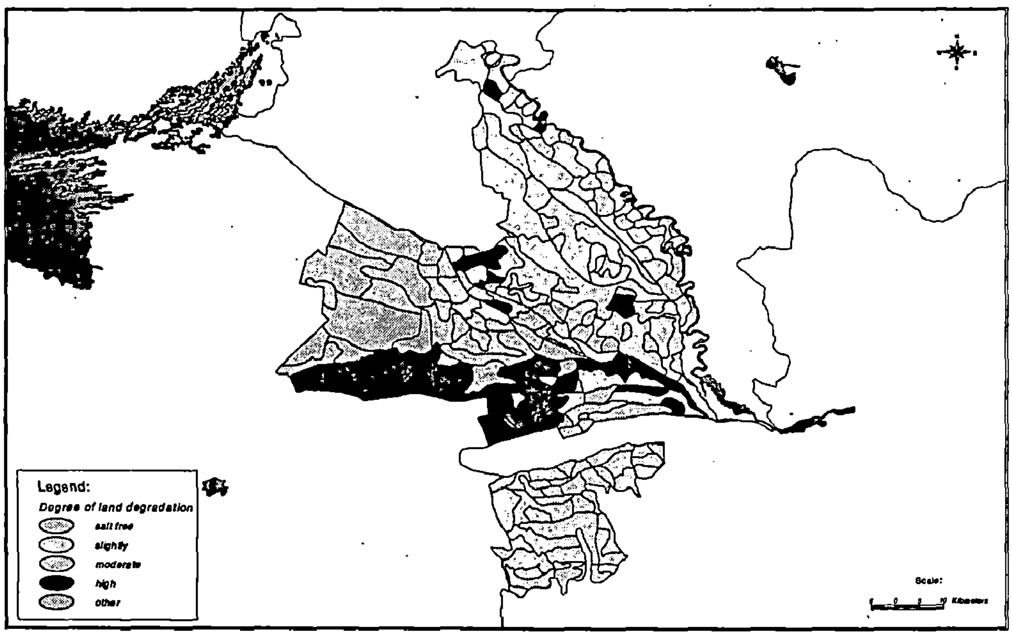
Region	Total Area '000 ha	Degree of natural risk		
		Moderate	High	Total
1. Uzbekistan	45244.64	5189.65	5033.61	10223,26
Including irrigated area	7086.342	3565.13	437.76	4002.89
2. Syrdarya region	505.653	135.81	81.37	414.18
3. Kashkadarya region	2859.685	61.12	34.09	363.94

Source: MAWR, Uzbekistan, 1998

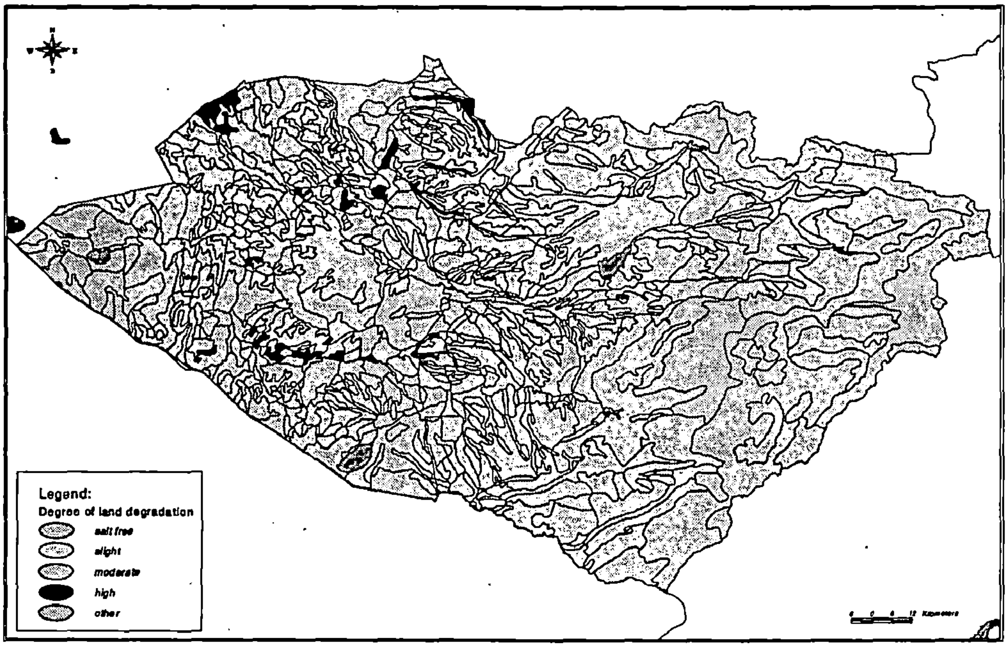
Figure 4.4 Anthropogenic causes of land degradation in Uzbekistan

a) Uzbekistan

b) Syrdarya region



c) Kashkadarya region



The total GIS area of land degradation due to land and water mismanagement in the country is 10.223 Mha or about 22.6% of total lands. From this amount 5.33 Mha is characterized with high degree of land degradation. These degradation lands are extended mainly in irrigated areas of the mean and downstream of the Syr-darya River basin (Djizak, Syrdarya, Central Fergana, etc) and Amu-Darya River basin (Bukhara, Khorezm, Karakalpakstan, Kashkadarya, etc).

4.6 Social and Economic Conditions

In the last 50 years the population of Uzbekistan has increased 3.7 times, although the areas under crops expanded only to 1.4 times. The production growth was achieved at the expense of irrigation and chemicalization. The sharp increase of the load upon the land brought about degradation, salinisation and other phenomena. The consequence of cotton monoculture was the exceptionally high levels of contamination of food products with the residual quantities of pesticides and toxic chemical elements. However, the problem of contamination and, in general, the quality of the food products is as acute as ever, since the most part of the production does not meet the requirements of the state standard. There are reasons to believe, that it is the contamination of food products together with the drinking water of poor quality, which is one of the main causes of increased sickness rate and mortality of the population of ecologically unfavorable areas (NEAP, 2000).

Basically there are two major threats to productivity and sustainability of irrigated agriculture:

i) Constrained farmers' incentives to improve production and productivity,

ii) The deterioration of the production base. It is estimated that the deterioration/losses of the resource base for agricultural production costs the country US$ 1,000 million annually at economic prices (WB, 1999). Current situations do not give farmers the incentive to optimise output and labour productivity, to the detriment of farmers and, therefore, of the country as a whole. Indeed, worldwide experience shows that rural development has always preceded general economic development.

4.7 Successful and failure cases as example on management and rehabilitation of different type of Salinity

The intensive development of irrigation in the late 1950s with careless reclamation of problem soils and disposal of CDW to the rivers has created the premises to start the land degradation processes in Uzbekistan. All these led to development of secondary-hydromorphic soils with the increase in basin-wide soil and river salinisation. The excessive use of water by irrigation sector has resulted in the gradually drying up of the Aral Sea and desertification of its coastal areas.

4.7.1 Aral Sea Catastrophe

Aral Sea problem has been until 1998 presented to the external world by the Governments of the five republics as an environmental disaster of global importance and thus warranting a massive international assistance. Man's action has influenced in the past and present to the river runoff into the lake and therefore the size of the Aral Sea (ASBP).

One of the world's largest inland seas, it is situated within Uzbekistan and Kazakhstan, and has shrunk by more than half in the last 30 years. The last 200 years however the lake level has been quite stable, until the 1960ies when the full-scale development of cotton production through irrigated agriculture in Central Asia was started.

To the present time, the Aral Sea has reduced 5 times in volume and 18 m decrease in level. More than 40,000 km^2 of the bottom of the sea with highly salinized soil have been exposed, and they are intensely eroded by the winds. The process of natural overgrowing has started on the part of the bottom of the water basin coming out of water. Simultaneously, the quick degradation and desertification of the estuary ecosystems of the Amu Darya and the Syr Darya take place. More than 50 highly productive lakes with the total area up to 60,000 ha have completely dried out (NEAP, 2000).

Today, international and domestic agencies acknowledge that land and water use patterns have to become sustainable again. Only a drastic restructuring of agricultural production in the region would save the 35-42 km^3 of water per year needed to stabilize the Aral Sea surface. Whether this goal can be achieved at all, is to be seriously doubted and would at best take decades to accomplish. Therefore, most recently, efforts to develop the region have shifted from saving the Aral Sea at all costs to the urgently needed amelioration of the health, wealth and livelihood of the people living in the Aral Sea Basin (UNESCO, 2000, ZEF Bonn, 2001).

4.7.2 Water Resources and Salt Management on the Regional and National Level

Several studies and investment projects have already addressed one or more facets of the problems outlined above. Since 2000 Uzbekistan suffers from serious water shortage. Available limit of water resources has been exhausted completely. Natural resource and production base of agriculture and I&D sectors is under threat. Regional environmental problems, such as desertification in the Aral Sea Region, land degradation and reduction of crop yield and biodiversity, and a number of others have important socio-economic value for the local community. The actions connected with water and salt management plans cannot and should not be based only on reasons of local efficiency. These suppose active national actions and interstate cooperation in implementation of national and international programs and projects (WEMP, Sc-A1, 2001).

At the Government level there is a clear understanding of the necessity to reform water management system, increase its democratic level and water use efficiency. Recently the National Interdepartmental Commission has prepared the Program on Irrigated Lands Improvement from the year 2001 to 2010, and formulated the main concept of increasing water management efficiency and legal, institutional measures for water saving. The basic strategic framework for addressing the deterioration of the national production base is provided by recent Decrees of the President. The Governmental Program on Irrigated Lands Improvement, in short and medium terms, provides implementation of the legal, institutional, financial economic and social tools for stage-by-stage privatisation of agricultural lands and irrigation management, with broad participation of the public and international financing agencies.

The Project on Irrigation and Drainage Development Strategy supported by the World Bank and Netherlands Government considerably contributed in elaboration of approaches and model of institutional development of Uzbekistan. The strategy is based on the belief that the sector's decline is caused by water losses, insufficient drainage, and insufficient maintenance, and that addressing the causes as well as the effects deserves the highest priority. Once these problems and their disastrous effects have been brought under control, the next task is to rehabilitate and modernize the infrastructre, to adapt it to the changing conditions of the sector (Abdullaev,*at el*, 2000).

Proposed I&D Development Strategy Project involves two phases.Three categories of policy instruments are available to pursue the consolidation objective as well as the rehabilitation objective: i) agricultural policies; ii) institutional policies; iii) budgetary policies. The institutional changes have considerable financial impact, which, in turn, necessitates changes in prevailing agricultural policies. The first phase, called the *Consolidation-cum-Emergency Phase*, includes a public investment programme in the main and inter-farm networks. The public investment programme should not exceed US$ 2 billion for a five-year period. In addition, there would be an on-farm investment requirement of which the cost (to be borne by the users) would be in the order of US$ 1 billion. The second phase is the *Rehabilitation-cum-Modernization Programme*, it is different in size and type of works. Where economically, socially and environmentally justified, I&D facilities will be rehabilitated, and adjusted to today's requirements, taking into account changes in cropping pattern, irrigation techniques, production structures, etc. The size of this phase in terms of funds required is in the order of US$ 20 billion, of which some US$ 8 billion for the public investment component, and about US$ 12 billion for works within the boundaries of the former sovkhoz-kolkhozes, at the expense of the users (I&D Strategy, 2001).

In order to mitigate crisis situation in the Aral Sea Basin the Agency GEF of the International Fund for Saving the Aral Sea (IFAS), has decided to develop Aral Sea Basin Program. The National and Regional Water and Salt Management Plans are a Sub-component A1 of the Water and Environmental Management Project (WEMP). The Sub-component A1 of WEMP has the overall objective of developing water and salt management plans for the Aral Sea Basin. The aims are to: i) provide a consistent set of policies and strategies relating to water conservation, including improvement of irrigation and drainage infrastructure, and improvement of the O&M; ii) develop a framework for interstate cooperation in water and salt management, and preparation of international agreements relating to (1) water allocation mechanisms and river salinity standards, (2) investment in national and regional water infrastructure, and (3) funding of the Basin agencies in charge of water resources and infrastructure (WEMP, Sc-A1, 2001).

4.7.3 *Integrated Management and Rehabilitation of Salt-affected Soils on the Local Level*

FAO Project of "Integrated Management for Sustainable Use of Salt Affected and Gypsiferous Soils" (FAO/UZB/2801) is the first stage of cooperation of Uzbekistan within the framework of special program of FAO on food security. Main objective of the project is to assist the Government of the Republic of Uzbekistan to introduce and demonstrate appropriate integrated low-cost, low-risk management techniques for rehabilitation and improvement of salt-affected and gypsiferous irrigated lands in support of food security in the country. The present assistance of FAO is directly connected with National Action Plan of Government of Republic of Uzbekistan on the Program of Safety Food of the country, National Program of Irrigated Land Improvement and National Action Plan on Environment for the period of 2001 t. 2010 (Proceedings FAO RW, 2003).

The main task of FAO project TCP/UZB/2801(A) are:

i) To facilitate capacity building;

ii) To demonstrate real integrated rehabilitation low-cost and low-risk management techniques for sustainable use of problem soils and introduction its to the large-scale agricultural program;

iii) iii) To ensure multi-level training programs; and

iv) iv) To improve farmer's knowledge and experience, enhance their motivations and incomes.

Rehabilitation and management of salt-affected and gypsiferous soils require a combination of methods depending on careful identification of production constraints, the causes and requirements. These methods should be tested first in pilot demonstration farms under local conditions before they can be recommended in a larger-scale program.

The suitable pilot area of Uzbekistan was found in Syrdarya and Kashkadarya regions where the impact of degradation and problem soils would be more pronounced. Project is supported by the administration of oblast and rayon levels. Farm leaders and farmers are also interested in this project and involved in implementation of the project.

Experiment is planned for 2 years and proposed to cultivate 4 main crops of crop rotation: winter wheat, green gram, barley and cotton. The first year of the experiment it was envisaged to grow winter wheat on the three demonstration pilot farms.

The selected demonstration plots are divided into 10 demonstration options and each excludes consequently one of the measures listed in the scope of integrated management. The gypsiferous soils plot is divided into 2 sections: (1) shallow gypsum (0.2-0.3m) and deep gypsum (0.5-1.0m) soils. Preliminary soil investigation indicates that soils at the selected pilot area have small level of absorbing capacity and amount of exchange capacitance, neutral or light alkalinity response. Table 4.10 shows data of soil sampling from the selected demonstration farms in Syrdarya region.

Table 4.10 Chemical Analysis of Soil Samples from Demonstration Salt affected and Waterlogged Farms, Syrdarya region, 2002

Parameter	Salt-affected Soils %				Waterlogged Soils %			
	0-20	20-35	35-65	65-100	0-20	20-35	35-65	65-100
Ec, ds/m	6.40	6.80	5.80	4.40	7.80	7.20	7.10	6.80
pH	8.40	8.60	8.20	8.20	8.40	8.30	8.30	8.30
Organic matter, %	0.22	0.24			0.9	0.24		
P_2O_5, mg/kg	29	31			7	6		
K_2O, mg/kg	289	308			308	173		
Exchange cations:								
Ca	0.80	1.60	1.60	1.20	0.80	1.20	0.80	0.80
Mg	4.80	3.60	4.00	3.20	6.00	5.60	5.20	6.00
Na	3.01	4.38	2.61	1.22	6.96	5.06	5.49	5.32
K	0.56	0.53	0.33	0.17	0.51	0.28	0.12	0.10

Source: Proceedings FAO RW, 2003

4.8 Irrigated Areas

Water resources development in medium and long-term proceeding from strategic tasks of agriculture, and firstly, irrigated agriculture assumes to increase the irrigated area to 4.555 mha. over the country by 2010 and in future to 6.441 Mha.

On the whole in water management systems of the basins of Syr-Darya and Amu-Darya the irrigated area and its use for the major crops is as follows. Use of irrigated area and types of crops are given in Table 4.11

Table 4.11 Use of Irrigated Area, '000 ha

Irrigated area and crops	Syr-Darya basin		Amu-Darya basin		Uzbekistan total	
	2002		2002	2010	2002	2010
Cotton	690		760	760	1450	1450
Small grains	565		640	1060	1205	1730
Rice	31		100	160	131	170
Other	50		52	260	102	361
Sub-total grain	646		792	1480	1438	2261
Vegetables, melons, potato	138		200	271	338	428
Alfalfa	137		270	640	407	879
Other fodder	42		203	503	245	619
Sub-total fodder	179		473	1143	652	1498
Perennial plants	247		348	382	595	646
Forests and plantations	33		49	117	82	158
Total:	**1933**		**2622**	**4153**	**4555**	**6441**

Source: MAWR, Uzbekistan,2000

In so called humidified zone of Amu-Darya delta it is provided estuary irrigation of 200,000 ha for distant-pasture livestock breeding of Karakalpakstan.

In Republic of Karakalpakstan for the medium term to lower load on Amu-Darya delta water resources it is planned reduce rice area to 55.000 ha. In future rice sowings would be increased to not more than 100.000 ha.

In cotton production stabilization of sowings is assumed at level of 1.450 Mha, which would provide production of about 4.5 mln. tons of raw cotton annually having in a view its processing and export of finished products and semi-processed goods.

In long-term, alongside with implementation of program on self-maintenance by food grain it is proposed that intensive irrigation of grain-fodder and forage crops that would allow to meet the requirements of livestock production and give an opportunity to introduce scientifically-based crop rotations and agriculture practice.

To 2010 irrigation development is assumed at moderate rate. Further it would be planned accelerated rates of agriculture sector development and irrigated agriculture in particular.

4.8.1 Condition and Operation of Irrigation and Drainage Infrastructure

Condition and operation of irrigation and drainage infrastructure in basins of Syr-darya and Amu-darya is characterized by below parameters:

Syr-Darya River Basin

In Uzbekistan the actual abstraction for irrigation is 23.7 km^3, with average specific water consumption 12,400 m^3/ha. Thus, it ranges from 9,800 m3/ha (Dzhizzak Oblasts) to 15,300 m^3/ha (Ferghana Oblast). Coefficient of soil water availability varies from 0.66-0.71 (Syr-Darya and Dzhizzak Oblasts) to 1.03-1.05 (Tashkent and Andijan Oblasts. Efficiency of main and interfarm canals is from 0.79 (Ferghana Oblast) to 0.88-0.89 (Syr-Darya and Dzhizzak Oblasts). Therefore, from the main and interfarm canals from 11 to 21% of the irrigation water abstracted in a system is lost. Efficiency of an on-farm irrigation network ranges from 0.59 (Andijan Oblast) to 0.84-0.87 (Syr-Darya and Dzhizzak Oblasts), that is in on-farm canals there is a loss from 13 to 41% of transported irrigation water. Efficiency of furrow irrigation is about 0.69, i.e. on irrigated fields it is lost up to 31% of irrigation water to be supplied.

Total water drained from irrigated land is about 12.06 km3, of which some 1.5 km^3 (Dzhizzak and Syr-Darya Oblasts) is disposed out the irrigated area, the remaining is discharged into the rivers (9.8 km^3) and 0.76 km^3 is used for irrigation.

Drainage available on irrigated area is quite sufficient and makes 91% as a whole. However, at present technical condition of drainage systems does not provide necessary rate of drainage and water disposal. On 1.5 Mha. of irrigated land rehabilitation of drainage systems is required. The heaviest situation has developed in zones of increased risk (Hungry steppe, Central Ferghana, etc.).

Amu-Darya River Basin

In Uzbekistan the actual water abstraction for irrigation is 35.2 km^3 with average specific water consumption of 15,400 m3/ha and varies from 8,000 m^3/ha (Samarkand Oblast) to 22,600 m^3/ha (Khorezm Oblast). Coefficient of water availability ranges from 0.83 to 0.84 (Kashkadarya Oblast and Karakalpakstan) to 1.12 (Bukhara Oblast) 1.24 (Khorezm Oblast).

Efficiency of main and interfarm canals is from 0.75 (Karakalpakstan) to 0.83 (Samarkand Oblasts). Thus, from main and interfarm canals it is lost from 17 to 25% of irrigation water offtaken into a system. Efficiency of on-farm irrigation network ranges from 0.63 (Karakalpakstan) to 0.83 (Kashkadarya Oblast), i.e. in canals of this network from 17 to 37% of irrigation water is lost. Efficiency of furrow irrigation is about 0.68 that means loss of about 32% of water supplied in irrigated fields.

Total disposal of collector drain water from irrigated land is 10.5 km^3 or about 30% of water supply. Outside the irrigated area it is disposed some 6.7 km3 (Karakalpakstan 1.8 km^3, Bukhara Oblast 1.24 km^3, Kashkadarya Oblast 0.94 km^3, Khorezm Oblasts 2.68 km^3 and in Samarkand Oblasts 0.07 km^3). Remaining CDW is discharged into the river (3.4 km^3) and 0.4 km^3 is used for irrigation. Available soil drainage is 80%. In the most part of collector drainage systems as a whole the technical condition doesn't provide necessary drainage standard. On 1.825 Mha irrigated area rehabilitation and construction of drainage systems is needed. The critical situation has developed in zones of the increased risk (Republic Karakalpakstan, Karshi steppe, Bukhara Oblast, etc).

On the one hand existing situation indicates technical, ecological and economic problems available in irrigation and drainage sector, on the other hand water resources potential for irrigated agriculture for future development.

4.8.2 Operation and Management of Irrigation Systems

Operation of irrigation system is characterized by its reliability from the point of required quantity of water supplied for irrigation. Present level of reliability of services in mean water year per 1 ha of irrigated area ranges within 31% by zones of planning. In low and very low water years this fluctuation is 38.7-43.4% that indicates problems available in efficiency of existing irrigation systems.

Alongside with fluctuations of the water flows connected with water availability in natural water sources reliability of operation of hydromeliorative systems depends on a level of technical operation and a technical condition of system objects and controllability.

The most important integrating index of hydromeliorative system condition is its useful operating life, characterising its level of operation reliability. One of the most important signs of reliability of hydromeliorative system reliability is capacity of canals, pipelines and structures.

Capacity of these system structures is determined by comparative analysis of actual minimum, normal and maximum discharge with the correspondent estimated values.

For zones of planning one of the indexes of water loss risk under supply, besides efficiency of the system, is deterioration of the main components of the hydromeliorative system. As a whole, capital assets of the water management organizations has deterioration over 29% to the present time, with fluctuations by zones of planning from 20.2% to 49.9%. It is assumed, that given imperfections in technical operation and maintenance of hydromeliorative systems, the technical resource of systems would be much higher and would come nearer to critical parameters of their possible functioning.

The following may be referred to such objects in the nearest future, Syrdaryaremvod (49.9%), OD KMC (42.0%), Zardolvodkhoz (37.8%), Bukhararemvod (34.5%), etc.

Management of irrigation systems is aimed to maintain reliability level of the objects and ensure limited water supply, which is determined by the following hierarchical chain:

MAWR → Water Resources Departments in zones of planning → Department of Interdistrict Canals → District Water Departments → Water Users including the farms having an autonomy in water intake and water use → the other water users supplied with water from on-farm canals.

4.9 Problem Soils

4.9.1 Soil salinization

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) salinisation of the old and new irrigated areas. 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 salinisation. Occurrence of the secondary salinisation on irrigated area in Uzbekistan is shown in Table 4.12

Table 4.12 Occurrence of secondary salinization in Irrigated areas of Uzbekistan, 1999

Region	Irrigated Area (000 ha)	Salinization Degree, %			Total Saline Area	
		Light	Moderate	High	000 ha	%
Andijan	272.1	4.4	4.3	0.0	23.8	9.7
Namangan	277.8	9.5	4.0	0.6	39.3	10.4
Fergana	356.9	29.1	18.7	8.3	103.8	53
Syr-Darya	293.7	54.3	25.2	7.2	254.9	99.1
Djizzak	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	373.0	2.2	1.2	0.2	13.6	6.8
Bukhara	273.6	58.2	27.0	10.1	260.5	38.9
Navoiy	127.7	53.5	28.7	4.9	111.2	86.6
Surkhandarya	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	471.8	94.3
Total	4275.2	30.8	18.3	4.5	2111.6	50.3

Source: (MAWR, Uzbekistan), 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.

4.9.2 Water logging

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 4.13

Table 4.13 Distribution of the waterlogging area (1999), 000 ha

Month	Surveyed area	Less 1m	1,0-1.5m	1.5-2.0m
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

According data of the 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 10,3% of total irrigated area. In Djizak region varies in the 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. Highly saline lands are abandoned and turn into contaminated area. Low level of water probability complicates to cover water requirements for leaching and an irrigation of agricultural crops. Some important problems are used for leaching in parts of mid and lower stream of the rivers are return flows with a poor quality(MMTU,1997).

4.9.3 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%) 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.

CHAPTER – 5

CROP WATER REQUIREMENT

5.1 General

The water needed for raising a crop in a crop period is called water requirement. It includes consumptive use and other economically unavoidable losses and that applied for special operations such as land preparation, transplanting, leaching of salts and etc. The water requirement for different crop is needed for scheduling of irrigations in planning the farm of irrigation system, in the design of irrigation projects and in water resources development. Crop needs in particular quantities of water for their optimum growth. Excessive or deficit amount of water could effect crop growth and ultimately lower the crop yields. Conditions influencing the rate of water use by crops include the type of crop, stages of its growth, climatic parameters like temperature, wind humidity and geographic al parameters like altitude, sunshine hours, available water supply and soil characteristics.

5.2 Methods of estimation of crop water requirement

There are several methods available for calculating the crop water requirement. Out of these Modified Penman method widely used. The evaportanspiration of a reference crop can be determined by the formula given below (5.1)

$$ETo = C\,[W \times Rn + (1-W) \times f(U) \times (ea-ed) \qquad (5.1)$$

Where

ea-ed – the difference between the saturation vapour pressure at mean air temperature and mean actual vapour pressure in air

f (U) – the function of the wind is given by (5.2)

$$f(U) = [0.27(1 + U/100)] \qquad (5.2)$$

W- Temperature and altitude dependent weighting factor

Rn – The total net radiation in equiualentevaporation in mm/day is given by (5.3)

$$Rn = 0.75 \times Rs - Rnl \qquad (5.3)$$

Rnl – Net long wave radiation in mm/day

Rs – Incoming short wave radiation in mm/day is given by (5.4)

$$Rs=(0.25+0.50n/N)\times Ra \qquad (5.4)$$

R (n/N)- Function of ratio of the sunshine duration

f (T)- Function of temperature

f(ed) – Function of actual vapour pressure

Ra – Extra radiation in mm/day

n – Actual sunshine hours per day

N – Maximum possible sunshine hours per day

C – Adjustment factor for ratio U day / U night, relative humidity Rs and U day

5.3 CROPWAT software

CROPWAT is a program that uses the FAO (1992) Penman-Monteith method for calculating reference crop evaportanspiration. These estimates are used in crop water requirements and irrigation scheduling calculations. CROPWAT software has been applied to calculate crop water requirements for the main crops of Uzbekistan taking into account climate data, soil characteristics and cropping pattern. Daily potential evaportanspiration (ETo) is calculated for Tashkent province of Uzbekistan using climatologically data, which is given appendix 3.

5.4. Software Results

As already mentioned the software takes climatic data, cropping pattern, soil characteristics as input data. In response to the inputs, the software provides evapotranspiration, net irrigation requirement at any specified time domain. Maximum ETo observed in the month August where daily ETo is 5.57mm and minimum ETo is 1.68mm in the month of December. Average daily ETo works out to be 3.48mm. Total ETo in a year 1273mm/year where total rainfall 714.1mm/year for Tashkent region. Total Irrigation Water Requirement in the field without any loss for the crops are as follows

5/12	1.96	30.00	0.10	0.19	0.97	0.82	0.00	0.00
6/12	1.95	30.00	0.10	0.20	0.98	0.82	0.00	0.00
7/12	1.93	30.00	0.10	0.20	0.99	0.83	0.00	0.00
8/12	1.92	30.00	0.10	0.20	0.99	0.83	0.00	0.00
9/12	1.91	30.00	0.11	0.20	1.00	0.84	0.00	0.00
10/12	1.90	30.00	0.11	0.21	1.01	0.84	0.00	0.00
11/12	1.89	30.00	0.11	0.21	1.02	0.85	0.00	0.00
12/12	1.88	30.00	0.11	0.21	1.02	0.85	0.00	0.00
13/12	1.87	30.00	0.11	0.21	1.03	0.86	0.00	0.00
14/12	1.86	30.00	0.12	0.21	1.04	0.86	0.00	0.00
15/12	1.85	30.00	0.12	0.22	1.05	0.86	0.00	0.00
16/12	1.84	30.00	0.12	0.22	1.05	0.87	0.00	0.00
17/12	1.83	30.00	0.12	0.22	1.06	0.87	0.00	0.00
18/12	1.82	30.00	0.12	0.22	1.06	0.88	0.00	0.00
19/12	1.82	30.00	0.12	0.23	1.07	0.88	0.00	0.00
20/12	1.81	30.00	0.13	0.23	1.07	0.88	0.00	0.00
21/12	1.81	30.00	0.13	0.23	1.08	0.88	0.00	0.00
22/12	1.80	30.00	0.13	0.23	1.08	0.89	0.00	0.00
23/12	1.80	30.00	0.13	0.24	1.08	0.89	0.00	0.00
24/12	1.79	30.00	0.13	0.24	1.08	0.89	0.00	0.00
25/12	1.79	30.00	0.14	0.24	1.09	0.89	0.00	0.00
26/12	1.79	30.00	0.14	0.25	1.09	0.89	0.00	0.00
27/12	1.78	30.00	0.14	0.25	1.09	0.89	0.00	0.00
28/12	1.78	30.00	0.14	0.25	1.09	0.89	0.00	0.00
29/12	1.78	30.00	0.14	0.25	1.08	0.89	0.00	0.00
30/12	1.78	30.00	0.14	0.26	1.08	0.89	0.00	0.00
31/12	1.78	30.00	0.15	0.26	1.08	0.89	0.00	0.00
1/1	1.75	30.00	0.15	0.26	1.02	0.85	0.00	0.00
2/1	1.75	30.00	0.15	0.26	1.02	0.85	0.00	0.00
3/1	1.75	30.00	0.15	0.27	1.01	0.84	0.00	0.00
4/1	1.75	30.00	0.15	0.27	1.00	0.83	0.00	0.00
5/1	1.75	30.00	0.16	0.27	0.99	0.83	0.00	0.00
6/1	1.75	30.00	0.16	0.27	0.98	0.82	0.00	0.00
7/1	1.75	30.00	0.16	0.28	0.97	0.81	0.00	0.00
8/1	1.75	30.00	0.16	0.28	0.96	0.80	0.00	0.00
9/1	1.75	30.00	0.16	0.28	0.95	0.80	0.00	0.00
10/1	1.75	30.00	0.16	0.29	0.94	0.79	0.00	0.00
11/1	1.75	30.00	0.17	0.29	0.93	0.78	0.00	0.00
12/1	1.75	30.00	0.17	0.30	0.92	0.77	0.00	0.00
13/1	1.76	30.00	0.17	0.30	0.91	0.76	0.00	0.00
14/1	1.76	30.00	0.17	0.30	0.89	0.76	0.00	0.00
15/1	1.76	30.00	0.17	0.31	0.88	0.75	0.00	0.00
16/1	1.77	30.00	0.18	0.31	0.87	0.74	0.00	0.00
17/1	1.77	30.00	0.18	0.31	0.86	0.73	0.00	0.00
18/1	1.78	30.00	0.18	0.32	0.85	0.72	0.00	0.00
19/1	1.78	30.00	0.18	0.32	0.84	0.71	0.00	0.00
20/1	1.79	30.00	0.18	0.33	0.82	0.70	0.00	0.00
21/1	1.80	30.00	0.18	0.33	0.81	0.69	0.00	0.00
22/1	1.80	30.00	0.19	0.34	0.80	0.69	0.00	0.00
23/1	1.81	30.00	0.19	0.34	0.79	0.68	0.00	0.00

15/3	2.79	30.00	0.28	0.79	0.65	0.58	0.21	0.05
16/3	2.82	30.00	0.28	0.80	0.66	0.59	0.21	0.05
17/3	2.85	30.00	0.28	0.81	0.67	0.60	0.22	0.05
18/3	2.88	30.00	0.29	0.83	0.68	0.60	0.22	0.05
19/3	2.91	30.00	0.29	0.84	0.69	0.61	0.23	0.05
20/3	2.94	30.00	0.29	0.85	0.70	0.62	0.23	0.05
21/3	2.97	30.00	0.29	0.87	0.71	0.63	0.23	0.05
22/3	3.00	30.00	0.29	0.88	0.73	0.64	0.24	0.06
23/3	3.03	30.00	0.30	0.90	0.74	0.65	0.24	0.06
24/3	3.06	30.00	0.30	0.91	0.75	0.66	0.25	0.06
25/3	3.09	30.00	0.30	0.92	0.76	0.67	0.25	0.06
26/3	3.12	30.00	0.30	0.94	0.78	0.68	0.26	0.06
27/3	3.15	30.00	0.30	0.95	0.79	0.69	0.26	0.06
28/3	3.18	30.00	0.30	0.97	0.80	0.70	0.27	0.06
29/3	3.21	30.00	0.31	0.98	0.81	0.71	0.27	0.06
30/3	3.24	30.00	0.31	1.00	0.82	0.72	0.28	0.06
31/3	3.27	30.00	0.31	1.02	0.84	0.73	0.29	0.07
1/4	3.30	30.00	0.31	1.03	0.85	0.74	0.29	0.07
2/4	3.33	30.00	0.31	1.05	0.86	0.74	0.30	0.07
3/4	3.36	30.00	0.32	1.06	0.87	0.75	0.31	0.07
4/4	3.40	30.00	0.32	1.08	0.88	0.76	0.32	0.07
5/4	3.43	30.00	0.32	1.09	0.88	0.76	0.33	0.08
6/4	3.46	30.00	0.32	1.11	0.89	0.77	0.34	0.08
7/4	3.49	30.00	0.32	1.13	0.90	0.77	0.35	0.08
8/4	3.52	30.00	0.32	1.14	0.90	0.78	0.37	0.08
9/4	3.55	30.00	0.33	1.16	0.91	0.78	0.38	0.09
10/4	3.58	30.00	0.33	1.18	0.91	0.78	0.40	0.09
11/4	3.61	30.00	0.33	1.19	0.91	0.78	0.41	0.10
12/4	3.64	30.00	0.33	1.21	0.91	0.78	0.43	0.10
13/4	3.68	30.00	0.33	1.23	0.91	0.78	0.45	0.10
14/4	3.71	30.00	0.34	1.25	0.90	0.77	0.47	0.11
15/4	3.74	30.00	0.34	1.26	0.89	0.77	0.49	0.11
16/4	3.77	30.00	0.34	1.28	0.89	0.76	0.52	0.12
17/4	3.80	30.00	0.34	1.30	0.87	0.75	0.55	0.13
18/4	3.83	30.00	0.34	1.31	0.86	0.74	0.58	0.13
19/4	3.86	30.00	0.34	1.33	0.85	0.72	0.61	0.14
20/4	3.89	30.00	0.34	1.34	0.83	0.71	0.63	0.15
21/4	3.92	30.00	0.34	1.35	0.80	0.69	0.66	0.15
22/4	3.95	30.00	0.34	1.36	0.78	0.67	0.70	0.16
23/4	3.98	30.00	0.34	1.37	0.75	0.64	0.73	0.17
24/4	4.01	30.00	0.34	1.38	0.72	0.62	0.77	0.18
25/4	4.04	30.00	0.34	1.39	0.68	0.59	0.81	0.19
26/4	4.07	30.00	0.34	1.40	0.64	0.55	0.85	0.20
27/4	4.10	30.00	0.34	1.41	0.60	0.52	0.90	0.21
28/4	4.13	30.00	0.34	1.42	0.55	0.48	0.95	0.22
29/4	4.16	30.00	0.34	1.43	0.50	0.43	1.00	0.23
30/4	4.19	30.00	0.34	1.44	0.44	0.38	1.06	0.25
1/5	4.22	30.00	0.34	1.45	0.38	0.33	1.12	0.26
2/5	4.24	30.00	0.34	1.46	0.31	0.27	1.19	0.28
3/5	4.27	30.00	0.34	1.47	0.24	0.21	1.26	0.29

4/5	4.30	30.00	0.34	1.48	0.16	0.15	1.34	0.31
5/5	4.33	30.00	0.34	1.49	0.07	0.07	1.42	0.33
6/5	4.36	30.00	0.34	1.50	0.00	0.00	1.50	0.35
7/5	4.38	30.00	0.34	1.51	0.00	0.00	1.51	0.35
8/5	4.41	30.00	0.34	1.52	0.00	0.00	1.52	0.35
9/5	4.44	30.00	0.34	1.53	0.00	0.00	1.53	0.35
10/5	4.46	30.00	0.34	1.54	0.00	0.00	1.54	0.36
11/5	4.49	30.00	0.34	1.55	0.00	0.00	1.55	0.36
12/5	4.52	30.00	0.34	1.56	0.00	0.00	1.56	0.36
13/5	4.54	30.00	0.34	1.57	0.00	0.00	1.57	0.36
14/5	4.57	30.00	0.34	1.58	0.00	0.00	1.58	0.36
15/5	4.59	30.00	0.34	1.58	0.00	0.00	1.58	0.37
16/5	4.62	30.00	0.34	1.59	0.00	0.00	1.59	0.37
17/5	4.64	30.00	0.34	1.60	0.00	0.00	1.60	0.37
18/5	4.66	30.00	0.34	1.61	0.00	0.00	1.61	0.37
19/5	4.69	30.00	0.34	1.62	0.00	0.00	1.62	0.37
20/5	4.71	30.00	0.34	1.62	0.00	0.00	1.62	0.38
21/5	4.73	30.00	0.34	1.63	0.00	0.00	1.63	0.38
22/5	4.75	30.00	0.34	1.64	0.00	0.00	1.64	0.38
23/5	4.78	30.00	0.34	1.65	0.00	0.00	1.65	0.38
24/5	4.80	30.00	0.34	1.66	0.00	0.00	1.66	0.38
25/5	4.82	30.00	0.34	1.66	0.00	0.00	1.66	0.38
26/5	4.84	30.00	0.34	1.67	0.08	0.08	1.59	0.37
27/5	4.86	30.00	0.34	1.68	0.09	0.09	1.59	0.37
28/5	4.88	30.00	0.34	1.68	0.10	0.10	1.58	0.37
29/5	4.90	30.00	0.34	1.69	0.11	0.11	1.58	0.37
30/5	4.92	30.00	0.34	1.65	0.12	0.12	1.54	0.36
31/5	4.94	30.00	0.33	1.61	0.13	0.12	1.49	0.35
1/6	4.96	30.00	0.32	1.58	0.13	0.13	1.45	0.33
2/6	4.97	30.00	0.31	1.54	0.14	0.14	1.40	0.32
3/6	4.99	30.00	0.30	1.50	0.15	0.14	1.35	0.31
4/6	5.01	30.00	0.29	1.46	0.15	0.15	1.31	0.30
5/6	5.03	30.00	0.28	1.42	0.16	0.16	1.26	0.29
6/6	5.04	30.00	0.27	1.38	0.17	0.16	1.22	0.28
7/6	5.06	30.00	0.26	1.33	0.17	0.17	1.17	0.27
8/6	5.07	30.00	0.25	1.29	0.17	0.17	1.12	0.26
9/6	5.09	30.00	0.25	1.25	0.18	0.17	1.08	0.25
10/6	5.10	30.00	0.24	1.21	0.18	0.18	1.03	0.24
11/6	5.11	30.00	0.23	1.17	0.19	0.18	0.99	0.23
12/6	5.13	30.00	0.22	1.12	0.19	0.18	0.94	0.22
13/6	5.14	30.00	0.21	1.08	0.19	0.18	0.90	0.21
14/6	5.15	30.00	0.20	1.04	0.19	0.19	0.85	0.20
15/6	5.16	30.00	0.19	0.99	0.19	0.19	0.81	0.19
16/6	5.18	30.00	0.18	0.95	0.19	0.19	0.76	0.18
17/6	5.19	30.00	0.17	0.90	0.19	0.19	0.72	0.17
18/6	5.20	30.00	0.17	0.86	0.19	0.19	0.67	0.16
19/6	5.21	30.00	0.16	0.81	0.19	0.18	0.63	0.15
20/6	5.21	30.00	0.15	0.77	0.19	0.18	0.58	0.14
21/6	5.22	30.00	0.14	0.72	0.19	0.18	0.54	0.13
22/6	5.23	30.00	0.13	0.67	0.18	0.18	0.50	0.12

23/6	5.24	30.00	0.12	0.63	0.18	0.17	0.45	0.11
24/6	5.25	30.00	0.11	0.58	0.17	0.17	0.41	0.10
25/6	5.25	30.00	0.10	0.54	0.17	0.17	0.37	0.09
26/6	5.26	30.00	0.09	0.49	0.16	0.16	0.33	0.08
27/6	5.26	30.00	0.08	0.44	0.16	0.15	0.29	0.07
28/6	5.27	30.00	0.08	0.40	0.15	0.15	0.25	0.06
Total	729.43			176.47	156.24	134.33	94.93	[0.09]

Crop Water Requirements Report

- Crop # 2 : MAIZE (Grain)
- Block # : [All blocks]
- Planting date : 1/4
- Calculation time step = 1 Day(s)
- Irrigation Efficiency = 50%

Date	ETo (mm/period)	Planted Area (%)	Crop Kc	CWR (ETm) (mm/period)	Total Rain (mm/period)	Effect. Rain (mm/period)	Irr. Req. (mm/period)	FWS (l/s/ha)
1/4	3.30	15.00	0.05	0.15	0.42	0.37	0.00	0.00
2/4	3.33	15.00	0.05	0.15	0.43	0.37	0.00	0.00
3/4	3.36	15.00	0.05	0.15	0.43	0.38	0.00	0.00
4/4	3.40	15.00	0.05	0.15	0.44	0.38	0.00	0.00
5/4	3.43	15.00	0.05	0.15	0.44	0.38	0.00	0.00
6/4	3.46	15.00	0.05	0.16	0.45	0.38	0.00	0.00
7/4	3.49	15.00	0.05	0.16	0.45	0.39	0.00	0.00
8/4	3.52	15.00	0.05	0.16	0.45	0.39	0.00	0.00
9/4	3.55	15.00	0.05	0.16	0.45	0.39	0.00	0.00
10/4	3.58	15.00	0.05	0.16	0.45	0.39	0.00	0.00
11/4	3.61	15.00	0.05	0.16	0.45	0.39	0.00	0.00
12/4	3.64	15.00	0.05	0.16	0.45	0.39	0.00	0.00
13/4	3.68	15.00	0.05	0.17	0.45	0.39	0.00	0.00
14/4	3.71	15.00	0.05	0.17	0.45	0.39	0.00	0.00
15/4	3.74	15.00	0.05	0.17	0.45	0.38	0.00	0.00
16/4	3.77	15.00	0.05	0.17	0.44	0.38	0.00	0.00
17/4	3.80	15.00	0.05	0.17	0.44	0.37	0.00	0.00
18/4	3.83	15.00	0.05	0.17	0.43	0.37	0.00	0.00
19/4	3.86	15.00	0.05	0.17	0.42	0.36	0.00	0.00
20/4	3.89	15.00	0.05	0.18	0.41	0.35	0.00	0.00
21/4	3.92	15.00	0.05	0.18	0.40	0.34	0.00	0.00
22/4	3.95	15.00	0.05	0.18	0.39	0.33	0.00	0.00

23/4	3.98	15.00	0.05	0.18	0.38	0.32	0.00	0.00
24/4	4.01	15.00	0.05	0.18	0.36	0.31	0.00	0.00
25/4	4.04	15.00	0.05	0.18	0.34	0.29	0.00	0.00
26/4	4.07	15.00	0.05	0.20	0.32	0.28	0.00	0.00
27/4	4.10	15.00	0.05	0.21	0.30	0.26	0.00	0.00
28/4	4.13	15.00	0.06	0.23	0.28	0.24	0.00	0.00
29/4	4.16	15.00	0.06	0.24	0.25	0.22	0.03	0.01
30/4	4.19	15.00	0.06	0.26	0.22	0.19	0.07	0.02
1/5	4.22	15.00	0.07	0.28	0.19	0.17	0.11	0.03
2/5	4.24	15.00	0.07	0.29	0.16	0.14	0.15	0.04
3/5	4.27	15.00	0.07	0.31	0.12	0.11	0.20	0.05
4/5	4.30	15.00	0.08	0.32	0.08	0.07	0.25	0.06
5/5	4.33	15.00	0.08	0.34	0.04	0.04	0.30	0.07
6/5	4.36	15.00	0.08	0.36	0.00	0.00	0.36	0.08
7/5	4.38	15.00	0.09	0.37	0.00	0.00	0.37	0.09
8/5	4.41	15.00	0.09	0.39	0.00	0.00	0.39	0.09
9/5	4.44	15.00	0.09	0.41	0.00	0.00	0.41	0.09
10/5	4.46	15.00	0.10	0.43	0.00	0.00	0.43	0.10
11/5	4.49	15.00	0.10	0.44	0.00	0.00	0.44	0.10
12/5	4.52	15.00	0.10	0.46	0.00	0.00	0.46	0.11
13/5	4.54	15.00	0.11	0.48	0.00	0.00	0.48	0.11
14/5	4.57	15.00	0.11	0.50	0.00	0.00	0.50	0.12
15/5	4.59	15.00	0.11	0.52	0.00	0.00	0.52	0.12
16/5	4.62	15.00	0.12	0.53	0.00	0.00	0.53	0.12
17/5	4.64	15.00	0.12	0.55	0.00	0.00	0.55	0.13
18/5	4.66	15.00	0.12	0.57	0.00	0.00	0.57	0.13
19/5	4.69	15.00	0.13	0.59	0.00	0.00	0.59	0.14
20/5	4.71	15.00	0.13	0.61	0.00	0.00	0.61	0.14
21/5	4.73	15.00	0.13	0.63	0.00	0.00	0.63	0.15
22/5	4.75	15.00	0.14	0.65	0.00	0.00	0.65	0.15
23/5	4.78	15.00	0.14	0.67	0.00	0.00	0.67	0.15
24/5	4.80	15.00	0.14	0.69	0.00	0.00	0.69	0.16
25/5	4.82	15.00	0.15	0.70	0.00	0.00	0.70	0.16
26/5	4.84	15.00	0.15	0.72	0.04	0.04	0.68	0.16
27/5	4.86	15.00	0.15	0.74	0.05	0.05	0.70	0.16
28/5	4.88	15.00	0.16	0.76	0.05	0.05	0.71	0.17
29/5	4.90	15.00	0.16	0.78	0.06	0.05	0.73	0.17
30/5	4.92	15.00	0.16	0.80	0.06	0.06	0.74	0.17
31/5	4.94	15.00	0.17	0.82	0.06	0.06	0.76	0.18
1/6	4.96	15.00	0.17	0.84	0.07	0.07	0.78	0.18
2/6	4.97	15.00	0.17	0.86	0.07	0.07	0.79	0.18
3/6	4.99	15.00	0.18	0.88	0.07	0.07	0.81	0.19
4/6	5.01	15.00	0.18	0.90	0.08	0.07	0.83	0.19
5/6	5.03	15.00	0.18	0.90	0.08	0.08	0.83	0.19
6/6	5.04	15.00	0.18	0.91	0.08	0.08	0.83	0.19
7/6	5.06	15.00	0.18	0.91	0.09	0.08	0.83	0.19
8/6	5.07	15.00	0.18	0.91	0.09	0.08	0.83	0.19
9/6	5.09	15.00	0.18	0.92	0.09	0.09	0.83	0.19
10/6	5.10	15.00	0.18	0.92	0.09	0.09	0.83	0.19
11/6	5.11	15.00	0.18	0.92	0.09	0.09	0.83	0.19

12/6	5.13	15.00	0.18	0.92	0.09	0.09	0.83	0.19
13/6	5.14	15.00	0.18	0.93	0.09	0.09	0.83	0.19
14/6	5.15	15.00	0.18	0.93	0.10	0.09	0.83	0.19
15/6	5.16	15.00	0.18	0.93	0.10	0.09	0.84	0.19
16/6	5.18	15.00	0.18	0.93	0.10	0.09	0.84	0.19
17/6	5.19	15.00	0.18	0.93	0.10	0.09	0.84	0.19
18/6	5.20	15.00	0.18	0.94	0.10	0.09	0.84	0.20
19/6	5.21	15.00	0.18	0.94	0.10	0.09	0.84	0.20
20/6	5.21	15.00	0.18	0.94	0.09	0.09	0.85	0.20
21/6	5.22	15.00	0.18	0.94	0.09	0.09	0.85	0.20
22/6	5.23	15.00	0.18	0.94	0.09	0.09	0.85	0.20
23/6	5.24	15.00	0.18	0.94	0.09	0.09	0.86	0.20
24/6	5.25	15.00	0.18	0.94	0.09	0.08	0.86	0.20
25/6	5.25	15.00	0.18	0.95	0.08	0.08	0.86	0.20
26/6	5.26	15.00	0.18	0.95	0.08	0.08	0.87	0.20
27/6	5.26	15.00	0.18	0.95	0.08	0.08	0.87	0.20
28/6	5.27	15.00	0.18	0.95	0.08	0.07	0.87	0.20
29/6	5.27	15.00	0.18	0.95	0.07	0.07	0.88	0.20
30/6	5.28	15.00	0.18	0.95	0.07	0.07	0.88	0.20
1/7	5.28	15.00	0.18	0.95	0.06	0.06	0.89	0.21
2/7	5.28	15.00	0.18	0.95	0.06	0.06	0.89	0.21
3/7	5.29	15.00	0.18	0.95	0.05	0.05	0.90	0.21
4/7	5.29	15.00	0.18	0.95	0.05	0.05	0.90	0.21
5/7	5.29	15.00	0.18	0.95	0.04	0.04	0.91	0.21
6/7	5.29	15.00	0.18	0.95	0.00	0.00	0.95	0.22
7/7	5.29	15.00	0.18	0.95	0.00	0.00	0.95	0.22
8/7	5.29	15.00	0.18	0.95	0.00	0.00	0.95	0.22
9/7	5.29	15.00	0.18	0.95	0.00	0.00	0.95	0.22
10/7	5.29	15.00	0.18	0.95	0.00	0.00	0.95	0.22
11/7	5.28	15.00	0.18	0.95	0.00	0.00	0.95	0.22
12/7	5.28	15.00	0.18	0.95	0.00	0.00	0.95	0.22
13/7	5.28	15.00	0.18	0.95	0.00	0.00	0.95	0.22
14/7	5.27	15.00	0.18	0.95	0.00	0.00	0.95	0.22
15/7	5.27	15.00	0.18	0.93	0.00	0.00	0.93	0.22
16/7	5.27	15.00	0.17	0.91	0.00	0.00	0.91	0.21
17/7	5.26	15.00	0.17	0.89	0.00	0.00	0.89	0.21
18/7	5.25	15.00	0.17	0.87	0.00	0.00	0.87	0.20
19/7	5.25	15.00	0.16	0.85	0.00	0.00	0.85	0.20
20/7	5.24	15.00	0.16	0.83	0.00	0.00	0.83	0.19
21/7	5.23	15.00	0.16	0.81	0.00	0.00	0.81	0.19
22/7	5.23	15.00	0.15	0.79	0.00	0.00	0.79	0.18
23/7	5.22	15.00	0.15	0.77	0.00	0.00	0.77	0.18
24/7	5.21	15.00	0.15	0.76	0.00	0.00	0.76	0.17
25/7	5.20	15.00	0.14	0.74	0.00	0.00	0.74	0.17
26/7	5.19	15.00	0.14	0.72	0.00	0.00	0.72	0.17
27/7	5.18	15.00	0.13	0.70	0.00	0.00	0.70	0.16
28/7	5.17	15.00	0.13	0.68	0.00	0.00	0.68	0.16
29/7	5.16	15.00	0.13	0.66	0.00	0.00	0.66	0.15
30/7	5.14	15.00	0.12	0.64	0.00	0.00	0.64	0.15
31/7	5.13	15.00	0.12	0.62	0.00	0.00	0.62	0.14

1/8	5.12	15.00	0.12	0.60	0.00	0.00	0.60	0.14
2/8	5.10	15.00	0.11	0.58	0.00	0.00	0.58	0.13
3/8	5.09	15.00	0.11	0.56	0.00	0.00	0.56	0.13
4/8	5.08	15.00	0.11	0.54	0.00	0.00	0.54	0.13
5/8	5.06	15.00	0.10	0.52	0.00	0.00	0.52	0.12
6/8	5.05	15.00	0.10	0.50	0.00	0.00	0.50	0.12
7/8	5.03	15.00	0.10	0.48	0.00	0.00	0.48	0.11
8/8	5.01	15.00	0.09	0.46	0.00	0.00	0.46	0.11
9/8	5.00	15.00	0.09	0.44	0.00	0.00	0.44	0.10
10/8	4.98	15.00	0.09	0.43	0.00	0.00	0.43	0.10
11/8	4.96	15.00	0.08	0.41	0.00	0.00	0.41	0.09
12/8	4.94	15.00	0.08	0.39	0.00	0.00	0.39	0.09
13/8	4.92	15.00	0.08	0.37	0.00	0.00	0.37	0.09
Total	637.59			82.49	15.80	13.98	73.71	[0.13]

Crop Water Requirements Report

- Crop # 3 : CABBAGE (Crucifers)
- Block # : [All blocks]
- Planting date : 15/7
- Calculation time step = 1 Day(s)
- Irrigation Efficiency = 50%

Date	ETo (mm/period)	Planted Area (%)	Crop Kc	CWR (ETm) (mm/period)	Total Rain (mm/period)	Effect. Rain (mm/period)	Irr. Req. (mm/period)	FWS (l/s/ha)
15/7	5.27	15.00	0.10	0.55	0.00	0.00	0.55	0.13
16/7	5.27	15.00	0.10	0.55	0.00	0.00	0.55	0.13
17/7	5.26	15.00	0.10	0.55	0.00	0.00	0.55	0.13
18/7	5.25	15.00	0.10	0.55	0.00	0.00	0.55	0.13
19/7	5.25	15.00	0.10	0.55	0.00	0.00	0.55	0.13
20/7	5.24	15.00	0.10	0.55	0.00	0.00	0.55	0.13
21/7	5.23	15.00	0.10	0.55	0.00	0.00	0.55	0.13
22/7	5.23	15.00	0.10	0.55	0.00	0.00	0.55	0.13
23/7	5.22	15.00	0.10	0.55	0.00	0.00	0.55	0.13
24/7	5.21	15.00	0.10	0.55	0.00	0.00	0.55	0.13
25/7	5.20	15.00	0.10	0.55	0.00	0.00	0.55	0.13
26/7	5.19	15.00	0.10	0.54	0.00	0.00	0.54	0.13
27/7	5.18	15.00	0.10	0.54	0.00	0.00	0.54	0.13
28/7	5.17	15.00	0.10	0.54	0.00	0.00	0.54	0.13
29/7	5.16	15.00	0.10	0.54	0.00	0.00	0.54	0.13
30/7	5.14	15.00	0.10	0.54	0.00	0.00	0.54	0.13

31/7	5.13	15.00	0.10	0.54	0.00	0.00	0.54	0.12
1/8	5.12	15.00	0.10	0.54	0.00	0.00	0.54	0.12
2/8	5.10	15.00	0.10	0.54	0.00	0.00	0.54	0.12
3/8	5.09	15.00	0.10	0.53	0.00	0.00	0.53	0.12
4/8	5.08	15.00	0.10	0.53	0.00	0.00	0.53	0.12
5/8	5.06	15.00	0.10	0.53	0.00	0.00	0.53	0.12
6/8	5.05	15.00	0.10	0.53	0.00	0.00	0.53	0.12
7/8	5.03	15.00	0.10	0.53	0.00	0.00	0.53	0.12
8/8	5.01	15.00	0.10	0.53	0.00	0.00	0.53	0.12
9/8	5.00	15.00	0.11	0.53	0.00	0.00	0.53	0.12
10/8	4.98	15.00	0.11	0.54	0.00	0.00	0.54	0.12
11/8	4.96	15.00	0.11	0.54	0.00	0.00	0.54	0.13
12/8	4.94	15.00	0.11	0.55	0.00	0.00	0.55	0.13
13/8	4.92	15.00	0.11	0.55	0.00	0.00	0.55	0.13
14/8	4.91	15.00	0.11	0.56	0.00	0.00	0.56	0.13
15/8	4.89	15.00	0.12	0.56	0.00	0.00	0.56	0.13
16/8	4.87	15.00	0.12	0.57	0.00	0.00	0.57	0.13
17/8	4.85	15.00	0.12	0.57	0.00	0.00	0.57	0.13
18/8	4.83	15.00	0.12	0.58	0.00	0.00	0.58	0.13
19/8	4.80	15.00	0.12	0.58	0.00	0.00	0.58	0.14
20/8	4.78	15.00	0.12	0.59	0.00	0.00	0.59	0.14
21/8	4.76	15.00	0.12	0.59	0.00	0.00	0.59	0.14
22/8	4.74	15.00	0.13	0.60	0.00	0.00	0.60	0.14
23/8	4.72	15.00	0.13	0.60	0.00	0.00	0.60	0.14
24/8	4.69	15.00	0.13	0.61	0.00	0.00	0.61	0.14
25/8	4.67	15.00	0.13	0.61	0.00	0.00	0.61	0.14
26/8	4.65	15.00	0.13	0.61	0.00	0.00	0.61	0.14
27/8	4.62	15.00	0.13	0.62	0.00	0.00	0.62	0.14
28/8	4.60	15.00	0.13	0.62	0.00	0.00	0.62	0.14
29/8	4.57	15.00	0.14	0.62	0.00	0.00	0.62	0.14
30/8	4.55	15.00	0.14	0.63	0.00	0.00	0.63	0.15
31/8	4.52	15.00	0.14	0.63	0.00	0.00	0.63	0.15
1/9	4.50	15.00	0.14	0.63	0.00	0.00	0.63	0.15
2/9	4.47	15.00	0.14	0.64	0.00	0.00	0.64	0.15
3/9	4.44	15.00	0.14	0.64	0.00	0.00	0.64	0.15
4/9	4.42	15.00	0.15	0.64	0.00	0.00	0.64	0.15
5/9	4.39	15.00	0.15	0.65	0.00	0.00	0.65	0.15
6/9	4.36	15.00	0.15	0.65	0.00	0.00	0.65	0.15
7/9	4.33	15.00	0.15	0.65	0.00	0.00	0.65	0.15
8/9	4.31	15.00	0.15	0.65	0.00	0.00	0.65	0.15
9/9	4.28	15.00	0.15	0.65	0.00	0.00	0.65	0.15
10/9	4.25	15.00	0.15	0.66	0.00	0.00	0.66	0.15
11/9	4.22	15.00	0.16	0.66	0.00	0.00	0.66	0.15
12/9	4.19	15.00	0.16	0.66	0.00	0.00	0.66	0.15
13/9	4.16	15.00	0.16	0.66	0.00	0.00	0.66	0.15
14/9	4.14	15.00	0.16	0.65	0.00	0.00	0.65	0.15
15/9	4.11	15.00	0.16	0.65	0.00	0.00	0.65	0.15
16/9	4.08	15.00	0.16	0.64	0.00	0.00	0.64	0.15
17/9	4.05	15.00	0.16	0.64	0.00	0.00	0.64	0.15
18/9	4.02	15.00	0.16	0.63	0.00	0.00	0.63	0.15

19/9	3.99	15.00	0.16	0.63	0.00	0.00	0.63	0.15
20/9	3.96	15.00	0.16	0.62	0.00	0.00	0.62	0.14
21/9	3.93	15.00	0.16	0.62	0.00	0.00	0.62	0.14
22/9	3.90	15.00	0.16	0.61	0.00	0.00	0.61	0.14
23/9	3.87	15.00	0.16	0.61	0.00	0.00	0.61	0.14
24/9	3.83	15.00	0.16	0.60	0.00	0.00	0.60	0.14
25/9	3.80	15.00	0.16	0.60	0.05	0.04	0.55	0.13
26/9	3.77	15.00	0.16	0.59	0.14	0.11	0.48	0.11
27/9	3.74	15.00	0.16	0.59	0.23	0.17	0.42	0.10
28/9	3.71	15.00	0.16	0.58	0.31	0.23	0.36	0.08
29/9	3.68	15.00	0.16	0.58	0.38	0.28	0.30	0.07
30/9	3.65	15.00	0.16	0.57	0.44	0.32	0.25	0.06
1/10	3.62	15.00	0.16	0.57	0.50	0.36	0.21	0.05
2/10	3.59	15.00	0.16	0.56	0.55	0.40	0.17	0.04
3/10	3.55	15.00	0.16	0.56	0.59	0.43	0.13	0.03
4/10	3.52	15.00	0.16	0.55	0.63	0.46	0.10	0.02
5/10	3.49	15.00	0.16	0.55	0.66	0.48	0.07	0.02
6/10	3.46	15.00	0.16	0.55	0.69	0.50	0.04	0.01
7/10	3.43	15.00	0.16	0.54	0.71	0.52	0.02	0.00
8/10	3.40	15.00	0.16	0.53	0.73	0.53	0.00	0.00
9/10	3.37	15.00	0.16	0.52	0.74	0.55	0.00	0.00
10/10	3.34	15.00	0.15	0.52	0.76	0.56	0.00	0.00
11/10	3.31	15.00	0.15	0.51	0.76	0.56	0.00	0.00
12/10	3.27	15.00	0.15	0.50	0.77	0.57	0.00	0.00
13/10	3.24	15.00	0.15	0.49	0.77	0.57	0.00	0.00
14/10	3.21	15.00	0.15	0.48	0.77	0.57	0.00	0.00
15/10	3.18	15.00	0.15	0.48	0.77	0.57	0.00	0.00
16/10	3.15	15.00	0.15	0.47	0.76	0.57	0.00	0.00
17/10	3.12	15.00	0.15	0.46	0.76	0.57	0.00	0.00
18/10	3.09	15.00	0.15	0.45	0.75	0.57	0.00	0.00
19/10	3.06	15.00	0.15	0.45	0.74	0.56	0.00	0.00
20/10	3.03	15.00	0.14	0.44	0.73	0.56	0.00	0.00
21/10	3.00	15.00	0.14	0.43	0.72	0.55	0.00	0.00
22/10	2.97	15.00	0.14	0.42	0.71	0.54	0.00	0.00
Total	433.87			56.92	17.13	12.73	45.46	[0.11]

Crop Water Requirements Report

- Crop # 4 : COTTON
- Planting date : 7/4
- Calculation time step = 1 Day(s)
- Irrigation Efficiency = 50%

Date	ETo (mm/period)	Planted Area (%)	Crop Kc	CWR (ETm)	Total Rain	Effect. Rain	Irr. Req.	FWS (l/s/ha)
				---------- (mm/period)	----------			
7/4	3.49	40.00	0.14	0.49	1.20	1.03	0.00	0.00
8/4	3.52	40.00	0.14	0.49	1.20	1.04	0.00	0.00
9/4	3.55	40.00	0.14	0.50	1.21	1.04	0.00	0.00
10/4	3.58	40.00	0.14	0.50	1.21	1.04	0.00	0.00
11/4	3.61	40.00	0.14	0.51	1.21	1.04	0.00	0.00
12/4	3.64	40.00	0.14	0.51	1.21	1.04	0.00	0.00
13/4	3.68	40.00	0.14	0.51	1.21	1.04	0.00	0.00
14/4	3.71	40.00	0.14	0.52	1.20	1.03	0.00	0.00
15/4	3.74	40.00	0.14	0.52	1.19	1.02	0.00	0.00
16/4	3.77	40.00	0.14	0.53	1.18	1.01	0.00	0.00
17/4	3.80	40.00	0.14	0.53	1.17	1.00	0.00	0.00
18/4	3.83	40.00	0.14	0.54	1.15	0.98	0.00	0.00
19/4	3.86	40.00	0.14	0.54	1.13	0.97	0.00	0.00
20/4	3.89	40.00	0.14	0.54	1.10	0.94	0.00	0.00
21/4	3.92	40.00	0.14	0.55	1.07	0.92	0.00	0.00
22/4	3.95	40.00	0.14	0.55	1.04	0.89	0.00	0.00
23/4	3.98	40.00	0.14	0.56	1.00	0.86	0.00	0.00
24/4	4.01	40.00	0.14	0.56	0.96	0.82	0.00	0.00
25/4	4.04	40.00	0.14	0.57	0.91	0.78	0.00	0.00
26/4	4.07	40.00	0.14	0.57	0.86	0.74	0.00	0.00
27/4	4.10	40.00	0.14	0.57	0.80	0.69	0.00	0.00
28/4	4.13	40.00	0.14	0.58	0.74	0.63	0.00	0.00
29/4	4.16	40.00	0.14	0.58	0.67	0.58	0.01	0.00
30/4	4.19	40.00	0.14	0.59	0.59	0.51	0.07	0.02
1/5	4.22	40.00	0.14	0.59	0.51	0.44	0.15	0.03
2/5	4.24	40.00	0.14	0.59	0.42	0.37	0.23	0.05
3/5	4.27	40.00	0.14	0.60	0.32	0.28	0.31	0.07
4/5	4.30	40.00	0.14	0.60	0.21	0.20	0.41	0.09
5/5	4.33	40.00	0.14	0.61	0.10	0.10	0.51	0.12
6/5	4.36	40.00	0.14	0.61	0.00	0.00	0.61	0.14
7/5	4.38	40.00	0.15	0.64	0.00	0.00	0.64	0.15
8/5	4.41	40.00	0.15	0.68	0.00	0.00	0.68	0.16
9/5	4.44	40.00	0.16	0.71	0.00	0.00	0.71	0.16
10/5	4.46	40.00	0.17	0.75	0.00	0.00	0.75	0.17
11/5	4.49	40.00	0.17	0.78	0.00	0.00	0.78	0.18
12/5	4.52	40.00	0.18	0.82	0.00	0.00	0.82	0.19
13/5	4.54	40.00	0.19	0.85	0.00	0.00	0.85	0.20

14/5	4.57	40.00	0.19	0.89	0.00	0.00	0.89	0.21
15/5	4.59	40.00	0.20	0.92	0.00	0.00	0.92	0.21
16/5	4.62	40.00	0.21	0.96	0.00	0.00	0.96	0.22
17/5	4.64	40.00	0.21	1.00	0.00	0.00	1.00	0.23
18/5	4.66	40.00	0.22	1.03	0.00	0.00	1.03	0.24
19/5	4.69	40.00	0.23	1.07	0.00	0.00	1.07	0.25
20/5	4.71	40.00	0.24	1.11	0.00	0.00	1.11	0.26
21/5	4.73	40.00	0.24	1.15	0.00	0.00	1.15	0.27
22/5	4.75	40.00	0.25	1.18	0.00	0.00	1.18	0.27
23/5	4.78	40.00	0.26	1.22	0.00	0.00	1.22	0.28
24/5	4.80	40.00	0.26	1.26	0.00	0.00	1.26	0.29
25/5	4.82	40.00	0.27	1.30	0.00	0.00	1.30	0.30
26/5	4.84	40.00	0.28	1.34	0.11	0.11	1.23	0.28
27/5	4.86	40.00	0.28	1.37	0.12	0.12	1.25	0.29
28/5	4.88	40.00	0.29	1.41	0.13	0.13	1.28	0.30
29/5	4.90	40.00	0.30	1.45	0.15	0.14	1.31	0.30
30/5	4.92	40.00	0.30	1.49	0.16	0.15	1.34	0.31
31/5	4.94	40.00	0.31	1.53	0.17	0.16	1.37	0.32
1/6	4.96	40.00	0.32	1.57	0.18	0.17	1.40	0.32
2/6	4.97	40.00	0.32	1.61	0.19	0.18	1.43	0.33
3/6	4.99	40.00	0.33	1.65	0.20	0.19	1.46	0.34
4/6	5.01	40.00	0.34	1.69	0.21	0.20	1.49	0.34
5/6	5.03	40.00	0.34	1.73	0.21	0.21	1.52	0.35
6/6	5.04	40.00	0.35	1.77	0.22	0.21	1.55	0.36
7/6	5.06	40.00	0.36	1.81	0.23	0.22	1.59	0.37
8/6	5.07	40.00	0.36	1.85	0.23	0.23	1.62	0.38
9/6	5.09	40.00	0.37	1.89	0.24	0.23	1.66	0.38
10/6	5.10	40.00	0.38	1.93	0.24	0.24	1.69	0.39
11/6	5.11	40.00	0.38	1.97	0.25	0.24	1.73	0.40
12/6	5.13	40.00	0.39	2.01	0.25	0.24	1.77	0.41
13/6	5.14	40.00	0.40	2.05	0.25	0.24	1.80	0.42
14/6	5.15	40.00	0.41	2.09	0.25	0.25	1.84	0.43
15/6	5.16	40.00	0.41	2.13	0.26	0.25	1.88	0.44
16/6	5.18	40.00	0.42	2.17	0.26	0.25	1.92	0.44
17/6	5.19	40.00	0.43	2.21	0.26	0.25	1.96	0.45
18/6	5.20	40.00	0.43	2.25	0.26	0.25	2.00	0.46
19/6	5.21	40.00	0.44	2.29	0.25	0.25	2.04	0.47
20/6	5.21	40.00	0.45	2.33	0.25	0.24	2.08	0.48
21/6	5.22	40.00	0.45	2.37	0.25	0.24	2.12	0.49
22/6	5.23	40.00	0.46	2.40	0.24	0.24	2.17	0.50
23/6	5.24	40.00	0.47	2.44	0.24	0.23	2.21	0.51
24/6	5.25	40.00	0.47	2.48	0.23	0.23	2.26	0.52
25/6	5.25	40.00	0.48	2.52	0.23	0.22	2.30	0.53
26/6	5.26	40.00	0.48	2.52	0.22	0.21	2.31	0.53
27/6	5.26	40.00	0.48	2.53	0.21	0.21	2.32	0.54
28/6	5.27	40.00	0.48	2.53	0.20	0.20	2.33	0.54
29/6	5.27	40.00	0.48	2.53	0.19	0.19	2.34	0.54
30/6	5.28	40.00	0.48	2.53	0.18	0.18	2.36	0.55
1/7	5.28	40.00	0.48	2.53	0.17	0.17	2.37	0.55
2/7	5.28	40.00	0.48	2.54	0.16	0.15	2.38	0.55

3/7	5.29	40.00	0.48	2.54	0.14	0.14	2.40	0.55
4/7	5.29	40.00	0.48	2.54	0.13	0.13	2.41	0.56
5/7	5.29	40.00	0.48	2.54	0.11	0.11	2.43	0.56
6/7	5.29	40.00	0.48	2.54	0.00	0.00	2.54	0.59
7/7	5.29	40.00	0.48	2.54	0.00	0.00	2.54	0.59
8/7	5.29	40.00	0.48	2.54	0.00	0.00	2.54	0.59
9/7	5.29	40.00	0.48	2.54	0.00	0.00	2.54	0.59
10/7	5.29	40.00	0.48	2.54	0.00	0.00	2.54	0.59
11/7	5.28	40.00	0.48	2.54	0.00	0.00	2.54	0.59
12/7	5.28	40.00	0.48	2.54	0.00	0.00	2.54	0.59
13/7	5.28	40.00	0.48	2.53	0.00	0.00	2.53	0.59
14/7	5.27	40.00	0.48	2.53	0.00	0.00	2.53	0.59
15/7	5.27	40.00	0.48	2.53	0.00	0.00	2.53	0.59
16/7	5.27	40.00	0.48	2.53	0.00	0.00	2.53	0.59
17/7	5.26	40.00	0.48	2.52	0.00	0.00	2.52	0.58
18/7	5.25	40.00	0.48	2.52	0.00	0.00	2.52	0.58
19/7	5.25	40.00	0.48	2.52	0.00	0.00	2.52	0.58
20/7	5.24	40.00	0.48	2.52	0.00	0.00	2.52	0.58
21/7	5.23	40.00	0.48	2.51	0.00	0.00	2.51	0.58
22/7	5.23	40.00	0.48	2.51	0.00	0.00	2.51	0.58
23/7	5.22	40.00	0.48	2.50	0.00	0.00	2.50	0.58
24/7	5.21	40.00	0.48	2.50	0.00	0.00	2.50	0.58
25/7	5.20	40.00	0.48	2.50	0.00	0.00	2.50	0.58
26/7	5.19	40.00	0.48	2.49	0.00	0.00	2.49	0.58
27/7	5.18	40.00	0.48	2.49	0.00	0.00	2.49	0.58
28/7	5.17	40.00	0.48	2.48	0.00	0.00	2.48	0.57
29/7	5.16	40.00	0.48	2.47	0.00	0.00	2.47	0.57
30/7	5.14	40.00	0.48	2.47	0.00	0.00	2.47	0.57
31/7	5.13	40.00	0.48	2.46	0.00	0.00	2.46	0.57
1/8	5.12	40.00	0.48	2.46	0.00	0.00	2.46	0.57
2/8	5.10	40.00	0.48	2.45	0.00	0.00	2.45	0.57
3/8	5.09	40.00	0.48	2.44	0.00	0.00	2.44	0.57
4/8	5.08	40.00	0.48	2.44	0.00	0.00	2.44	0.56
5/8	5.06	40.00	0.48	2.43	0.00	0.00	2.43	0.56
6/8	5.05	40.00	0.48	2.42	0.00	0.00	2.42	0.56
7/8	5.03	40.00	0.48	2.41	0.00	0.00	2.41	0.56
8/8	5.01	40.00	0.48	2.41	0.00	0.00	2.41	0.56
9/8	5.00	40.00	0.48	2.40	0.00	0.00	2.40	0.56
10/8	4.98	40.00	0.48	2.39	0.00	0.00	2.39	0.55
11/8	4.96	40.00	0.48	2.38	0.00	0.00	2.38	0.55
12/8	4.94	40.00	0.48	2.37	0.00	0.00	2.37	0.55
13/8	4.92	40.00	0.48	2.36	0.00	0.00	2.36	0.55
14/8	4.91	40.00	0.48	2.35	0.00	0.00	2.35	0.55
15/8	4.89	40.00	0.48	2.35	0.00	0.00	2.35	0.54
16/8	4.87	40.00	0.48	2.34	0.00	0.00	2.34	0.54
17/8	4.85	40.00	0.48	2.33	0.00	0.00	2.33	0.54
18/8	4.83	40.00	0.48	2.32	0.00	0.00	2.32	0.54
19/8	4.80	40.00	0.48	2.31	0.00	0.00	2.31	0.53
20/8	4.78	40.00	0.48	2.30	0.00	0.00	2.30	0.53
21/8	4.76	40.00	0.48	2.29	0.00	0.00	2.29	0.53

22/8	4.74	40.00	0.48	2.27	0.00	0.00	2.27	0.53
23/8	4.72	40.00	0.48	2.26	0.00	0.00	2.26	0.52
24/8	4.69	40.00	0.48	2.25	0.00	0.00	2.25	0.52
25/8	4.67	40.00	0.48	2.22	0.00	0.00	2.22	0.51
26/8	4.65	40.00	0.47	2.19	0.00	0.00	2.19	0.51
27/8	4.62	40.00	0.47	2.16	0.00	0.00	2.16	0.50
28/8	4.60	40.00	0.46	2.13	0.00	0.00	2.13	0.49
29/8	4.57	40.00	0.46	2.09	0.00	0.00	2.09	0.48
30/8	4.55	40.00	0.45	2.06	0.00	0.00	2.06	0.48
31/8	4.52	40.00	0.45	2.03	0.00	0.00	2.03	0.47
1/9	4.50	40.00	0.45	2.00	0.00	0.00	2.00	0.46
2/9	4.47	40.00	0.44	1.97	0.00	0.00	1.97	0.46
3/9	4.44	40.00	0.44	1.94	0.00	0.00	1.94	0.45
4/9	4.42	40.00	0.43	1.91	0.00	0.00	1.91	0.44
5/9	4.39	40.00	0.43	1.88	0.00	0.00	1.88	0.43
6/9	4.36	40.00	0.42	1.85	0.00	0.00	1.85	0.43
7/9	4.33	40.00	0.42	1.82	0.00	0.00	1.82	0.42
8/9	4.31	40.00	0.41	1.79	0.00	0.00	1.79	0.41
9/9	4.28	40.00	0.41	1.76	0.00	0.00	1.76	0.41
10/9	4.25	40.00	0.41	1.72	0.00	0.00	1.72	0.40
11/9	4.22	40.00	0.40	1.69	0.00	0.00	1.69	0.39
12/9	4.19	40.00	0.40	1.67	0.00	0.00	1.67	0.39
13/9	4.16	40.00	0.39	1.64	0.00	0.00	1.64	0.38
14/9	4.14	40.00	0.39	1.61	0.00	0.00	1.61	0.37
15/9	4.11	40.00	0.38	1.58	0.00	0.00	1.58	0.36
16/9	4.08	40.00	0.38	1.55	0.00	0.00	1.55	0.36
17/9	4.05	40.00	0.38	1.52	0.00	0.00	1.52	0.35
18/9	4.02	40.00	0.37	1.49	0.00	0.00	1.49	0.34
19/9	3.99	40.00	0.37	1.46	0.00	0.00	1.46	0.34
20/9	3.96	40.00	0.36	1.43	0.00	0.00	1.43	0.33
21/9	3.93	40.00	0.36	1.40	0.00	0.00	1.40	0.33
22/9	3.90	40.00	0.35	1.38	0.00	0.00	1.38	0.32
23/9	3.87	40.00	0.35	1.35	0.00	0.00	1.35	0.31
24/9	3.83	40.00	0.34	1.32	0.00	0.00	1.32	0.31
25/9	3.80	40.00	0.34	1.29	0.12	0.12	1.18	0.27
26/9	3.77	40.00	0.34	1.27	0.38	0.30	0.97	0.22
27/9	3.74	40.00	0.33	1.24	0.61	0.46	0.78	0.18
28/9	3.71	40.00	0.33	1.21	0.82	0.61	0.60	0.14
29/9	3.68	40.00	0.32	1.19	1.01	0.74	0.44	0.10
30/9	3.65	40.00	0.32	1.16	1.18	0.86	0.30	0.07
1/10	3.62	40.00	0.31	1.14	1.33	0.97	0.17	0.04
2/10	3.59	40.00	0.31	1.11	1.46	1.07	0.05	0.01
3/10	3.55	40.00	0.31	1.09	1.58	1.15	0.00	0.00
4/10	3.52	40.00	0.30	1.06	1.68	1.22	0.00	0.00
5/10	3.49	40.00	0.30	1.04	1.77	1.29	0.00	0.00
6/10	3.46	40.00	0.29	1.01	1.84	1.34	0.00	0.00
7/10	3.43	40.00	0.29	0.99	1.90	1.39	0.00	0.00
8/10	3.40	40.00	0.28	0.96	1.95	1.43	0.00	0.00
9/10	3.37	40.00	0.28	0.94	1.99	1.46	0.00	0.00
10/10	3.34	40.00	0.27	0.92	2.02	1.48	0.00	0.00

11/10	3.31	40.00	0.27	0.89	2.04	1.50	0.00	0.00
12/10	3.27	40.00	0.27	0.87	2.05	1.52	0.00	0.00
13/10	3.24	40.00	0.26	0.85	2.06	1.52	0.00	0.00
14/10	3.21	40.00	0.26	0.83	2.05	1.53	0.00	0.00
15/10	3.18	40.00	0.25	0.81	2.05	1.53	0.00	0.00
16/10	3.15	40.00	0.25	0.78	2.04	1.53	0.00	0.00
17/10	3.12	40.00	0.24	0.76	2.02	1.52	0.00	0.00
18/10	3.09	40.00	0.24	0.74	2.00	1.51	0.00	0.00
Total	885.18			320.74	73.13	59.28	278.65	[0.33]

CHAPTER-6

APPLICATION OF WATER AND SALT BALANCE MODEL (WASIM)

6.1 Background

WASIM is a computer-based training package for the teaching and demonstration of issues involved in irrigation, drainage and salinity management. WASIM simulates the soil water and salinity relationships in response to different management strategies (e.g., drainage designs and water management practices) and environmental scenarios (e.g., weather data, soil types, cropping patterns).

The model carries out a one-dimensional, daily soil water balance. It aims to simulate the soil water storage and rates of input (infiltration) and output (evaportanspiration and drainage) of water in response to climate, irrigation, and canal seepage wherever relevant. The water and salt balances are computed midway between the drains. The soil profile is assumed to be homogeneous. The upper boundary is the soil surface and the lower boundary is the impermeable layer. Water is stored between these two boundaries in five stores (compartments). Overview of water and salt balance is given in figure 6.1

0. The surface (0 – 0.15m) layer,
1. The active root zone (0.15m – root depth),
2. The unsaturated compartment below the root zone (root depth – water table),
3. The saturated compartment above drain depth (water table – drain depth),
4. The saturated compartment below drain depth (drain depth – impermeable layer).

The boundary between compartments 1 and 2 will change as the roots grow. Before plantroots reach 0.15 m, compartment 1 will have zero thickness. Similarly the boundary between compartments 2 and 3 will fluctuate with the water table.

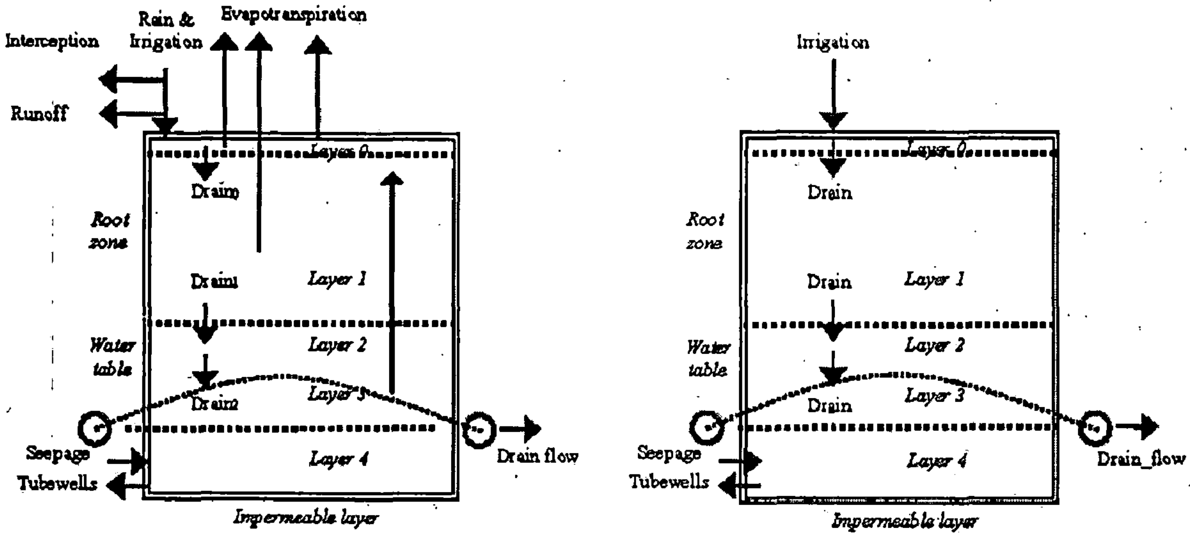


Figure 6.1 Overview of soil water and salt balance

6.2 Water Flow

If the volume water fraction of any compartment is brought above saturation any excess is assumed to be transferred to the compartment below immediately by drainage. If the volume water fraction is between the field capacity and saturation then the drainage released from the compartment is computed as an exponential function between the field capacity and saturation, which can be seen in Figure 6.2

$$q = \tau(\theta_{SAT} - \theta_{FC})\frac{(e^{(\theta-\theta_{FC})} - 1)}{(e^{(\theta_{SAT}-\theta_{FC})} - 1)}1000mm/m \qquad (6.1)$$

where

q : drainage from compartment, mm / m of compartment thickness / d
τ : drainage constant, dimensionless
θ : volume water fraction, dimensionless
θ_{FC} : volume water fraction at field capacity, dimensionless
θ_{SAT} : volume water fraction at saturation, dimensionless

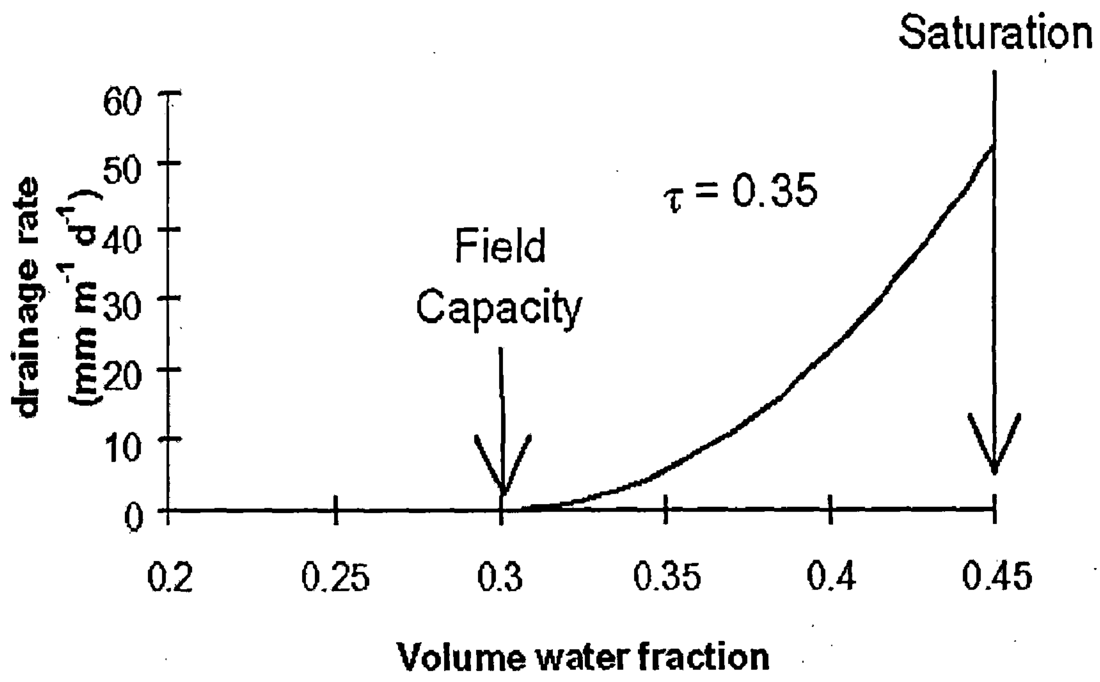


Figure 6.2 Example of drainage rate function

6.3 Salt Transport

The transfer of water drives the transfer of salt between soil compartments. A complete mixing model is assumed, such that

$$S_{j,i} = S_{j,i-1} + Sd_{j-1,i} - Sd_{j,I} \qquad (6.2)$$

where

$S_{j,i}$: mass of salt in compartment j on day i, mm dS m^{-1} d^{-1}

$Sd_{j,I}$: mass of salt in the water leaving compartment j on day i, mm dS m^{-1} d^{-1}

Salt moves with the water flow

$$Sd_j = q_j * EC_j * Le \qquad (6.3)$$

where

Sd_j : mass of salt in the water leaving compartment j, mm dS m^{-1} d^{-1}

q_j : rate of drainage from compartment j, mm d^{-1}

ECj : electrical conductivity of soil water in compartment j, dS m^{-1}

Le : leaching efficiency, dimensionless

The electrical conductivity of the saturation extract, *ECs* (or *ECe*), is often used as a measure of soil salinity. The *ECs* of the unsaturated compartments is calculated from

$$ECs = EC\frac{\theta}{\theta_{paste}} \qquad (6.4)$$

where

ECs : electrical conductivity of saturation extract, dS/m

EC : electrical conductivity, dS/m

θ: volume water fraction, dimensionless

θ_{paste} : volume water fraction of saturated paste, dimensionless

6.4 Application

WASIM has been applied in study area of Uzbekistan and details of the area are given below;

Name of the area: Kushman ata collective farm, Sh. Rashidov district, Syr-Darya Province, Republic of Uzbekistan

Soil type	: Serozems
Soil texture	: Loam, Sandy Loam
Main Crops	: Cotton and Wheat
Irrigation Method	: Furrow
Irrigation efficiency	: 50%

Technical Characteristics of Drainage:

Type of Drainage	: Subsurface tile drainage
Drain spacing	: 50-75 m
Depth of Drainage	: 3.0m
Diameter	: 76mm

Monthly average depth of ground water table in the field for the years 2001 and 2002 are given in the Tables 6.1 and 6.2 and Mineralization of ground water is given in the Table 6.3 (Source: SANIIRI, Uzbekistan).

Table 6.1 Monthly average depth of ground water in the field in 2001

No. Bore holes	Jan	Feb	March	April	May	June	July	August	September	October	November	December
1/1	1.84	1.52	0.78	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	NA	1.17	1.53	1.39	1.95	2.88	3.17	3.26	3.43	2.29	2.58
2/1	1.55	1.51	1.09	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	NA	NA	0.79	1.30	1.03	1.79	2.66	3.22	3.44	3.38	2.26	2.49
3/1	2.83	3.00	3.02	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	NA	NA	0.84	1.44	1.58	2.29	2.96	3.43	3.46	3.51	2.98	2.74
4	NA	NA	2.01	1.75	2.29	2.44	2.99	NA	NA	3.78	3.54	3.31
5	NA	NA	2.51	1.90	2.26	2.39	2.80	NA	NA	3.24	3.54	3.91
6	NA	NA	3.12	2.10	2.44	2.50	3.01	3.30	3.45	4.00	4.28	4.36
7/4	2.75	2.91	2.75	1.47	2.06	2.40	2.95	3.17	3.39	3.60	3.43	3.27
8	NA	NA	2.40	1.33	1.90	2.35	2.80	2.88	3.32	4.04	3.49	3.38
9	NA	NA	1.30	1.22	1.77	2.22	2.67	NA	NA	3.16	2.91	2.73
10/5	2.04	2.12	2.17	0.94	1.49	1.89	NA	NA	NA	NA	NA	NA
Average	**2.29**	**2.21**	**2.00**	**1.46**	**1.73**	**2.24**	**2.88**	**3.19**	**3.39**	**3.59**	**2.47**	**2.71**

NA: Not Available

6.2 Monthly average depth of ground water in the field in 2002

No. Bore holes	Jan	Feb	March	April	May	June	July	August	September	October
1	1.75	0.81	1.39	1.29	1.72	2.22	2.39	2.36	2.58	2.7
2	1.42	0.52	0.89	0.8	1.31	1.89	2.18	2.2	2.37	2.45
3	1.06	0.52	0.87	0.82	1.34	1.97	2.16	2.2	2.4	2.51
4	3.07	2.57	2.19	1.13	1.4	1.87	1.96	2.5	2.97	3.11
5	3.92	3.21	2.33	1.45	1.65	2.01	1.94	2.48	2.96	3.08
6	3.82	2.98	2.42	1.65	2.12	1.87	1.91	2.37	2.67	2.76
7	3.1	2.87	NA	NA	NA	2.27	1.3	1.94	2.95	3.19
8	3.06	2.8	2.35	1.09	1.33	1.89	1.04	1.43	2.56	2.81
9	2.53	2.3	1.91	0.82	1.02	1.5	0.8	1.08	2.27	2.44
10	NA	NA	NA	NA	1.49	2.12	1.71	2.2	3.03	2.24
11	NA	NA	NA	NA	NA	1.81	1.45	1.39	2.52	2.88
12	NA	NA	NA	NA	NA	1.54	0.85	0.72	1.98	2.29
Average	**1.7**	**0.87**	**1.23**	**1.03**	**1.45**	**1.93**	**1.42**	**1.67**	**2.6**	**2.71**

6.3 Mineralization of Ground water (g/l)

No. Of points	6th Jan	28th Feb	18th March	3rd July	5th July	6th July	12th Sept.	13th Sept.
1	5.18	4.38	4.33	5.11	NA	NA	NA	4.98
2	13.8	11.96	11.44	NA	NA	NA	NA	7.47
3	14.23	14.12	13.67	13.51	NA	NA	NA	16.23
4	6.72	7.38	7.39	8.45	7.55	NA	NA	7.32
5	NA	4.59	4.61	4.12	NA	4.8	NA	5.52
6	7.47	8.53	8.43	6.72	6.98	NA	NA	7.71
7	7.58	NA	NA	4.78	NA	NA	4.69	NA
8	11.04	11.28	11.79	13.54	NA	NA	5.55	NA
9	13.85	11.69	12.7	16.75	NA	NA	6.89	NA
10	NA	NA	NA	7.35	NA	NA	7.45	NA
11	NA	NA	NA	6.59	NA	NA	7.26	NA
12	NA	NA	NA	8.8	NA	NA	9.61	NA

6.5 Model results

As discussed earlier, WASIM is applied for the present study.Simulation was carried out for the period 8th April to 15th Septemeber 2000 taking into account of inputs daily rainfall, daily evapotranspiration, soil water characteristics, irrigation, drainage, mineralization of, irrigation water and crop management data. The results are given in appendix 4, however the corresponding graphical representations are discussed and presented below

Figure 6.3 and 6.4 shows effect of rainfall and irrigation on ETc .The average rainfall during the crop period the crop period was 0.2mm/day and average applied 2.8mm/day. It showed that rainfall is much insufficient to meet the Etc though the problem of salt accumulation remains over there. Figure 6.5 showed that with the given quantity of total water use the EC of root zone increased at positive rate and became maximum during maturity of crop stage. This shows that deficit of root zone soil moisture increased EC root zone. Since EC root zone is very important from crop production point of view, here it is indicated that due to increase in EC root zone beyond threshold value of cotton 7.5 dS/m the crop yield of cotton decreased.

As the ETc is much higher than rainfall and irrigation deficit increased in root zone. Increase of ETc is because of hot weather in vegetation period. The climate data is given in appendix3.

Figure 6.6 showed that there is almost no rainfall during cropping period and irrigation water applied also as per crop water requirement therefore there is no considerable recharge to ground water. Water table was stable at 2.1m.

Fig. 6.7 also shows that with development of crop growth stage root development increased and became constant after mid season of crop and crop cover also followed the same trend. Initial water table was 1.3 m in the field before sawing crop, WASIM predicted values showed that water table decreased from 1.3 to 2.10 and it was stable at same point during vegetation period. Cumulative rainfall, cumulative actual ET and cumulative irrigation also calculated during cropping period, which can be seen in Figure 6.8 Cumulative Irrigation is 500mm, cumulative rainfall 40.2mm and cumulative ET 693.7mm, which means that additional water has to be applied to meet ET during vegetation period.

Figure 6.9 also showed that water content in the root zone decreased causing effect on soil moisture deficiency. Since rainfall and irrigation water is almost similar at discussed rate during growing period the water table depth remain unaffected and drainage of soil moisture also followed the same trend. Results showed that soil water content, EC root zone, soil moisture deficiency all factors interrelated to each other and all directly dependent on total water use. In figure 6.10 it is shown that the EC root zone is much more than threshold value 7.5 dS/m at some stages of growing period so as to avoid the problem of salt concentration in the root zone the applied amount for leaching 5mm is not sufficient even to meet crop Kc in the climatic condition of study area. Therefore to solve the problem of salt accumulation in the root zone and keep the EC root zone below threshold value of 7.5 dS/m, it is suggested that irrigation must be increased or pre salt leaching techniques before planting crop should be adopted. FAO reported that cotton is grown on a wide range of soils but medium and heavy textured, deep soils with good water holding capacity characteristics are preferred. Acid and dense soils limit root penetration. The pH range is 5.5 to 8 with 7 to 8 regarded as optimum. The collected data from study showed that pH ranges between 8.20-8.60 in salt affected soils and pH ranges between 8.30-8.40 in waterlogged soils (Table 4.10), which is higher than FAO recommended. Therefore to get maximum yield, pH value must be decreased through leaching. FAO (Crop water requirement) report says that when cotton grown under conditions of high groundwater table, even for short duration, and when soils are wet for long periods, the yield may decrease up to 50%, not withstanding unrestricted water use. This maybe due to inadequate soil aeration. The data which is collected from the field showed that groundwater table depth during vegetation period average 1.5m, which is critical. Use of WASIM predicted value for the same period is average 2.2m. The area, which has been, simulated is in fact soil fertility degraded region and crop production is less compared to other regions of Uzbekistan. Results showed that crop yields decreases due to high salinity during vegetation period, because soil salinity exceeds more than crop threshold salinity during vegetation period because of highly contaminated irrigation and ground water. Therefore additional water must be applied to leach accumulated salts in the root zone otherwise it will adversely effect on crop yields. Also precautions should be considered before using of saline water in irrigation such as crop threshold salinity.

FIGURE 6.3.

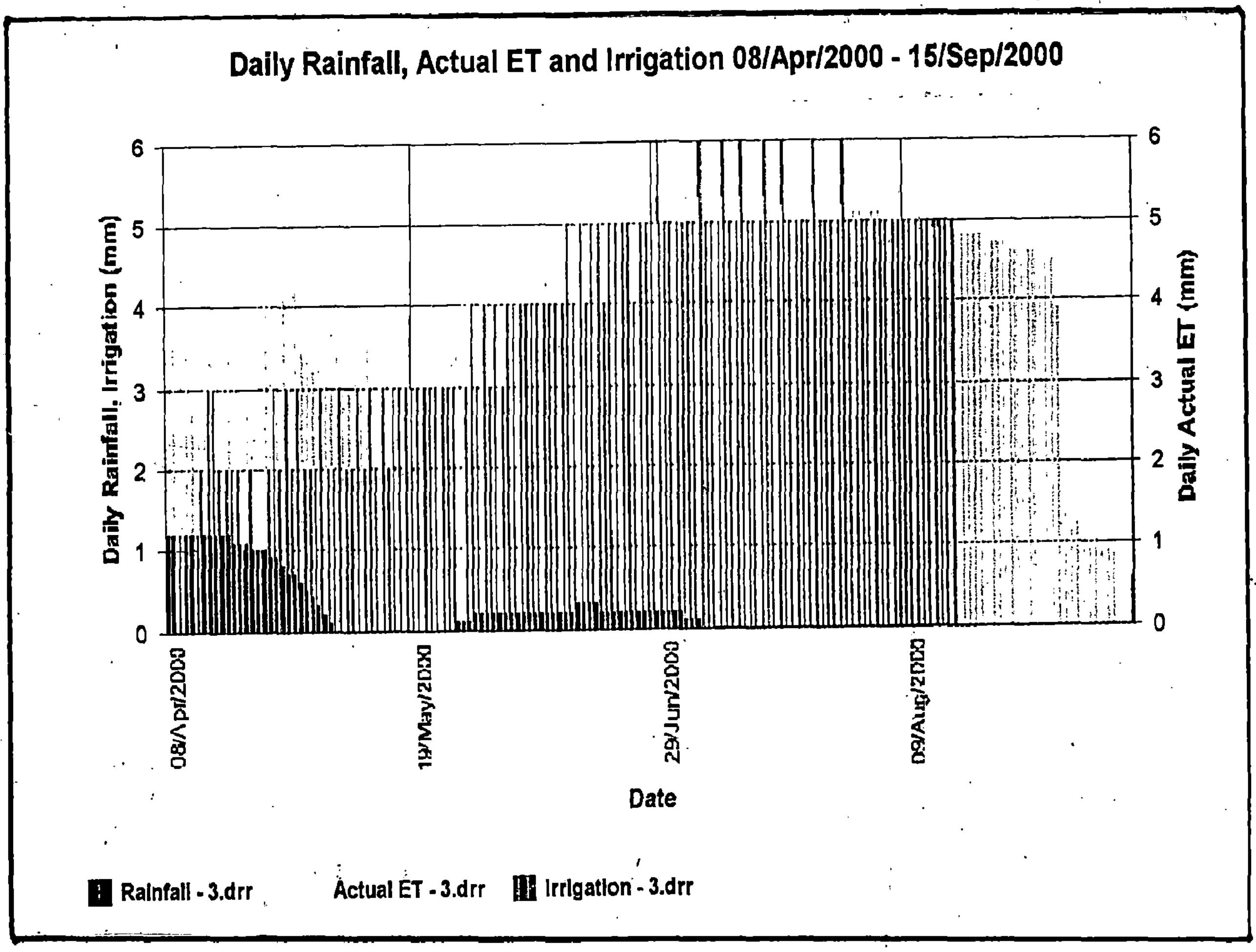
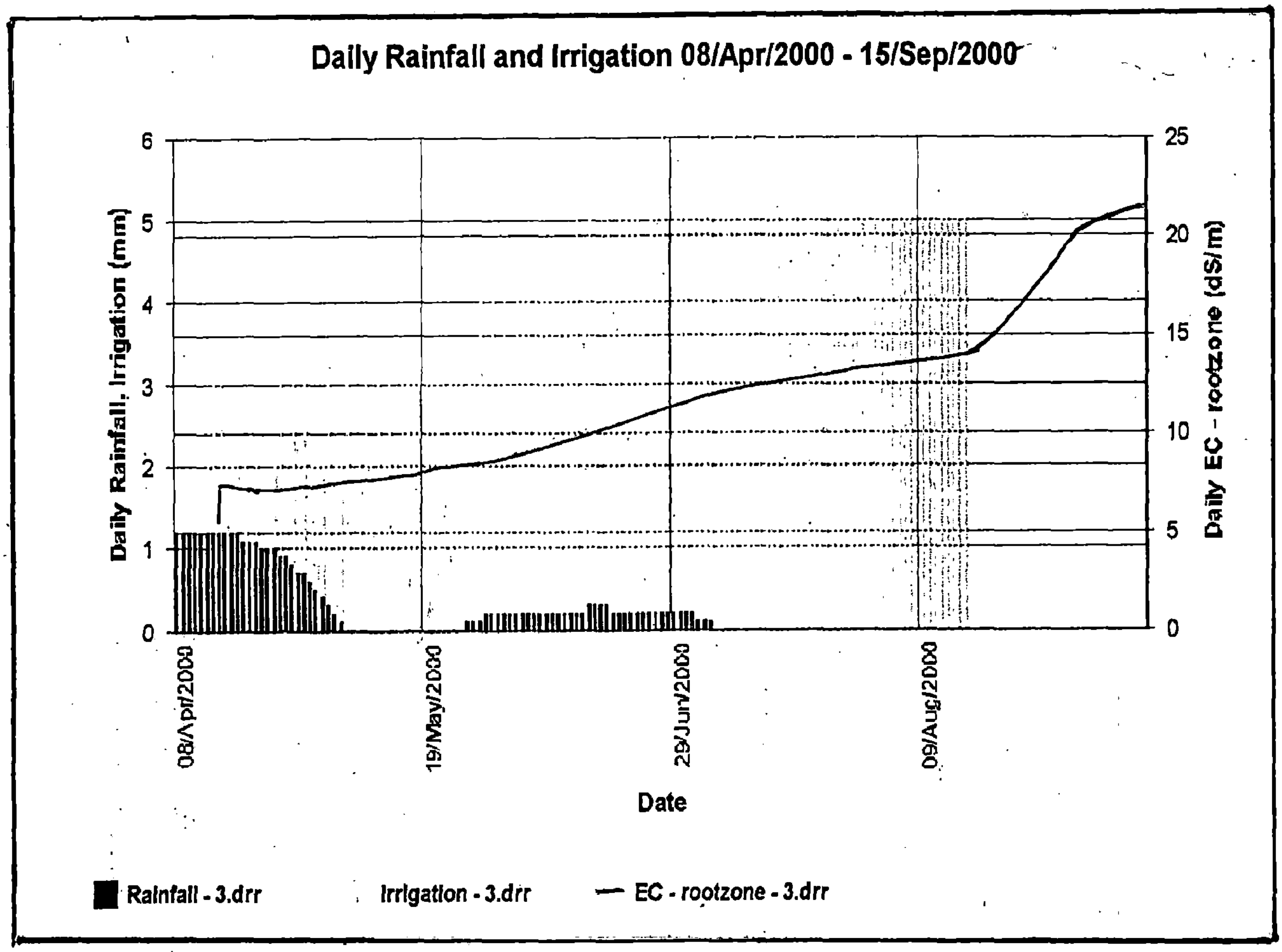

Daily Rainfall, Actual ET and Irrigation 08/Apr/2000 - 15/Sep/2000
Daily Rainfall, Irrigation (mm)
Daily Actual ET (mm)
0
1
2
3
4
5
6
08/Apr/2000
19/May/2000
29/Jun/2000
09/Aug/2000
Date
Rainfall - 3.drr
Actual ET - 3.drr
Irrigation - 3.drr

FIGURE 6.4.



Daily Rainfall and Irrigation 08/Apr/2000 - 15/Sep/2000
Daily Rainfall, Irrigation (mm)
Daily EC - rootzone (dS/m)
0
1
2
3
4
5
6
0
5
10
15
20
25
08/Apr/2000
19/May/2000
29/Jun/2000
09/Aug/2000
Date
Rainfall - 3.drr
Irrigation - 3.drr
EC - rootzone - 3.drr

FIGURE 6.5.

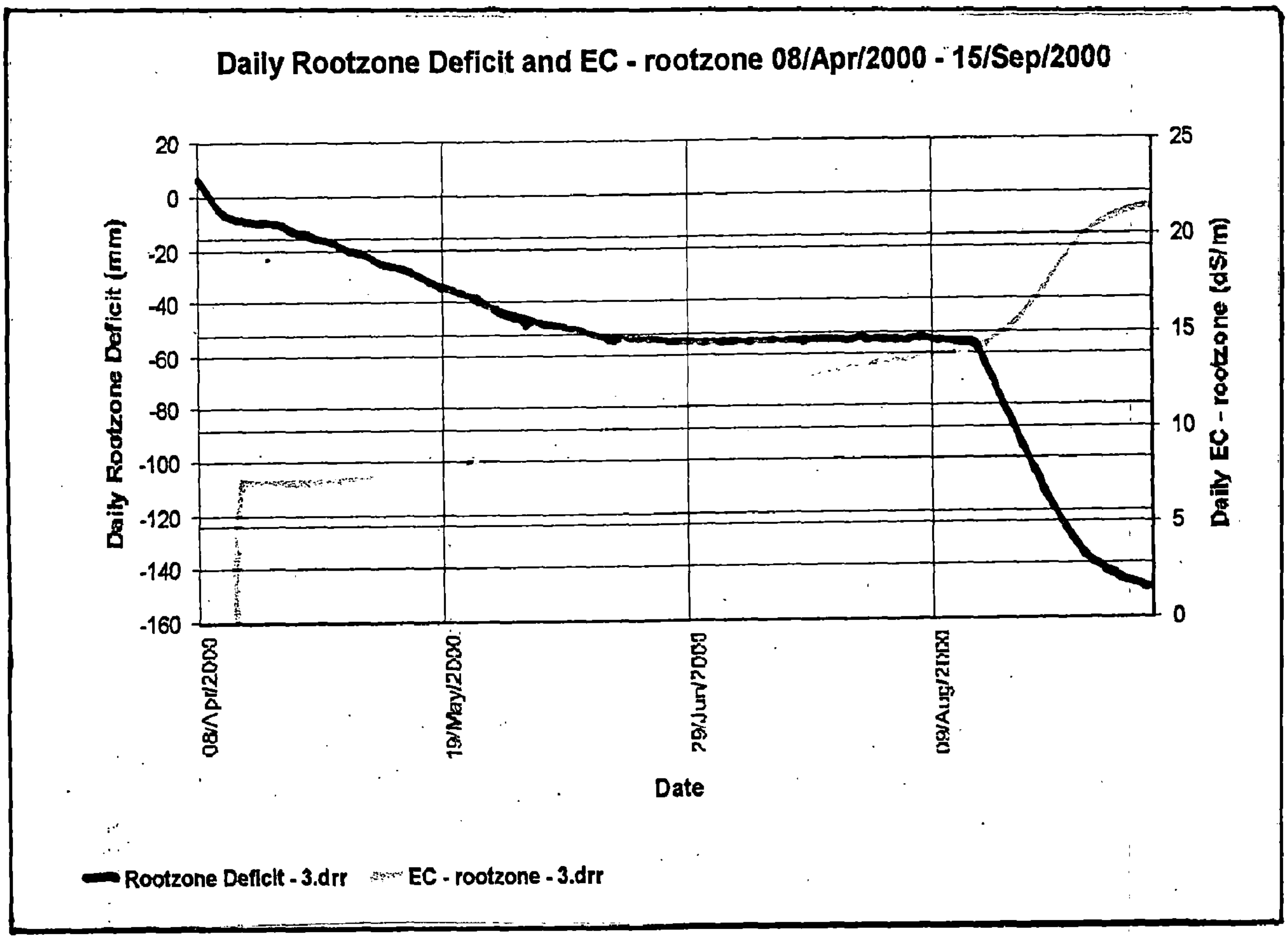
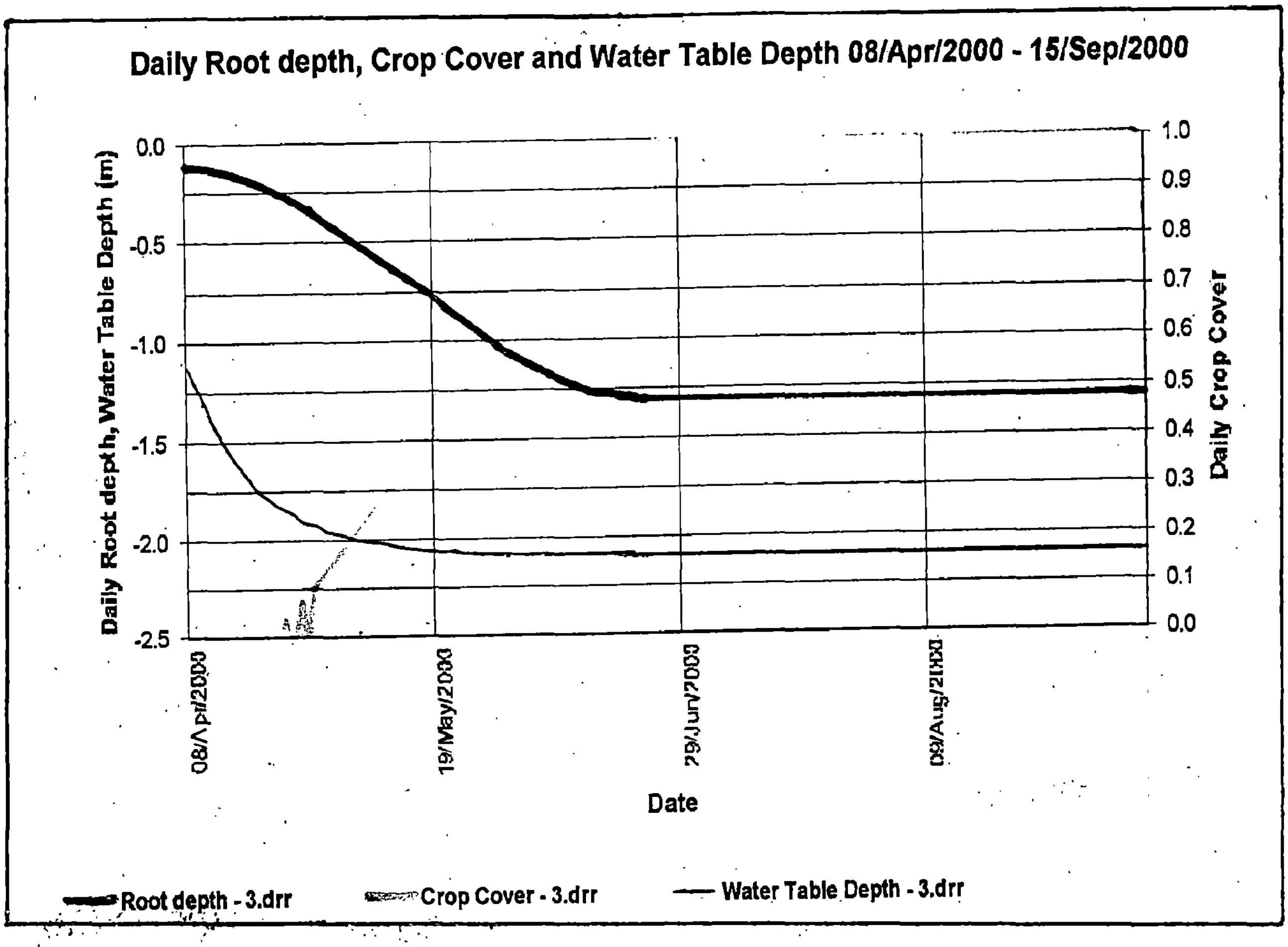

Daily Rootzone Deficit and EC - rootzone 08/Apr/2000 - 15/Sep/2000
Daily Rootzone Deficit (mm)
Daily EC - rootzone (dS/m)
20
0
-20
-40
-60
-80
-100
-120
-140
-160
25
20
15
10
5
0
08/Apr/2000
19/May/2000
29/Jun/2000
09/Aug/2000
Date
Rootzone Deficit - 3.drr
EC - rootzone - 3.drr

FIGURE 6.7.


Daily Root depth, Crop Cover and Water Table Depth 08/Apr/2000 - 15/Sep/2000
Daily Root depth, Water Table Depth (m)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
Daily Crop Cover
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
08/Apr/2000
19/May/2000
29/Jun/2000
09/Aug/2000
Date
Root depth - 3.drr
Crop Cover - 3.drr
Water Table Depth - 3.drr

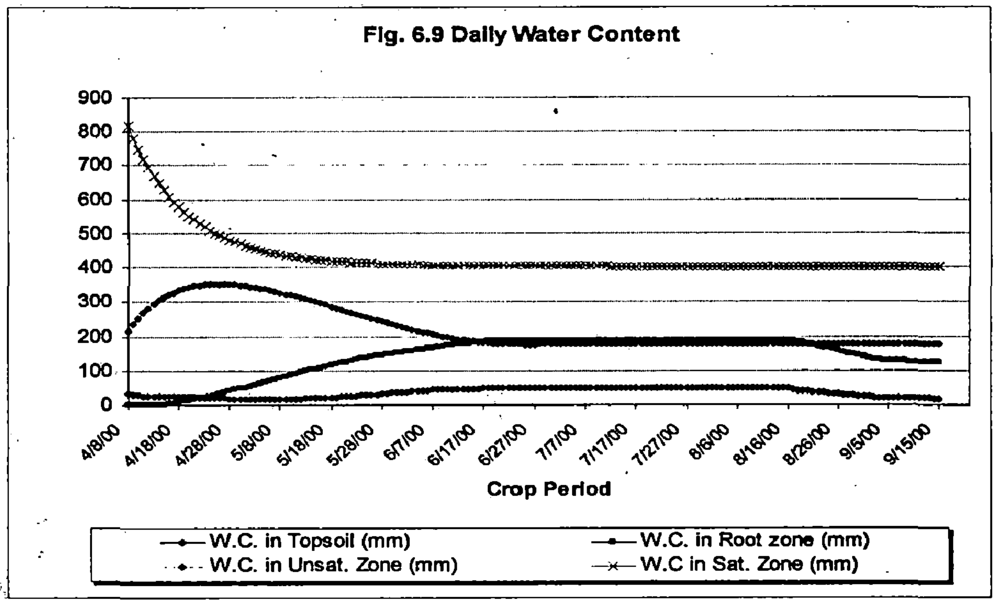


Fig. 6.9 Daily Water Content
900
800
700
600
500
400
300
200
100
0
4/8/00
4/18/00
4/28/00
5/8/00
5/18/00
5/28/00
6/7/00
6/17/00
6/27/00
7/7/00
7/17/00
7/27/00
8/6/00
8/16/00
8/26/00
9/5/00
9/15/00
Crop Period
W.C. in Topsoil (mm)
W.C. in Root zone (mm)
W.C. in Unsat. Zone (mm)
W.C in Sat. Zone (mm)

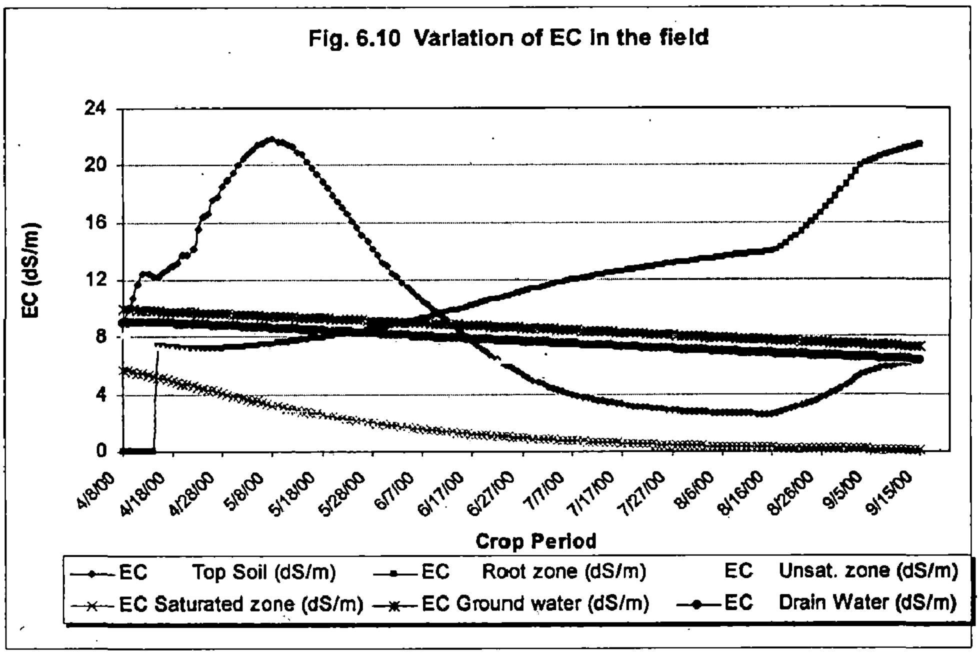


Fig. 6.10 Variation of EC in the field
EC (dS/m)
24
20
16
12
8
4
0
4/8/00
4/18/00
4/28/00
5/8/00
5/18/00
5/28/00
6/7/00
6/17/00
6/27/00
7/7/00
7/17/00
7/27/00
8/6/00
8/16/00
8/26/00
9/5/00
9/15/00
Crop Period
EC Top Soil (dS/m)
EC Root zone (dS/m)
EC Unsat. zone (dS/m)
EC Saturated zone (dS/m)
EC Ground water (dS/m)
EC Drain Water (dS/m)

CHAPTER-7

CONCLUSION AND RECOMMENDATIONS

Irrigation plays an important role in the economy of Uzbekistan. About 15 million people (60% of total population) depend on directly or indirectly on Irrigated Agriculture. Twenty to forty percent of the Gross Domestic Product (GDP) is derived from Agriculture. The available land of the republic is 44 Mha of which about 12 Mha are potentially suitable for irrigation including 4.277 mha of existing irrigation area. The other 30.9 Mha is desert pastures, mountains, sandy soils.

Precipitation in the plains is very low is in the order of (80-90 mm a year). To the east and south of the country rainfall reaches to (890-1000 mm a year). During vegetation period precipitation is less, therefore all crops must be irrigated. Main Irrigated crops are cotton, grains and vegetables. Common Irrigation methods are furrow, border, basin and drip irrigation.

Since the collapse of the Soviet Union both, government budget and farm income have fallen dramatically, water management institutions have weakened and infrastructure maintenance in many places have come to a standstill irrigation and drainage is becoming ineffective. All such problems have resulted in deterioration soil quality. Land has become salinized and waterlogged after deterioration of Irrigation and drainage infrastructure. In Uzbekistan area under salinization is 3.722 Mha. Salinization and waterlogging tendencies have irreversible damage crop and losses estimated in millions of tons of agricultural products.

In this study following issues discussed and presented regarding soil salinity and waterlogging.Major soil of Uzbekistan Arenosols, Calcisols, Cambisols, Fluvisol, Solonets, Sand, Regosols and Solonchak soils classified according to World Reference Base for Soil Resources. Extent of soil salinity and waterlogging area of Uzbekistan presented according to pH and EC values. Main causes of salinization identified such as natural and anthropogenic causes of soil salinization and waterlogging processes in the country. Also soil grouping GIS maps of grouping presented for the most salt affected regions (Syr-Darya and Kashkadarya) of Uzbekistan.

Soil salinization and waterlogging issues reviewed in arid and semi-arid countries withdraw lessons to Uzbekistan. Preventive/remedial measures recommended to minimize waterlogging and soil salinity hazards in irrigated agriculture management through hydro technical methods, leaching methods, surface drainage, subsurface drainage, mole drainage and physical methods such as sub soiling, gypsum application, reshaping of field drains and land leveling.

Irrigation water requirement has been calculated for the main crops of Uzbekistan with the help of Crop Water Requirement (CROPWAT) software with climate data obtained from Tashkent Meteorology station. Total Irrigation Water Requirement in the field without any loss for the main crops are determined in the study. Crop water requirement for Cotton 278.65 mm, Maize 73.71 mm, Winter Wheat 94.93 mm and Cabbage 45.46 mm

Water and Salt Balance Model (WASIM) computer based package has been applied to simulate daily soil water and salinity content in root zone for the cotton-growing field of Syr-Darya regions of Uzbekistan. It is recommended WASIM is very much helpful model to simulate water and salt balance in the root zone. It will help in making wise decisions on Water and Salt Management in Irrigated Agriculture.

Based on the present study, following are the main features and conclusions drawn: It can be concluded that there is significant impact of irrigation practices and their associated problems in the environment within the command of any irrigation project.

Finally it is recommended that to safeguard any project from the adverse environmental impact of irrigated agriculture, all possible measures must be taken to control waterlogging and salinization in the command.

Appendix 1

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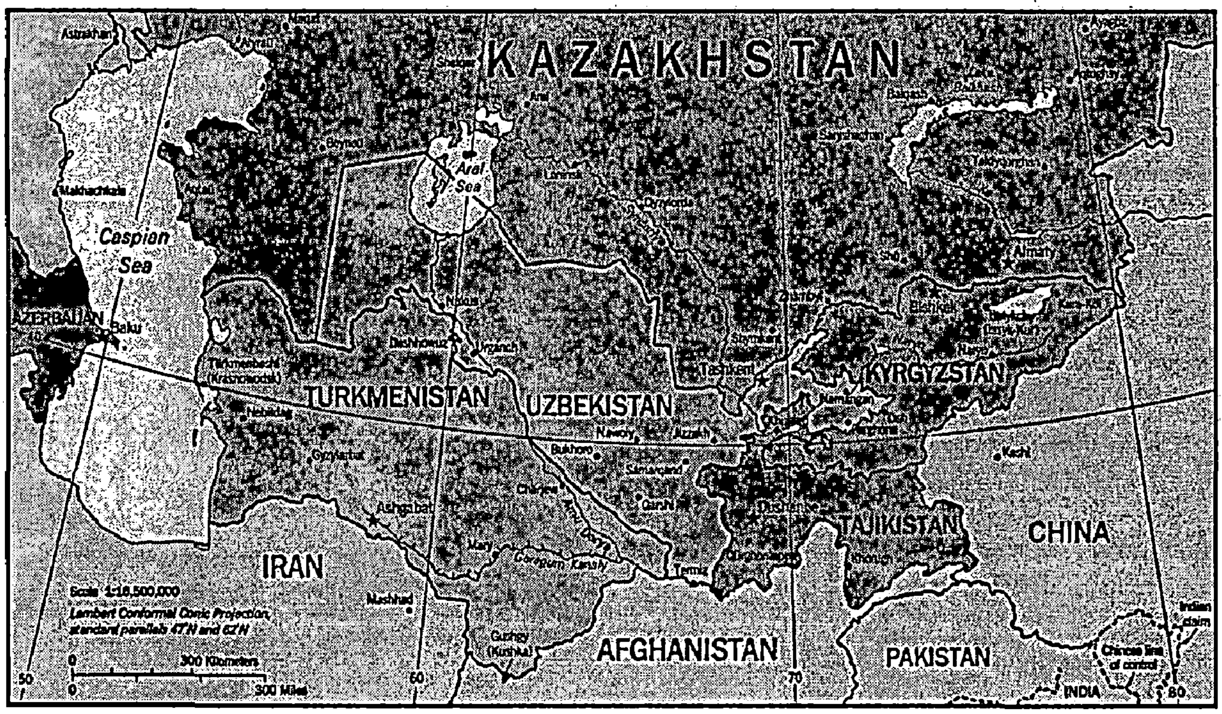
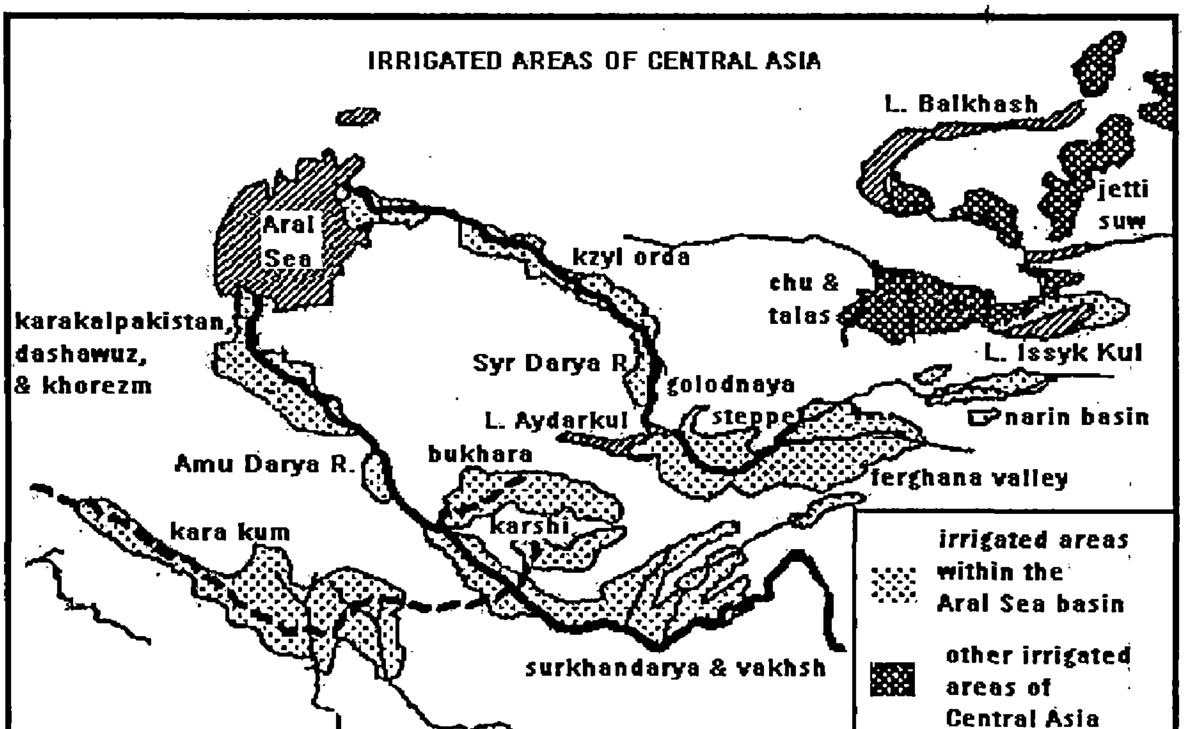
APPENDIX 2

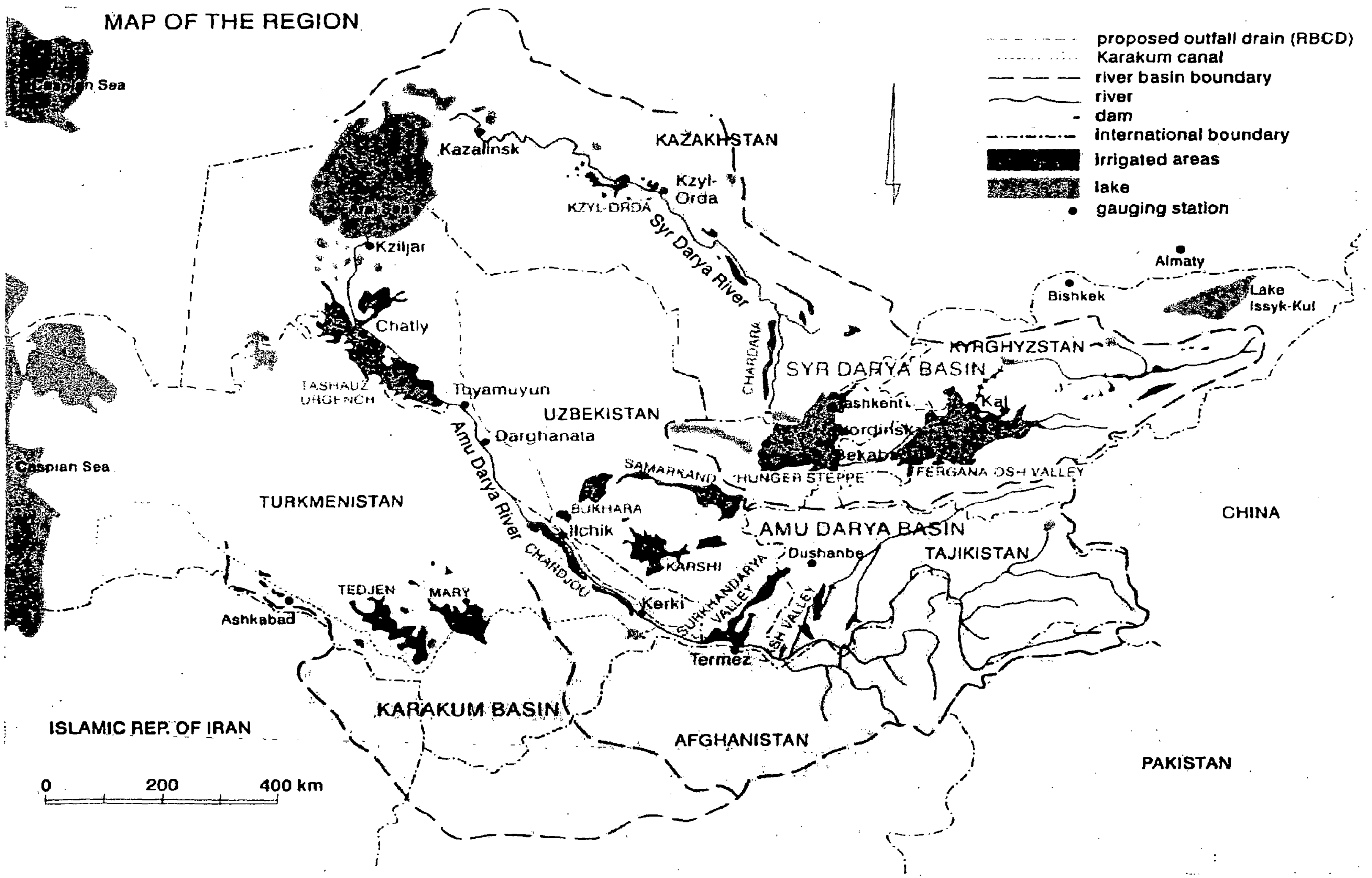
Maps

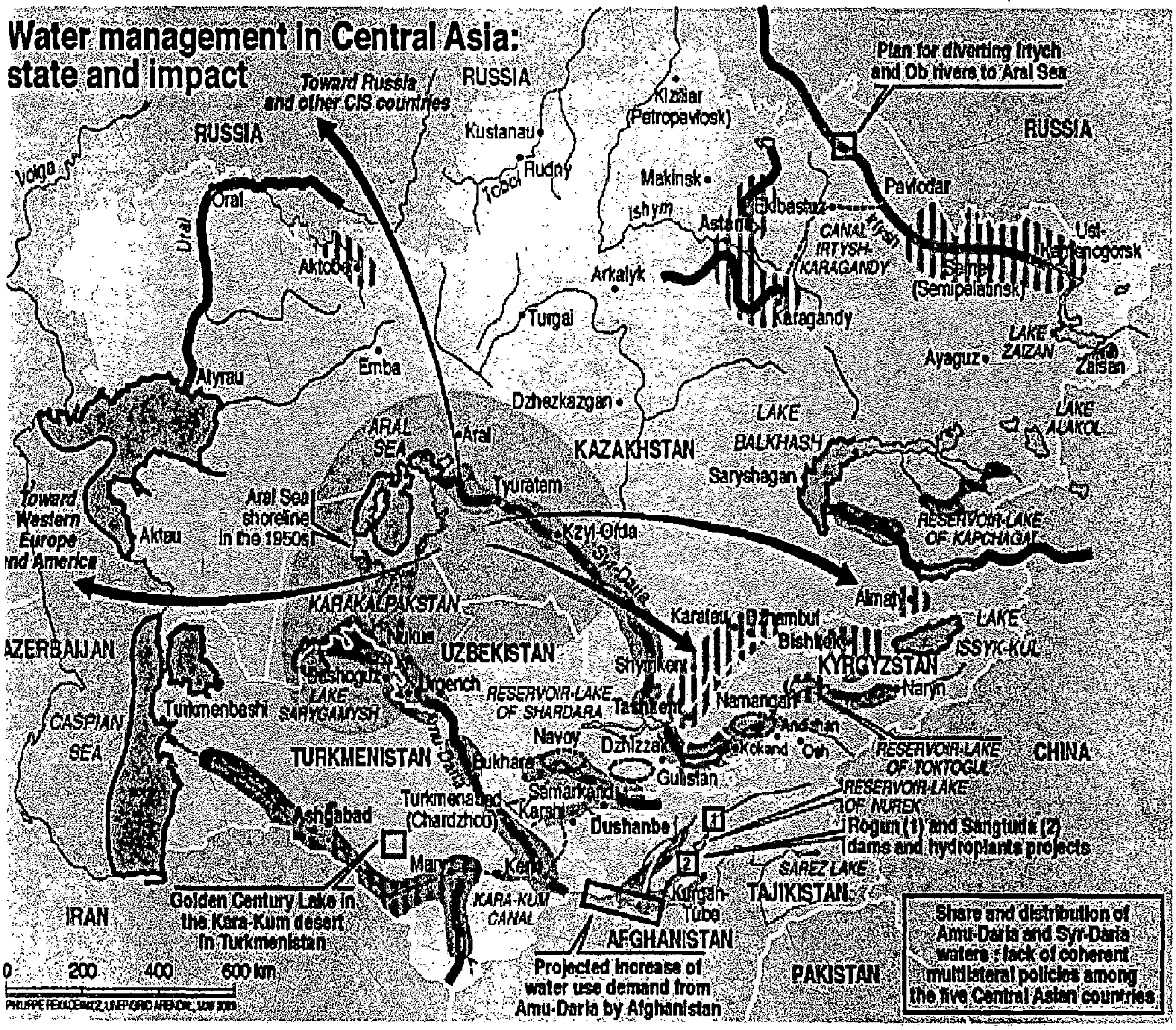




This map was adapted from Philip Micklin, *The Water Management Crisis in Soviet Central Asia*, *Carl Beck Papers in Russian and East European Studies*, No. 905 (1991), p. 90.

MAP OF THE REGION

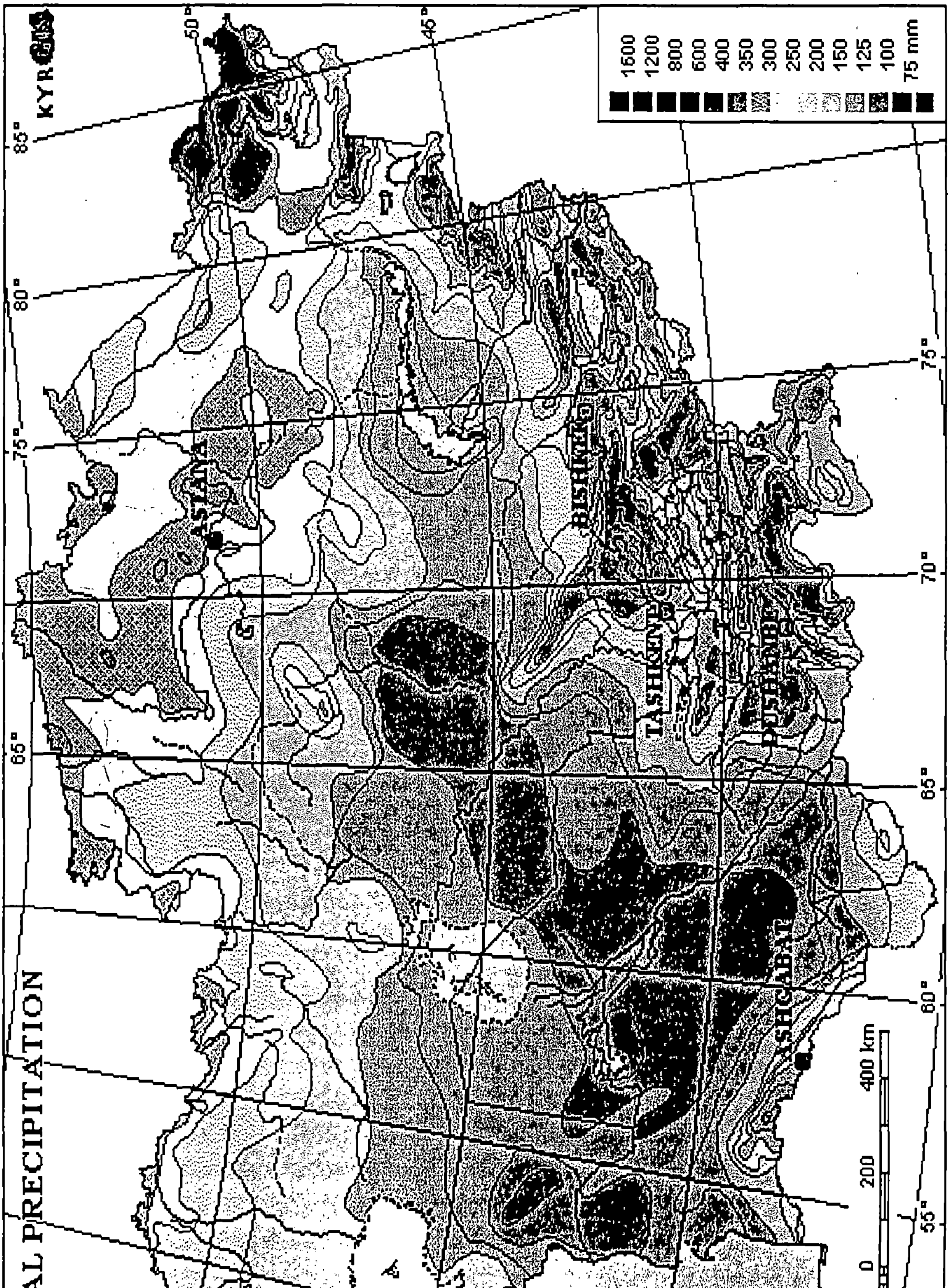




Polluted water bodies
- Rivers and canals
- Lakes
- Groundwater
- Areas under threat of flood and of pollution due to mismanagement of upstream water reservoirs and hazardous waste storage sites

Impact
- Former bed of the Aral Sea, uncovered area entirely desertified and saline
- Areas directly affected by the consequences of the shrinkage of the Aral Sea (toxic salts), leading to salinization and desertification
- Migration from environmentally degraded areas

Concerns for the future and potential areas of tension
- Areas of intensive and inefficient irrigated agriculture practices with potential to sterilize soil and threaten human health
- Projected water infrastructure or management plans that could lead to international tensions or conflicts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ASTANA
BISHKEK
TASHKENT
DUSHANBE
ASHGABAT
1600
1200
800
600
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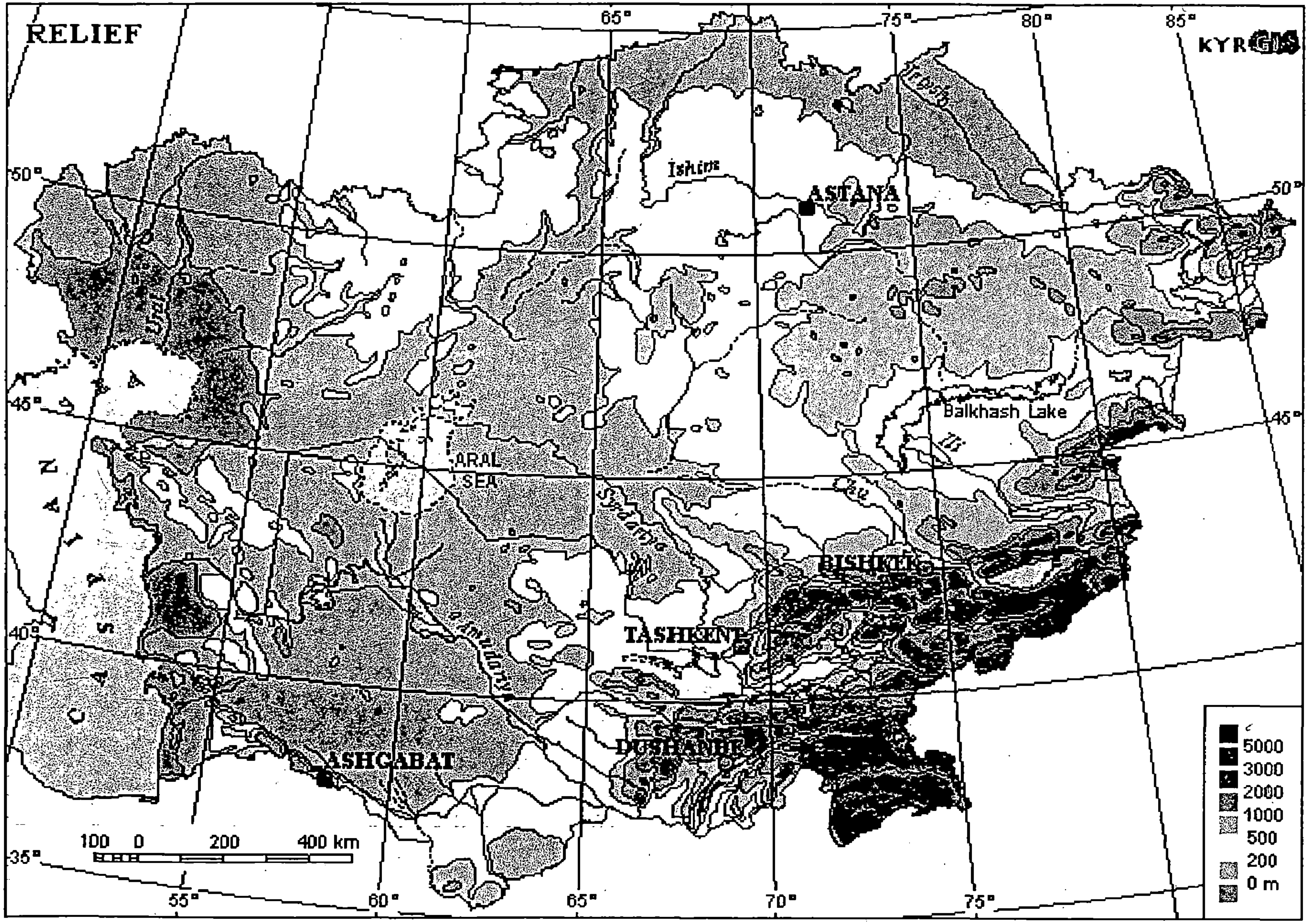
350
300
250
200
150
125
100
75 mm
100 0 200 400 km
C A S P I A N


RELIEF
KYRGIS
ASTANA
Ishim
Balkhash Lake
ARAL
SEA
BISHKEK
TASHKENT
DUSHANBE
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3000
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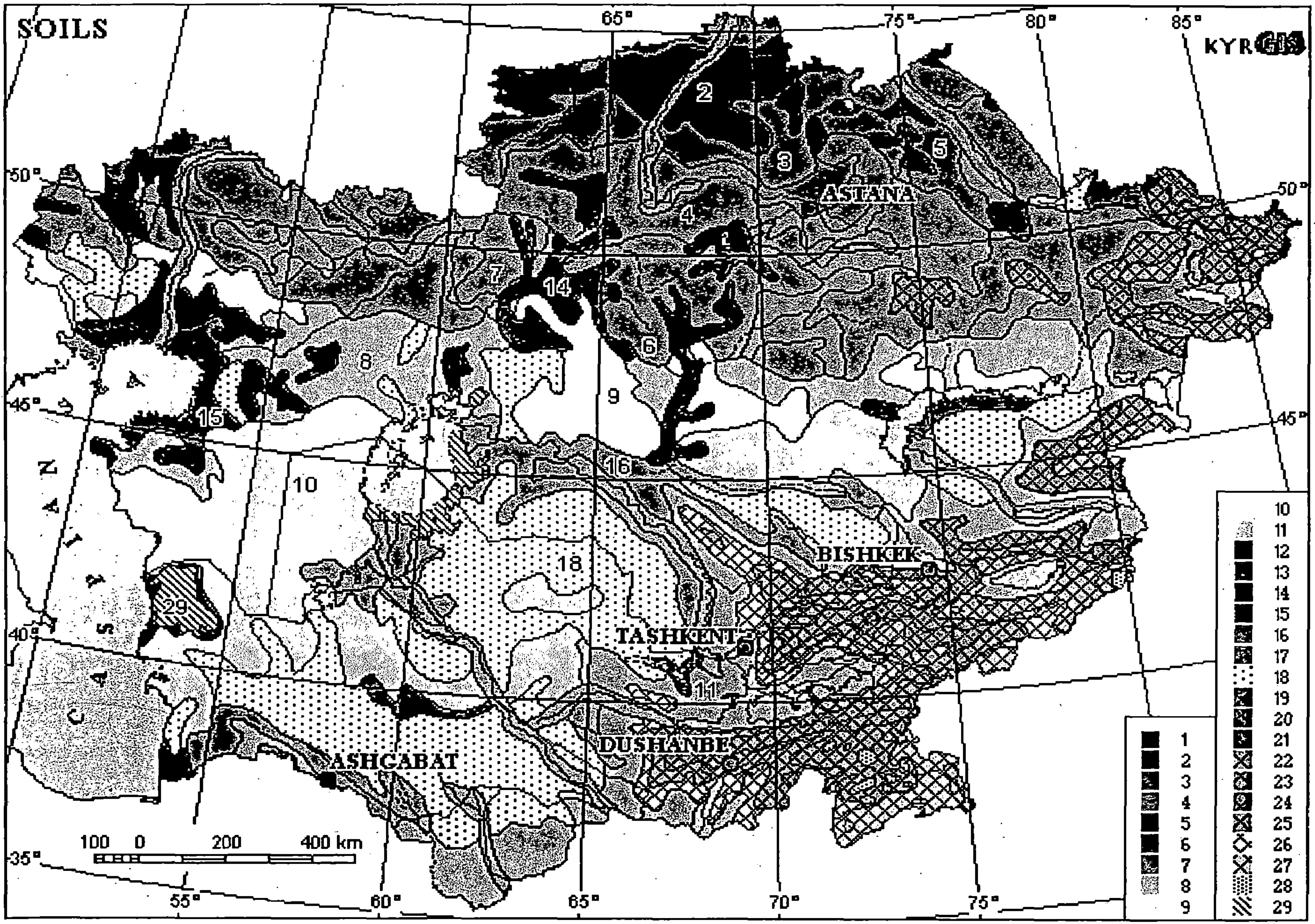
85°


SOILS
KYRGIS
ASTANA
BISHKEK
TASHKENT
DUSHANBE
ASHGABAT
CASPIAN
100 0 200 400 km
50°
45°
40°
35°
55°
60°
65°
70°
75°
80°
85°
1 2 3 4 5 6 7 8 9
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

N	Soils
1	Leached and Podzolized Chernozems
2	Usual Chernozems
3	Southern Chernozems
4	Dark - Chestnut and Chestnut Soils
5	Association of Dark- Chestnut and Chestnut Soils with Solonetzs
6	Light - Chestnut often Solonetz-Like Soils
7	Association of Light -Chestnut Soils with Solonetzs
8	Brown Semidesert often Solonetz-Like Soils
9	Association of Brown Semidesert Soils with Solonetzs
10	Association of Brown Semidesert Soils
11	Sierozems on the Sizeable Areas Transformed by the Irrigation
12	Bog Soils
13	Associations and Combinations of Meadow - Chernozem Soils, Solonetzs and Solods
14	Soil Associations with Solonetzs Predominance
15	Solonchaks often in Combination with Solonetzs
16	Combinations of Takyr Soils and Takyrs
17	Alluvial Soils and Meadow Soils
18	Sands and Weak Developed Sand Soils
19	Mountain Tundra Soils
20	Mountain Podzolic Acid Unpodzoled Soils
21	Mountain Gray Forest Soils
22	Mountain Meadow Soils
23	Mountain Meadow - Steppe Soils
24	Mountain Chernozems and Mountain Chestnut Soils
25	Mountain Cinnamon and Mountain Gray - Cinnamon Soils
26	Mountain Sierozems
27	High Mountain Desert Soils
28	Glaciers
29	Areas Appeared Due to Shrinkage of Caspian and Aral Seas

Appendix 3

Climate data

Station Sukkok, Parkent District, Tashkent Province
Height from the Sea level, .
Station : 1351

Height from the land surface, . :

Geographical Coordinates 41'24'N : 69'78'E

Year	Month	Average air temperature	Air temperature		Relative Humidity, %		Monthly average, Rainfall, . .	Wind speed, . /.
			maximum	minimum.	minimum	Average		
1980	I	-1.2	3.9	-5	40	57	59	1.3
	II	-2.6	2.1	-6	56	69	133.5	1
	III	3.4	8	-0.5	49	65	114.4	1.5
	IV	13.6	18.1	9	38	53	185.1	1.8
	V	16.7	21.4	12.3	42	55	58.6	1.5
	VI	21.1	26	16.5	29	38	17.3	1.5
	VII	25	30.1	20.4	26	31	0	1.4
	VIII	22.1	27.4	17.6	27	36	11.2	1.5
	IX	18.1	23.9	13.8	25	33	0.7	1.6
	X	11.5	16.6	7.5	38	51	70.8	1.4
	XI	9.6	14.2	6.1	39	53	83.2	1.6
	XII	5.6	10.5	2.3	33	44	34.3	1.4
		142.9	202.2	94	442	585	768.1	17.5
	Annual average	11.91	16.85	7.83	36.83	48.75	64.01	1.46
1981	I	1.5	5.5	-1.5	48	65	87.3	1.2
	II	0.9	5.2	-2.1	48	68	88.9	1.1
	III	6.9	11.5	3.3	45	62	163.4	1.7
	IV	11.3	16.1	7.4	42	60	105.2	1.6
	V	15.7	20.5	11.5	44	58	166.4	1.5
	VI	19.4	24.1	14.9	33	44	24.5	1.5
	VII	22.7	27.3	18.4	35	44	18.5	1.3
	VIII	21	26.1	16.7	31	41	14.8	1.7
	IX	17.2	22.7	12.9	30	38	52	1.7
	X	8.7	13.8	5	37	50	16.6	1.4
	XI	6.7	11.4	3.1	35	47	96.9	1.4
	XII	3	8	-0.4	41	55	35.2	1.7
		135	192.2	89.2	469	632	869.7	17.8
	Annual average	11.25	16.02	7.43	39.08	52.67	72.48	1.48

Year	Month	Average air temperature	Air temperature maximum	minimum.	Relative Humidity, % minimum	Average	Monthly average, Rainfall, . .	Wind speed, . /.
1982	I	1.2	5.9	-2.6	40	52	54.8	1.3
	II	-0.8	3.9	-4.6	39	56	70.1	1.5
	III	3.2	7.9	-0.5	51	69	169.1	1.2
	IV	13.3	18.5	9	36	48	33.5	1.6
	V	17.1	21.9	12.6	33	44	33.1	1.4
	VI	20.8	25.7	16.1	29	36	68.1	1.5
	VII	22.6	27.4	18.3	30	38	4.6	1.4
	VIII	21.9	26.9	17.3	27	34	0.5	1.4
	IX	16.6	22	12.3	28	37	61	1.5
	X	10.8	16	6.8	42	56	175.4	1.2
	XI	1.5	5.8	-1.7	47	62	73.9	0.8
	XII	1.2	6	-1.9	33	43	44.6	0.8
		129.4	187.9	81.1	435	575	788.7	15.6
	Annual average	10.78	15.66	6.76	36.25	47.92	65.73	1.30
1983	I	0.4	4.5	-2.9	39	54	106.8	0.7
	II	3.4	8.5	-0.1	30	43	50.5	1.1
	III	3.4	7.9	-0.3	46	61	86.6	1
	IV	11.3	15.7	7.5	45	58	142.3	1.2
	V	15.8	20.2	11.3	41	53	108.4	1.3
	VI	20.8	25.5	16	31	39	14.6	1.5
	VII	25.3	30	21.1	26	31	0	1.2
	VIII	24.1	29.2	19.9	27	34	0	1.2
	IX	17.7	23.1	13.5	29	36	0.3	1.4
	X	11.1	17.1	6.6	27	38	2.2	1.3
	XI	9.3	14.5	5.3	29	41	86.8	1.4
	XII	1.5	6.6	-1.8	41	52	84.6	0.8
		144.1	202.8	96.1	411	540	683.1	14.1
	Annual average	12.01	16.90	8.01	34.25	45.00	56.93	1.18
1984	I	-2	2.5	-5.3	38	50	31.1	0.7
	II	-7	-2.3	-10.6	51	66	74.4	0.6
	III	4.9	10	1.3	46	62	163	0.9
	IV	10.5	15.4	6.3	35	51	79.7	1.3
	V	15.8	21.1	11.9	38	47	62.1	1.4
	VI	21.8	26.8	17.2	30	38	2.6	1.3
	VII	25.6	30.6	20.9	28	34	0	1.4
	VIII	25.2	30.7	20.4	28	34	0	1.4
	IX	16.6	22.3	12.3	28	37	2.5	1.6
	X	10.8	16.3	6.8	35	46	97.3	1.3
	XI	6	10.9	2	41	58	186.8	1
	XII	-6.1	-0.9	-9.5	41	53	53.8	0.7
		122.1	183.4	73.7	439	576	753.3	13.6
	Annual average	10.18	15.28	6.14	36.58	48.00	62.78	1.13

Year	Month	Average air temperature	Air temperature		Relative Humidity, %		Monthly average, Rainfall, . .	Wind speed, . /.
			maximum	minimum.	minimum	Average		
1985	I	-0.2	4.7	-4	41	56	116.5	1.2
	II	3.8	9.3	-1	32	49	94.3	1.8
	III	1.6	6.3	-1.9	50	66	133.2	1.3
	IV	12.9	17.9	8.9	37	52	109.9	1.7
	V	15.7	20.5	12.1	38	49	74.5	1.5
	VI	22.2	27.1	17.9	27	35	10.5	1.4
	VII	24.3	29.3	20.2	27	34	0.4	1.4
	VIII	21	26.2	17.1	30	39	3.9	1.3
	IX	18.8	24.8	14.5	23	30	0	1.4
	X	9.9	15.6	5.7	41	56	63.8	1.4
	XI	5	10.4	1.4	31	44	31.4	1.2
	XII	2.8	7.5	-0.2	46	59	59.2	1.3
		137.8	199.6	90.7	423	569	697.6	16.9
	Annual average	11.48	16.63	7.56	35.25	47.42	58.13	1.41
1986	I	2.1	6.9	-1	35	49	69.3	1.3
	II	1.9	6.5	-1.2	46	60	29.4	1.1
	III	0.8	6	-2.6	49	64	97.2	1.1
	IV	10.2	15.4	6.5	44	57	87.1	1.4
	V	16.8	22.2	12.3	33	44	40.1	1.5
	VI	20.1	25.4	15.7	29	38	16.6	1.6
	VII	23.8	29.6	19.3	25	31	5.4	1.3
	VIII	22.2	27.8	17.9	25	32	0	1.4
	IX	19.5	25.6	15.2	25	34	50.5	1.6
	X	12.2	18.5	8.2	36	51	65.3	1.3
	XI	4.8	9.4	1.7	40	54	59.3	1.2
	XII	1	5.5	-2.2	42	57	194.6	1.5
		135.4	198.8	89.8	429	571	714.8	16.3
	Average year	11.28	16.57	7.48	35.75	47.58	59.57	1.36
1987	I	2.9	7.6	-0.5	34	48	84.2	1.4
	II	2.8	8.1	-0.9	43	61	92.3	1.3
	III	6.3	10.8	3.1	50	69	246.4	1.3
	IV	8.8	13.5	4.9	47	65	274.7	1.6
	V	15.6	20.3	11.2	36	47	49.6	1.6
	VI	19.2	23.9	14.8	34	43	8.2	1.6
	VII	21.2	26	17.2	41	52	55.4	1.3
	VIII	23.9	28.6	19.9	30	37	0.8	1.5
	IX	17.2	23	12.8	32	43	14.7	1.5
	X	6.3	11	3	48	61	95.5	1.2
	XI	6.1	11	2.2	37	53	73.3	1.3
	XII	6	11.3	1.9	36	49	69.4	1.3
		136.3	195.1	89.6	468	628	1064.5	16.9
	Average year	11.36	16.26	7.47	39.00	52.33	88.71	1.41

Year	Month	Average air	Air temperature		Relative Humidity		Monthly	Wind	
		temperature			, %		average,	speed, . /.	
			maximum	minimum.	minimum	Average	Rainfall, . .		
1988	I	0.9	5.5	-2.4	42	57	103.2	0.9	
	II	1	5.8	-2.7	45	60	56.2	1	
	III	3.6	8.1	0.1	49	68	158.7	1	
	IV	13.1	17.9	9.3	40	53	68.5	1.4	
	V	14.2	19	10.2	41	54	86.3	1.5	
	VI	22.5	27.2	18	29	37	3.8	1.7	
	VII	24.5	29.6	20.3	28	36	0.5	1.8	
	VIII	21.5	26.8	17.2	32	41	0.5	1.9	
	IX	17.6	23.7	13	30	41	12.4	2	
	X	10.7	16.4	6.6	31	42	43.6	1.8	
	XI	10.3	15.7	6.3	31	45	54.2	1.8	
	XII	5	10.3	1.4	37	52	118.1	1.9	
		144.9	206	97.3	435	586	706	18.7	
	Annual average	12.08	17.17	8.11	36.25	48.83	58.83	1.56	
1989	I	-2.6	2	-5.9	37	53	92.7	1.5	
	II	-3.9	0.9	-7.3	44	60	84.6	1.5	
	III	5.7	10.6	2	41	54	106.7	1.9	
	IV	8.2	13.7	3.5	34	49	107.7	2	
	V	13.8	18.6	9.7	44	56	50.3	1.8	
	VI	20.5	25.6	15.8	29	37	2.4	2	
	VII	23.6	28.6	19.3	32	39	4.2	1.8	
	VIII	22.6	28.2	18.2	25	32	0	2	
	IX	16.6	22.5	11.7	29	41	19.1	2	
	X	13.2	18.9	8.6	31	43	30.6	1.9	
	XI	5.1	10.6	1	36	50	84.6	1.8	
	XII	4.7	9.1	1.5	48	64	182.9	1.7	
		127.5	189.3	78.1	430	578	765.8	21.9	
	Annual average	10.63	15.78	6.51	35.83	48.17	63.82	1.83	
1990	I	-1.5	3.2	-4.9	52	66	100	1.4	
	II	0.2	4.5	-2.7	53	67	68.5	1.3	
	III	4.6	9.3	1	46	58	137.5	1.9	
	IV	9.6	14.2	5.7	50	65	276	2	
	V	17.1	21.9	12.7	39	53	28.6	1.9	
	VI	23.5	28.8	19.1	31	40	11.4	1.9	
	VII	22.5	27.8	17.9	31	40	14	1.8	
	VIII	22.9	28.5	18.4	30	38	0.3	1.9	
	IX	19.4	25.7	14.4	23	31	0	2.2	
	X	11.1	16.9	6.8	36	49	114.3	1.9	
	XI	8.8	14.4	4.8	32	44	40.3	2	
	XII	0.6	5	-2.2	50	65	65.2	1.4	
		138.8	200.2	91	473	616	856.1	21.6	
	Annual average	11.57	16.68	7.58	39.42	51.33	71.34	1.80	

Year	Month	Average air temperature	Air temperature maximum	minimum.	Relative Humidity, % minimum	Average	Monthly average, Rainfall, . .	Wind speed, . /.
1991	I	-1	3.8	-4.4	46	60	84.5	1.6
	II	-0.2	4.7	-3.5	50	63	55	1.5
	III	3.7	8.4	0.3	55	69	127.9	1.3
	IV	11.6	16.4	7.7	47	59	160.1	1.9
	V	14.6	19.7	10.6	47	62	156.2	1.9
	VI	19.6	25.3	15	38	50	40.3	1.7
	VII	23.2	28.9	18.8	30	40	8.3	1.9
	VIII	21.8	27.9	17.5	25	32	0.3	1.8
	IX	17.7	23.4	13.3	33	42	17.7	2
	X	12	18.2	8.3	31	41	7.6	2
	XI	6.4	11.9	2.7	41	57	28.1	1.5
	XII	2.3	7.2	-1.2	47	63	267.1	1.9
		131.7	195.8	85.1	490	638.00	953.1	21
	Annual average	10.98	16.32	7.09	40.83	53.17	79.43	1.75
1992	I	0.6	5.3	-2.6	45	62	99.4	1.6
	II	2.2	7.4	-1.2	43	58	120.2	2
	III	1.8	6.5	-1.6	48	62	84.4	1.6
	IV	11.2	15.7	7.5	49	64	131.2	1.9
	V	11.9	16.2	8.1	59	70	190	1.7
	VI	19.5	24.7	15.1	39	50	25.4	2.1
	VII	22.7	27.6	18.2	36	46	2.2	1.9
	VIII	20	25.2	15.9	37	48	6.4	1.8
	IX	15.7	21.3	11.3	35	48	3.1	1.9
	X	11.2	16.6	7	37	49	19	1.8
	XI	9.8	15.3	5.8	36	47	27.2	1.8
	XII	4.1	8.9	0.6	46	61	104.1	1.7
		130.7	190.7	84.1	510	665.00	812.6	21.8
	Annual average	10.89	15.89	7.01	42.50	55.42	67.72	1.82
1993	I	-1.3	3.5	-4.6	44	58	55.3	1.7
	II	0.9	5.4	-2.4	56	71	228.3	1.7
	III	2.9	7.3	-0.6	52	67	210.3	1.8
	IV	10.8	16.2	6.5	42	57	169.6	2
	V	13	17.8	8.9	49	65	149.4	1.8
	VI	20.2	25.4	15.3	41	52	41.8	1.8
	VII	22.7	27.7	18.3	32	41	0	1.9
	VIII	20.3	26	15.8	33	44	10	1.9
	IX	17.4	23.6	12.8	32	45	8.7	2.1
	X	9.3	15.1	5.5	41	56	43.4	1.6
	XI	3.3	7.8	-0.1	58	73	173.8	1.2
	XII	2.5	7.7	-0.9	43	59	136.1	1.1
		122	183.5	74.5	523	688.00	1226.7	20.6
	Annual average	10.17	15.29	6.21	43.58	57.33	102.23	1.72
1994	I	-0.3	5.2	-4	38	50	90.7	1.3
	II	-2.5	2.9	-6.5	45	61	98.5	1.1
	III	6.7	12.1	3	41	58	110.6	1.8
	IV	8.1	13.2	3.6	44	57	166.4	1.9

	V	16.4	21.4	11.8	42	55	153.7	2	
	VI	21.7	26.9	17.3	36	45	51.1	2	
	VII	22.6	27.7	18.4	29	37	0	1.8	
	VIII	22.6	28.3	18.1	27	36	0	1.9	
	IX	14.1	19.9	9.7	33	45	12.3	1.8	
	X	11.4	17.4	7.7	37	51	9.3	1.8	
	XI	9.9	15.4	5.6	40	56	240	2.1	
	XII	0.8	5.5	-2.6	46	59	135.2	1.8	
		131.5	195.9	82.1	458	610.00	1067.8	21.3	
	Annual average	10.96	16.33	6.84	38.17	50.83	88.98	1.78	
1995	I	-0.2	5.1	-3.7	38	52	68.1	1.7	
	II	1.2	5.9	-1.7	50	64	64	1.6	
	III	4.4	9.6	0.9	51	67	113.7	1.7	
	IV	11.3	16.6	7.4	40	52	41.5	2.1	
	V	15.9	21.2	11.6	39	51	57.9	2	
	VI	21.2	26.7	16.7	31	42	17.8	2	
	VII	24	29.5	19.3	27	37	5.1	1.8	
	VIII	22.9	28.9	18.1	27	37	0.3	1.9	
	IX	17.6	23.9	13.1	31	44	0.2	2	
	X	10.5	16.5	6.2	36	50	73.1	1.7	
	XI	9.1	15.3	5.5	27	40	43.8	1.8	
	XII	0.6	6.1	-3	36	51	55	1.7	
		138.5	205.3	90.4	433	587.00	540.5	22	
	Annual average	11.54	17.11	7.53	36.08	48.92	45.04	1.83	
1996	I	-2	3	-5.3	46	58	48.5	1.6	
	II	0.1	5.4	-3.7	50	64	138.1	1.6	
	III	2.5	7	-0.6	57	72	114.4	1.6	
	IV	8.7	13.9	4.7	43	59	168.2	2.2	
	V	14.8	19.9	10.6	36	47	12.2	2	
	VI	20.5	25.9	16	31	42	51.8	2	
	VII	22.7	28.1	18.4	32	41	18.9	1.2	
	VIII	21.4	27.6	16.6	23	31	0	1.9	
	IX	18.7	24.9	14.1	26	37	30.6	1.8	
	X	10.9	16.7	6.8	35	49	28.3	1.5	
	XI	4.1	9.3	1.5	45	59	32.8	1.3	
	XII	5.3	10.9	2.2	31	44	14.3	1.5	
		127.7	192.6	81.3	455	603.00	658.1	20.2	
	Annual average	10.64	16.05	6.78	37.92	50.25	54.84	1.68	
1997	I	2	7	-1.8	42	56	119	1.7	
	II	0	6	-4.1	41	54	117.3	1.7	
	III	4.9	9.9	1.5	49	65	106.8	1.6	
	IV	12	17.2	8.7	56	68	160.3	1.7	
	V	14.6	19.9	10.6	48	62	196.4	1.3	
	VI	21.6	27	17.1	35	46	23.2	1.7	
	VII	24.5	30.3	19.8	28	36	0	1.5	
	VIII	22.3	28.3	17.3	26	35	2.9	1.9	
	IX	18.4	24.8	13.7	26	35	0	1.8	
	X	15	21.5	11.2	31	43	28.6	1.8	
	XI	4.6	10.2	0.8	45	60	80.2	1.5	

	XII	2.1	6.9	-1	49	61	98.9	1.6	
		142	209	93.8	476	621.00	933.6	19.8	
	Annual average	11.83	17.42	7.82	39.67	51.75	77.80	1.65	
1998	I	-0.3	4.5	-3.6	48	62	138.7	1.5	
	II	-0.3	5.1	-4.1	55	68	178.3	1.5	
	III	4.1	9.8	0.3	47	65	209	1.8	
	IV	12.8	18.2	8.9	46	60	150.3	1.8	
	V	14.2	19.2	9.8	51	66	179.5	1.8	
	VI	19.5	24.5	15.2	45	58	63.6	1.7	
	VII	23.3	28.7	18.8	36	46	45	1.4	
	VIII	22.4	28	18.2	35	45	2.3	1.6	
	IX	18.5	24.1	14.2	32	44	15.2	1.9	
	X	11.5	18	7.4	40	52	29.3	1.5	
	XI	8.4	14.4	4.6	36	49	60.7	1.3	
	XII	5.5	11.4	1.3	37	53	107.1	1.2	
		139.6	205.9	91	508	668.00	1179	19	
	Annual average	11.63	17.16	7.58	42.33	55.67	98.25	1.58	
1999	I	0.8	6.4	-2.4	41	56	124.3	1.3	
	II	5.5	10.9	2	39	55	111.4	1.3	
	III	3	7.7	-0.3	56	71	141.7	1.1	
	IV	9.4	14.7	5.3	45	58	114.5	1.4	
	V	16.3	21.8	11.8	40	53	153.4	1.4	
	VI	19.8	25.2	14.9	33	43	29	1.3	
	VII	21.2	26.8	16.4	39	50	76.1	1.2	
	VIII	23.7	29.3	19.1	31	39	7	1.4	
	IX	17.7	23.9	13.1	36	48	22.1	1.3	
	X	13.3	19.9	9.2	36	49	15.3	1.4	
	XI	4.5	9.9	0.9	50	66	220.1	1.4	
	XII	5	10.6	1.6	36	48	26.9	1.5	
		140.2	207.1	91.6	482	636.00	1041.8	16	
	Annual average	11.68	17.26	7.63	40.17	53.00	86.82	1.33	
2000	I	1.3	7.3	-2.3	41	57	102.3	1.4	142
	II	0.4	6.8	-3.7	36	53	42.6	1.3	188.4
	III	5	11	1	39	53	74.6	1.5	196.7
	IV	14.1	19.5	9.7	35	48	86.5	1.7	227.1
	V	18.2	23.8	13.3	32	45	8.5	1.5	274.4
	VI	21.1	27.1	16	28	38	19.2	1.3	340
	VII	23.5	29.3	18.7	26	36	8.8	1.3	364
	VIII	23.5	29.7	18.4	25	34	3	1.5	350.1
	IX	18.5	24.8	13.9	28	38	9.1	1.5	272.8
	X	9.1	14.6	5	50	65	158.6	1.2	134.6
	XI	3.8	9.2	0.5	45	62	93.3	1	154
	XII	3.7	8.2	0.2	46	60	107.7	1.2	102
		142.2	211.3	90.7	431	589.00	714.2	16.4	
	Annual average	11.85	17.61	7.56	35.92	49.08	59.52	1.37	

WASIM Simulation Results

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	ECe Top Soil (dS/m)	ECe Rootzone (dS/m)	ECe Unsat. Zone (dS/m)	Water Fraction - Top Soil	Date
4/8/2000	Cotton	0.11	0	1.20	3.50	0.00	-6.64	1.13	29.14	4.45	0	4.26	0.21	4/8/2000
4/9/2000	Cotton	0.12	0	1.20	3.60	0.00	-3.63	1.21	27.21	4.48	0	4.15	0.19	4/9/2000
4/10/2000	Cotton	0.12	0	1.20	3.60	0.00	-0.34	1.29	25.53	4.49	0	4.07	0.18	4/10/2000
4/11/2000	Cotton	0.13	0	1.20	3.60	0.00	3.19	1.36	24.05	4.50	0	4.00	0.16	4/11/2000
4/12/2000	Cotton	0.13	0	1.20	2.67	0.00	6.04	1.42	22.73	4.50	0	3.94	0.15	4/12/2000
4/13/2000	Cotton	0.14	0	1.20	2.94	2.00	7.35	1.47	21.56	4.54	0	3.89	0.16	4/13/2000
4/14/2000	Cotton	0.15	0	1.20	3.45	3.00	8.35	1.53	20.51	4.61	0	3.85	0.16	4/14/2000
4/15/2000	Cotton	0.15	0	1.20	3.70	3.00	8.68	1.57	19.57	4.68	3.85	3.81	0.16	4/15/2000
4/16/2000	Cotton	0.16	0	1.20	3.61	2.00	9.09	1.61	18.72	4.73	3.82	3.78	0.16	4/16/2000
4/17/2000	Cotton	0.17	0	1.20	3.44	2.00	9.33	1.65	17.96	4.78	3.80	3.75	0.16	4/17/2000
4/18/2000	Cotton	0.19	0	1.20	3.35	2.00	9.48	1.69	17.28	4.83	3.79	3.72	0.16	4/18/2000
4/19/2000	Cotton	0.20	0	1.10	3.31	2.00	9.69	1.72	16.66	4.87	3.77	3.69	0.16	4/19/2000
4/20/2000	Cotton	0.21	0	1.10	2.82	1.00	10.41	1.75	16.09	4.90	3.75	3.67	0.15	4/20/2000
4/21/2000	Cotton	0.22	0	1.10	2.93	2.00	10.25	1.78	15.58	4.94	3.74	3.65	0.15	4/21/2000
4/22/2000	Cotton	0.24	0.01	1.00	2.64	1.00	10.89	1.80	15.12	4.97	3.72	3.63	0.15	4/22/2000
4/23/2000	Cotton	0.25	0.03	1.00	4.00	1.00	12.88	1.83	14.70	4.99	3.71	3.61	0.14	4/23/2000
4/24/2000	Cotton	0.27	0.04	1.00	4.00	2.00	13.88	1.85	14.32	5.04	3.70	3.59	0.13	4/24/2000
4/25/2000	Cotton	0.28	0.05	0.90	4.00	3.00	13.98	1.87	13.97	5.11	3.68	3.57	0.13	4/25/2000
4/26/2000	Cotton	0.30	0.07	0.90	3.98	2.00	15.07	1.88	13.65	5.15	3.67	3.56	0.13	4/26/2000
4/27/2000	Cotton	0.32	0.08	0.80	4.10	3.00	15.37	1.90	13.36	5.22	3.66	3.54	0.13	4/27/2000
4/28/2000	Cotton	0.34	0.09	0.70	3.63	2.00	16.29	1.92	13.09	5.27	3.65	3.53	0.12	4/28/2000
4/29/2000	Cotton	0.35	0.11	0.70	4.20	3.00	16.79	1.93	12.85	5.34	3.64	3.52	0.12	4/29/2000
4/30/2000	Cotton	0.37	0.12	0.60	3.44	2.00	17.64	1.94	12.62	5.39	3.63	3.51	0.12	4/30/2000
5/1/2000	Cotton	0.39	0.13	0.50	3.32	2.00	18.45	1.95	12.42	5.43	3.62	3.49	0.12	5/1/2000
5/2/2000	Cotton	0.41	0.15	0.40	3.21	2.00	19.26	1.97	12.23	5.48	3.61	3.48	0.11	5/2/2000
5/3/2000	Cotton	0.43	0.16	0.30	3.96	3.00	19.92	1.98	12.06	5.55	3.60	3.47	0.11	5/3/2000
5/4/2000	Cotton	0.45	0.17	0.20	3.03	2.00	20.75	1.98	11.90	5.60	3.59	3.46	0.11	5/4/2000
5/5/2000	Cotton	0.47	0.19	0.10	2.95	2.00	21.60	1.99	11.75	5.64	3.58	3.45	0.11	5/5/2000
5/6/2000	Cotton	0.50	0.20	0.00	3.69	3.00	22.29	2.00	11.62	5.72	3.58	3.45	0.11	5/6/2000
5/7/2000	Cotton	0.52	0.22	0.00	2.90	2.00	23.19	2.01	11.49	5.76	3.57	3.44	0.11	5/7/2000
5/8/2000	Cotton	0.54	0.23	0.00	2.92	2.00	24.11	2.01	11.38	5.81	3.56	3.43	0.11	5/8/2000
5/9/2000	Cotton	0.56	0.25	0.00	3.69	3.00	24.80	2.02	11.27	5.88	3.55	3.42	0.12	5/9/2000
5/10/2000	Cotton	0.58	0.26	0.00	2.99	2.00	25.79	2.03	11.18	5.93	3.55	3.41	0.12	5/10/2000
5/11/2000	Cotton	0.61	0.28	0.00	3.73	3.00	26.52	2.03	11.09	6.00	3.54	3.41	0.12	5/11/2000
5/12/2000	Cotton	0.63	0.30	0.00	3.03	2.00	27.55	2.04	11.01	6.04	3.53	3.40	0.12	5/12/2000
5/13/2000	Cotton	0.65	0.31	0.00	3.75	3.00	28.30	2.04	10.93	6.11	3.53	3.40	0.12	5/13/2000
5/14/2000	Cotton	0.68	0.33	0.00	3.12	2.00	29.42	2.05	10.86	6.16	3.52	3.39	0.13	5/14/2000
5/15/2000	Cotton	0.70	0.34	0.00	3.80	3.00	30.22	2.05	10.80	6.23	3.52	3.38	0.13	5/15/2000
5/16/2000	Cotton	0.72	0.36	0.00	3.82	3.00	31.04	2.05	10.74	6.30	3.51	3.38	0.14	5/16/2000
5/17/2000	Cotton	0.74	0.38	0.00	3.83	3.00	31.87	2.06	10.68	6.37	3.51	3.37	0.14	5/17/2000

WASIM Simulation Results

Water Fraction Root zone	Water Fraction Unsat. zone	EC Top Soil (dS/m)	EC Rootzone (dS/m)	EC Unsat. zone (dS/m)	EC Saturated zone (dS/m)	EC Ground water (dS/m)	EC Drain Water (dS/m)	W.C. in Topsoil (mm)	W.C. in Rootzone (mm)	W.C. in Unsat. Zone(mm)	W.C in Sat. Zone (mm)	W.C. in Ground water (mm)
0.22	0.22	9.08	0.00	8.19	5.73	9.97	9.03	31.41	0	216.53	817.54	2971.92
0.22	0.22	9.82	0.00	7.99	5.66	9.95	9.03	29.21	0	235.39	781.27	2971.92
0.22	0.22	10.69	0.00	7.82	5.59	9.92	9.03	26.92	0	252.32	748.70	2971.92
0.22	0.22	11.72	0.00	7.69	5.51	9.90	9.02	24.57	0	267.60	719.33	2971.92
0.22	0.22	12.47	0.00	7.58	5.43	9.88	9.01	23.10	0	281.38	692.82	2971.92
0.22	0.22	12.46	0.00	7.49	5.35	9.86	9.00	23.36	0	293.90	668.74	2971.92
0.22	0.22	12.25	0.00	7.40	5.27	9.84	9.00	24.12	0	305.28	646.86	2971.92
0.22	0.22	12.19	7.40	7.33	5.19	9.82	8.99	24.62	1.10	314.54	626.92	2971.92
0.22	0.22	12.52	7.36	7.27	5.10	9.80	8.97	24.21	3.22	321.87	608.75	2971.92
0.22	0.22	12.77	7.32	7.21	5.02	9.78	8.96	23.97	5.51	328.20	592.17	2971.92
0.22	0.22	12.97	7.28	7.15	4.93	9.76	8.95	23.82	7.97	333.62	577.01	2971.92
0.22	0.22	13.22	7.25	7.10	4.85	9.75	8.94	23.61	10.61	338.19	563.14	2971.92
0.22	0.22	13.70	7.22	7.06	4.76	9.73	8.92	22.89	13.41	341.99	550.45	2971.92
0.22	0.22	13.73	7.19	7.02	4.67	9.71	8.91	23.05	16.37	345.07	538.82	2971.92
0.22	0.22	14.17	7.17	6.98	4.58	9.70	8.90	22.44	19.46	347.50	528.15	2971.92
0.22	0.22	15.58	7.17	6.94	4.50	9.68	8.88	20.51	22.67	349.32	518.36	2971.92
0.22	0.22	16.44	7.17	6.91	4.41	9.66	8.87	19.63	25.97	350.57	509.37	2971.92
0.22	0.22	16.61	7.18	6.88	4.32	9.65	8.85	19.69	29.37	351.31	501.10	2971.92
0.22	0.22	17.54	7.19	6.85	4.24	9.63	8.83	18.82	32.86	351.56	493.51	2971.92
0.22	0.22	17.80	7.21	6.82	4.15	9.62	8.82	18.79	36.42	351.36	486.51	2971.92
0.22	0.22	18.56	7.23	6.79	4.06	9.60	8.80	18.19	40.06	350.74	480.08	2971.92
0.21	0.22	18.92	7.25	6.77	3.98	9.59	8.78	18.08	43.75	349.74	474.15	2971.92
0.21	0.22	19.52	7.28	6.74	3.89	9.57	8.77	17.68	47.51	348.39	468.69	2971.92
0.21	0.22	20.04	7.30	6.72	3.81	9.56	8.75	17.36	51.31	346.70	463.66	2971.92
0.21	0.22	20.50	7.33	6.70	3.73	9.54	8.73	17.12	55.15	344.71	459.01	2971.92
0.21	0.22	20.79	7.36	6.68	3.65	9.53	8.71	17.10	59.02	342.43	454.73	2971.92
0.21	0.22	21.14	7.39	6.66	3.57	9.51	8.69	16.96	62.91	339.89	450.78	2971.92
0.21	0.22	21.44	7.42	6.64	3.49	9.50	8.67	16.87	66.84	337.11	447.14	2971.92
0.20	0.22	21.53	7.46	6.63	3.41	9.48	8.66	17.00	70.76	334.11	443.77	2971.92
0.20	0.22	21.72	7.50	6.61	3.33	9.47	8.64	16.99	74.68	330.91	440.66	2971.92
0.20	0.22	21.84	7.53	6.60	3.25	9.45	8.62	17.04	78.60	327.52	437.79	2971.92
0.20	0.22	21.67	7.57	6.58	3.18	9.43	8.60	17.38	82.50	323.97	435.13	2971.92
0.20	0.22	21.68	7.61	6.57	3.11	9.42	8.58	17.51	86.36	320.26	432.68	2971.92
0.20	0.22	21.38	7.65	6.55	3.04	9.40	8.56	17.96	90.20	316.42	430.41	2971.92
0.20	0.22	21.30	7.70	6.54	2.96	9.39	8.54	18.17	94.01	312.46	428.32	2971.92
0.19	0.22	20.90	7.74	6.53	2.89	9.37	8.52	18.74	97.78	308.39	426.38	2971.92
0.19	0.22	20.75	7.78	6.52	2.83	9.36	8.50	19.01	101.48	304.22	424.59	2971.92
0.19	0.22	20.29	7.83	6.51	2.76	9.34	8.48	19.67	105.13	299.98	422.93	2971.92
0.19	0.22	19.82	7.88	6.50	2.69	9.33	8.46	20.36	108.72	295.67	421.40	2971.92
0.19	0.22	19.34	7.92	6.49	2.63	9.31	8.44	21.10	112.26	291.30	419.98	2971.92

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	ECe Top Soil (dS/m)	ECe Rootzone (dS/m)	ECe Unsat. Zone (dS/m)	Water Fraction - Top Soil	Date
5/18/2000	Cotton	0.77	0.39	0.00	3.89	3.00	32.76	2.06	10.63	6.44	3.50	3.37	0.15	5/18/2000
5/19/2000	Cotton	0.79	0.41	0.00	3.90	3.00	33.66	2.06	10.58	6.51	3.50	3.36	0.15	5/19/2000
5/20/2000	Cotton	0.81	0.42	0.00	3.92	3.00	34.58	2.06	10.54	6.58	3.49	3.36	0.16	5/20/2000
5/21/2000	Cotton	0.84	0.44	0.00	3.94	3.00	35.52	2.07	10.50	6.65	3.49	3.36	0.16	5/21/2000
5/22/2000	Cotton	0.86	0.46	0.00	4.00	3.00	36.52	2.07	10.46	6.72	3.48	3.35	0.17	5/22/2000
5/23/2000	Cotton	0.88	0.47	0.00	3.95	3.00	37.47	2.07	10.43	6.79	3.48	3.35	0.17	5/23/2000
5/24/2000	Cotton	0.90	0.49	0.00	3.88	3.00	38.35	2.07	10.40	6.86	3.48	3.34	0.18	5/24/2000
5/25/2000	Cotton	0.92	0.50	0.00	3.91	3.00	39.25	2.08	10.37	6.93	3.47	3.34	0.19	5/25/2000
5/26/2000	Cotton	0.94	0.52	0.10	3.98	3.00	40.14	2.08	10.34	7.00	3.47	3.34	0.20	5/26/2000
5/27/2000	Cotton	0.97	0.54	0.10	4.06	3.00	41.10	2.08	10.31	7.07	3.46	3.33	0.21	5/27/2000
5/28/2000	Cotton	0.99	0.55	0.10	4.54	4.00	41.54	2.08	10.29	7.17	3.46	3.33	0.22	5/28/2000
5/29/2000	Cotton	1.01	0.57	0.20	4.17	3.00	42.51	2.08	10.27	7.24	3.46	3.33	0.22	5/29/2000
5/30/2000	Cotton	1.03	0.58	0.20	4.61	4.00	42.92	2.08	10.25	7.32	3.46	3.33	0.24	5/30/2000
5/31/2000	Cotton	1.05	0.60	0.20	4.22	3.00	43.94	2.08	10.23	7.37	3.46	3.32	0.24	5/31/2000
6/1/2000	Cotton	1.06	0.62	0.20	4.69	4.00	44.43	2.08	10.21	7.43	3.46	3.32	0.25	6/1/2000
6/2/2000	Cotton	1.08	0.63	0.20	4.34	3.00	45.57	2.09	10.20	7.44	3.47	3.32	0.26	6/2/2000
6/3/2000	Cotton	1.10	0.65	0.20	4.72	4.00	46.09	2.09	10.18	7.45	3.48	3.32	0.27	6/3/2000
6/4/2000	Cotton	1.12	0.66	0.20	4.73	4.00	46.62	2.09	10.17	7.43	3.49	3.31	0.28	6/4/2000
6/5/2000	Cotton	1.13	0.68	0.20	4.74	4.00	47.16	2.09	10.16	7.38	3.51	3.31	0.28	6/5/2000
6/6/2000	Cotton	1.15	0.70	0.20	4.76	4.00	47.72	2.09	10.15	7.30	3.53	3.31	0.29	6/6/2000
6/7/2000	Cotton	1.16	0.71	0.20	4.84	4.00	48.36	2.09	10.14	7.21	3.56	3.31	0.29	6/7/2000
6/8/2000	Cotton	1.18	0.73	0.20	4.86	4.00	49.02	2.09	10.13	7.09	3.59	3.31	0.30	6/8/2000
6/9/2000	Cotton	1.19	0.74	0.20	4.87	4.00	49.69	2.09	10.12	6.97	3.61	3.30	0.30	6/9/2000
6/10/2000	Cotton	1.21	0.76	0.20	4.88	4.00	50.37	2.09	10.11	6.83	3.64	3.30	0.30	6/10/2000
6/11/2000	Cotton	1.22	0.78	0.20	4.90	4.00	51.07	2.09	10.10	6.69	3.67	3.30	0.30	6/11/2000
6/12/2000	Cotton	1.23	0.79	0.20	4.91	4.00	51.78	2.09	10.09	6.55	3.70	3.30	0.30	6/12/2000
6/13/2000	Cotton	1.24	0.81	0.20	5.10	5.00	51.68	2.09	10.09	6.39	3.73	3.30	0.31	6/13/2000
6/14/2000	Cotton	1.25	0.82	0.20	5.04	4.00	52.52	2.09	10.08	6.23	3.76	3.30	0.31	6/14/2000
6/15/2000	Cotton	1.26	0.84	0.30	5.20	5.00	52.42	2.09	10.07	6.06	3.80	3.30	0.31	6/15/2000
6/16/2000	Cotton	1.27	0.86	0.30	5.08	4.00	53.21	2.09	10.07	5.89	3.83	3.30	0.31	6/16/2000
6/17/2000	Cotton	1.28	0.87	0.30	5.20	5.00	53.11	2.09	10.06	5.72	3.87	3.29	0.32	6/17/2000
6/18/2000	Cotton	1.28	0.89	0.30	5.20	5.00	53.01	2.09	10.06	5.54	3.90	3.29	0.32	6/18/2000
6/19/2000	Cotton	1.29	0.90	0.20	5.12	4.00	53.93	2.09	10.05	5.36	3.93	3.29	0.32	6/19/2000
6/20/2000	Cotton	1.29	0.92	0.20	5.20	5.00	53.93	2.09	10.05	5.20	3.97	3.29	0.32	6/20/2000
6/21/2000	Cotton	1.30	0.94	0.20	5.20	5.00	53.93	2.10	10.05	5.03	4.00	3.29	0.32	6/21/2000
6/22/2000	Cotton	1.30	0.95	0.20	5.20	5.00	53.93	2.10	10.04	4.86	4.04	3.29	0.32	6/22/2000
6/23/2000	Cotton	1.30	0.97	0.20	5.20	5.00	53.93	2.10	10.04	4.70	4.07	3.29	0.32	6/23/2000
6/24/2000	Cotton	1.31	0.98	0.20	5.18	4.00	54.91	2.10	10.04	4.54	4.11	3.29	0.32	6/24/2000
6/25/2000	Cotton	1.31	1.00	0.20	5.20	5.00	54.91	2.10	10.03	4.39	4.14	3.29	0.32	6/25/2000
6/26/2000	Cotton	1.31	1.00	0.20	5.30	5.00	55.01	2.10	10.03	4.25	4.17	3.29	0.33	6/26/2000
6/27/2000	Cotton	1.31	1.00	0.20	5.30	6.00	54.11	2.10	10.03	4.11	4.21	3.29	0.33	6/27/2000
6/28/2000	Cotton	1.31	1.00	0.20	5.30	5.00	54.21	2.10	10.03	3.97	4.24	3.29	0.33	6/28/2000

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	ECe Top Soil (dS/m)	ECe Rootzone (dS/m)	ECe Unsat. Zone (dS/m)	Water Fraction - Top Soil	Date
6/30/2000	Cotton	1.31	1.00	0.20	5.30	5.00	54.41	2.10	10.02	3.71	4.31	3.29	0.33	6/30/2000
7/1/2000	Cotton	1.31	1.00	0.20	5.30	5.00	54.51	2.10	10.02	3.59	4.34	3.29	0.33	7/1/2000
7/2/2000	Cotton	1.31	1.00	0.20	5.30	5.00	54.61	2.10	10.02	3.49	4.37	3.29	0.33	7/2/2000
7/3/2000	Cotton	1.31	1.00	0.10	5.30	5.00	54.81	2.10	10.02	3.39	4.39	3.29	0.33	7/3/2000
7/4/2000	Cotton	1.31	1.00	0.10	5.30	5.00	55.01	2.10	10.02	3.30	4.42	3.29	0.33	7/4/2000
7/5/2000	Cotton	1.31	1.00	0.10	5.30	6.00	54.21	2.10	10.02	3.22	4.45	3.28	0.33	7/5/2000
7/6/2000	Cotton	1.31	1.00	0.00	5.30	5.00	54.51	2.10	10.01	3.13	4.48	3.28	0.33	7/6/2000
7/7/2000	Cotton	1.31	1.00		5.30	5.00	54.81	2.10	10.01	3.05	4.50	3.28	0.33	7/7/2000
7/8/2000	Cotton	1.31	1.00		5.30	5.00	55.11	2.10	10.01	2.98	4.53	3.28	0.33	7/8/2000
7/9/2000	Cotton	1.31	1.00		5.30	6.00	54.41	2.10	10.01	2.93	4.55	3.28	0.33	7/9/2000
7/10/2000	Cotton	1.31	1.00		5.30	5.00	54.71	2.10	10.01	2.86	4.58	3.28	0.33	7/10/2000
7/11/2000	Cotton	1.31	1.00		5.30	5.00	55.01	2.10	10.01	2.80	4.60	3.28	0.33	7/11/2000
7/12/2000	Cotton	1.31	1.00		5.30	6.00	54.31	2.10	10.01	2.75	4.62	3.28	0.33	7/12/2000
7/13/2000	Cotton	1.31	1.00		5.30	5.00	54.61	2.10	10.01	2.69	4.65	3.28	0.33	7/13/2000
7/14/2000	Cotton	1.31	1.00		5.30	5.00	54.91	2.10	10.01	2.64	4.67	3.28	0.33	7/14/2000
7/15/2000	Cotton	1.31	1.00		5.30	5.00	55.21	2.10	10.01	2.59	4.69	3.28	0.33	7/15/2000
7/16/2000	Cotton	1.31	1.00		5.30	6.00	54.51	2.10	10.01	2.56	4.71	3.28	0.33	7/16/2000
7/17/2000	Cotton	1.31	1.00		5.30	5.00	54.81	2.10	10.01	2.52	4.73	3.28	0.33	7/17/2000
7/18/2000	Cotton	1.31	1.00		5.20	5.00	55.01	2.10	10.01	2.48	4.75	3.28	0.33	7/18/2000
7/19/2000	Cotton	1.31	1.00		5.20	6.00	54.21	2.10	10.01	2.45	4.77	3.28	0.33	7/19/2000
7/20/2000	Cotton	1.31	1.00		5.20	5.00	54.41	2.10	10.01	2.41	4.79	3.28	0.33	7/20/2000
7/21/2000	Cotton	1.31	1.00		5.20	5.00	54.61	2.10	10.00	2.37	4.81	3.28	0.33	7/21/2000
7/22/2000	Cotton	1.31	1.00		5.20	5.00	54.81	2.10	10.00	2.34	4.83	3.28	0.33	7/22/2000
7/23/2000	Cotton	1.31	1.00		5.20	5.00	55.01	2.10	10.00	2.31	4.85	3.28	0.33	7/23/2000
7/24/2000	Cotton	1.31	1.00		5.20	6.00	54.21	2.10	10.00	2.30	4.87	3.28	0.33	7/24/2000
7/25/2000	Cotton	1.31	1.00		5.20	5.00	54.41	2.10	10.00	2.27	4.89	3.28	0.33	7/25/2000
7/26/2000	Cotton	1.31	1.00		5.20	5.00	54.61	2.10	10.00	2.24	4.91	3.28	0.33	7/26/2000
7/27/2000	Cotton	1.31	1.00		5.20	5.00	54.81	2.10	10.00	2.22	4.93	3.28	0.33	7/27/2000
7/28/2000	Cotton	1.31	1.00		5.20	5.00	55.01	2.10	10.00	2.20	4.95	3.28	0.33	7/28/2000
7/29/2000	Cotton	1.31	1.00		5.20	6.00	54.21	2.10	10.00	2.19	4.97	3.28	0.33	7/29/2000
7/30/2000	Cotton	1.31	1.00		5.10	5.00	54.31	2.10	10.00	2.17	4.98	3.28	0.33	7/30/2000
7/31/2000	Cotton	1.31	1.00		5.10	5.00	54.41	2.10	10.00	2.15	5.00	3.28	0.33	7/31/2000
8/1/2000	Cotton	1.31	1.00		5.10	5.00	54.51	2.10	10.00	2.13	5.02	3.28	0.33	8/1/2000
8/2/2000	Cotton	1.31	1.00		5.10	5.00	54.61	2.10	10.00	2.11	5.04	3.28	0.33	8/2/2000
8/3/2000	Cotton	1.31	1.00		5.10	5.00	54.71	2.10	10.00	2.10	5.05	3.28	0.33	8/3/2000
8/4/2000	Cotton	1.31	1.00		5.10	5.00	54.81	2.10	10.00	2.09	5.07	3.28	0.33	8/4/2000
8/5/2000	Cotton	1.31	1.00		5.10	5.00	54.91	2.10	10.00	2.08	5.09	3.28	0.33	8/5/2000
8/6/2000	Cotton	1.31	1.00		5.00	5.00	54.91	2.10	10.00	2.07	5.10	3.28	0.33	8/6/2000
8/7/2000	Cotton	1.31	1.00		5.00	5.00	54.91	2.10	10.00	2.05	5.12	3.28	0.33	8/7/2000
8/8/2000	Cotton	1.31	1.00		5.00	5.00	54.91	2.10	10.00	2.04	5.14	3.28	0.33	8/8/2000
8/9/2000	Cotton	1.31	1.00		5.00	5.00	54.91	2.10	10.00	2.03	5.15	3.28	0.33	8/9/2000
8/10/2000	Cotton	1.31	1.00		5.00	5.00	54.91	2.10	10.00	2.03	5.17	3.28	0.33	8/10/2000
8/11/2000	Cotton	1.31	1.00		5.00	5.00	54.91	2.10	10.00	2.03	5.19	3.28	0.33	8/11/2000

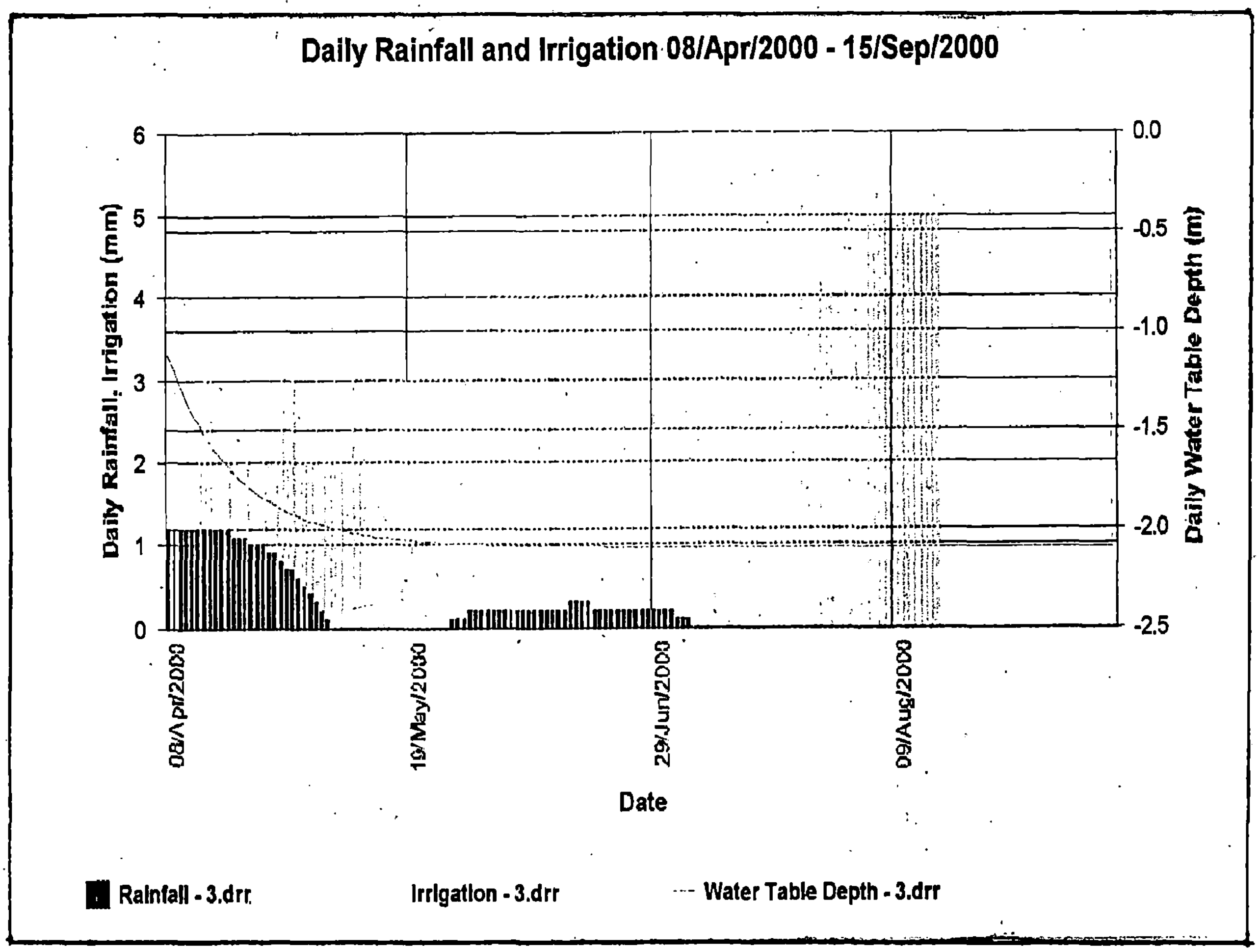
Water Fraction Root zone	Water Fraction Unsat. zone	EC Top Soil (dS/m)	EC Rootzone (dS/m)	EC Unsat. zone (dS/m)	EC Saturated zone (dS/m)	EC Ground water (dS/m)	EC Drain Water (dS/m)	W.C. in Topsoil (mm)	W.C. in Rootzone (mm)	W.C. in Unsat. Zone(mm)	W.C in Sat. Zone (mm)	W.C. in Ground water (mm)
0.19	0.22	18.87	7.97	6.48	2.57	9.30	8.42	21.87	115.70	286.89	418.67	2971.92
0.19	0.22	18.40	8.02	6.47	2.51	9.28	8.40	22.67	119.07	282.45	417.45	2971.92
0.18	0.22	17.94	8.08	6.46	2.45	9.26	8.38	23.50	122.36	277.99	416.33	2971.92
0.18	0.22	17.49	8.13	6.45	2.39	9.25	8.36	24.36	125.57	273.53	415.29	2971.92
0.18	0.22	17.06	8.18	6.45	2.33	9.23	8.34	25.24	128.65	269.06	414.33	2971.92
0.18	0.22	16.59	8.24	6.44	2.27	9.22	8.32	26.22	131.63	264.61	413.43	2971.92
0.18	0.22	16.09	8.29	6.43	2.22	9.20	8.31	27.32	134.52	260.18	412.61	2971.92
0.18	0.22	15.62	8.35	6.42	2.16	9.18	8.29	28.43	137.30	255.78	411.85	2971.92
0.18	0.22	15.16	8.41	6.42	2.11	9.17	8.27	29.59	139.97	251.42	411.14	2971.92
0.17	0.22	14.73	8.47	6.41	2.06	9.15	8.25	30.76	142.49	247.12	410.48	2971.92
0.17	0.22	14.13	8.53	6.41	2.01	9.14	8.23	32.48	144.89	242.87	409.88	2971.92
0.17	0.22	13.76	8.59	6.40	1.96	9.12	8.21	33.70	147.17	238.69	409.32	2971.92
0.17	0.22	13.23	8.66	6.40	1.91	9.10	8.19	35.46	149.37	234.59	408.80	2971.92
0.17	0.22	12.92	8.72	6.39	1.87	9.09	8.17	36.57	151.51	230.57	408.32	2971.92
0.17	0.22	12.47	8.79	6.39	1.82	9.07	8.15	38.16	153.59	226.65	407.87	2971.92
0.17	0.22	12.22	8.87	6.38	1.78	9.05	8.13	39.02	155.63	222.82	407.46	2971.92
0.17	0.22	11.82	8.94	6.38	1.73	9.04	8.11	40.35	157.70	219.10	407.07	2971.92
0.17	0.22	11.46	9.02	6.37	1.69	9.02	8.09	41.50	159.81	215.50	406.72	2971.92
0.16	0.22	11.13	9.10	6.37	1.65	9.00	8.07	42.46	161.96	212.02	406.39	2971.92
0.16	0.22	10.81	9.19	6.37	1.61	8.99	8.05	43.25	164.13	208.66	406.09	2971.92
0.16	0.22	10.52	9.27	6.36	1.57	8.97	8.03	43.87	166.23	205.44	405.81	2971.92
0.16	0.22	10.24	9.36	6.36	1.53	8.95	8.01	44.39	168.28	202.35	405.55	2971.92
0.16	0.22	9.96	9.45	6.36	1.49	8.94	7.99	44.80	170.26	199.41	405.30	2971.92
0.16	0.22	9.70	9.54	6.35	1.46	8.92	7.97	45.14	172.15	196.62	405.08	2971.92
0.16	0.22	9.44	9.63	6.35	1.42	8.90	7.95	45.42	173.91	193.98	404.87	2971.92
0.16	0.22	9.18	9.72	6.35	1.38	8.88	7.94	45.66	175.54	191.51	404.68	2971.92
0.16	0.22	8.82	9.81	6.35	1.35	8.87	7.92	46.46	177.24	189.20	404.50	2971.92
0.16	0.22	8.59	9.90	6.34	1.32	8.85	7.90	46.42	178.67	187.05	404.34	2971.92
0.16	0.22	8.24	9.99	6.34	1.28	8.83	7.88	47.10	180.14	185.08	404.19	2971.92
0.16	0.22	8.02	10.09	6.34	1.25	8.82	7.86	46.99	181.34	183.28	404.04	2971.92
0.16	0.22	7.70	10.18	6.34	1.22	8.80	7.84	47.57	182.55	181.66	403.91	2971.92
0.16	0.22	7.39	10.27	6.34	1.19	8.78	7.82	47.98	183.74	180.22	403.79	2971.92
0.16	0.22	7.21	10.37	6.33	1.16	8.76	7.80	47.61	184.50	178.96	403.68	2971.92
0.16	0.22	6.93	10.46	6.33	1.13	8.75	7.78	48.03	185.21	177.90	403.57	2971.92
0.16	0.22	6.66	10.56	6.33	1.10	8.73	7.77	48.33	185.84	177.01	403.48	2971.92
0.16	0.22	6.41	10.65	6.33	1.08	8.71	7.75	48.56	186.35	176.32	403.39	2971.92
0.16	0.22	6.17	10.75	6.33	1.05	8.69	7.73	48.74	186.71	175.82	403.31	2971.92
0.16	0.22	6.02	10.85	6.33	1.02	8.68	7.71	48.25	186.56	175.51	403.23	2971.92
0.16	0.22	5.79	10.96	6.33	1.00	8.66	7.69	48.62	186.35	175.40	403.16	2971.92
0.16	0.22	5.58	11.07	6.32	0.97	8.64	7.67	48.82	186.05	175.42	403.09	2971.92
0.16	0.22	5.31	11.15	6.32	0.95	8.62	7.66	49.57	186.21	175.45	403.03	2971.92
0.16	0.22	5.14	11.24	6.32	0.93	8.61	7.64	49.39	186.28	175.48	402.97	2971.92
0.16	0.22	4.98	11.33	6.32	0.90	8.59	7.62	49.29	186.28	175.51	402.92	2971.92

Date	Crop	Root Depth (m)	Crop Cover	Rainfall (mm)	Actual ET (mm)	Irrigation (mm)	Rzone Def (mm)	W. T. Depth (m)	Drain Flow (mm)	ECe Top Soil (dS/m)	ECe Rootzone (dS/m)	ECe Unsat. Zone (dS/m)	Water Fraction - Top Soil	Date
8/12/2000	Cotton	1.31	1.00		4.90	5.00	54.81	2.10	10.00	2.01	5.20	3.28	0.33	8/12/2000
8/13/2000	Cotton	1.31	1.00		4.90	5.00	54.71	2.10	10.00	2.00	5.22	3.28	0.33	8/13/2000
8/14/2000	Cotton	1.31	1.00		4.90	5.00	54.61	2.10	10.00	1.99	5.23	3.28	0.33	8/14/2000
8/15/2000	Cotton	1.31	1.00		4.90	5.00	54.51	2.10	10.00	1.99	5.25	3.28	0.33	8/15/2000
8/16/2000	Cotton	1.31	1.00		4.90	5.00	54.41	2.10	10.00	1.98	5.27	3.28	0.33	8/16/2000
8/17/2000	Cotton	1.31	1.00		4.80	0.00	59.21	2.10	10.00	1.91	5.28	3.28	0.30	8/17/2000
8/18/2000	Cotton	1.31	1.00		4.80	0.00	64.01	2.10	10.00	1.87	5.28	3.28	0.29	8/18/2000
8/19/2000	Cotton	1.31	1.00		4.80	0.00	68.81	2.10	10.00	1.84	5.28	3.28	0.27	8/19/2000
8/20/2000	Cotton	1.31	1.00		4.80	0.00	73.61	2.10	10.00	1.83	5.29	3.28	0.26	8/20/2000
8/21/2000	Cotton	1.31	1.00		4.80	0.00	78.41	2.10	10.00	1.82	5.29	3.28	0.25	8/21/2000
8/22/2000	Cotton	1.31	1.00		4.70	0.00	83.11	2.10	10.00	1.81	5.29	3.28	0.24	8/22/2000
8/23/2000	Cotton	1.31	1.00		4.70	0.00	87.81	2.10	10.00	1.81	5.29	3.28	0.23	8/23/2000
8/24/2000	Cotton	1.31	1.00		4.70	0.00	92.51	2.10	10.00	1.81	5.29	3.28	0.23	8/24/2000
8/25/2000	Cotton	1.31	1.00		4.70	0.00	97.21	2.10	10.00	1.81	5.29	3.28	0.22	8/25/2000
8/26/2000	Cotton	1.31	1.00		4.60	0.00	101.81	2.10	10.00	1.81	5.29	3.28	0.21	8/26/2000
8/27/2000	Cotton	1.31	1.00		4.60	0.00	106.41	2.10	10.00	1.81	5.29	3.28	0.20	8/27/2000
8/28/2000	Cotton	1.31	1.00		4.60	0.00	111.01	2.10	10.00	1.81	5.29	3.28	0.19	8/28/2000
8/29/2000	Cotton	1.31	1.00		4.60	0.00	115.61	2.10	10.00	1.81	5.29	3.28	0.18	8/29/2000
8/30/2000	Cotton	1.31	1.00		4.60	0.00	120.21	2.10	10.00	1.81	5.29	3.28	0.18	8/30/2000
8/31/2000	Cotton	1.31	1.00		4.50	0.00	124.71	2.10	10.00	1.81	5.29	3.28	0.17	8/31/2000
9/1/2000	Cotton	1.31	1.00		4.50	0.00	129.21	2.10	10.00	1.81	5.29	3.28	0.16	9/1/2000
9/2/2000	Cotton	1.31	1.00		4.50	0.00	133.71	2.10	10.00	1.81	5.29	3.28	0.15	9/2/2000
9/3/2000	Cotton	1.31	1.00		3.90	0.00	137.62	2.10	10.00	1.81	5.29	3.28	0.14	9/3/2000
9/4/2000	Cotton	1.31	1.00		1.38	0.00	139.00	2.10	10.00	1.81	5.29	3.28	0.14	9/4/2000
9/5/2000	Cotton	1.31	1.00		1.31	0.00	140.30	2.10	10.00	1.81	5.29	3.28	0.14	9/5/2000
9/6/2000	Cotton	1.31	1.00		1.24	0.00	141.54	2.10	10.00	1.81	5.29	3.28	0.14	9/6/2000
9/7/2000	Cotton	1.31	1.00		1.14	0.00	142.68	2.10	10.00	1.81	5.29	3.28	0.13	9/7/2000
9/8/2000	Cotton	1.31	1.00		1.08	0.00	143.76	2.10	10.00	1.81	5.29	3.28	0.13	9/8/2000
9/9/2000	Cotton	1.31	1.00		1.03	0.00	144.79	2.10	10.00	1.81	5.29	3.28	0.13	9/9/2000
9/10/2000	Cotton	1.31	1.00		0.95	0.00	145.74	2.10	10.00	1.81	5.29	3.28	0.13	9/10/2000
9/11/2000	Cotton	1.31	1.00		0.90	0.00	146.64	2.10	10.00	1.81	5.29	3.28	0.13	9/11/2000
9/12/2000	Cotton	1.31	1.00		0.85	0.00	147.49	2.10	10.00	1.81	5.29	3.28	0.13	9/12/2000
9/13/2000	Cotton	1.31	1.00		0.81	0.00	148.30	2.10	10.00	1.81	5.29	3.28	0.12	9/13/2000
9/14/2000	Cotton	1.31	1.00		0.75	0.00	149.05	2.10	10.00	1.81	5.29	3.28	0.12	9/14/2000
9/15/2000	Cotton	1.31	0.80		0.57	0.00	149.62	2.10	10.00	1.81	5.29	3.28	0.12	9/15/2000

Water Fraction Root zone	Water Fraction Unsat. zone	EC Top Soil (dS/m)	EC Rootzone (dS/m)	EC Unsat. zone (dS/m)	EC Saturated zone (dS/m)	EC Ground water (dS/m)	EC Drain Water (dS/m)	W.C. in Topsoil (mm)	W.C. in Rootzone (mm)	W.C. in Unsat. Zone(mm)	W.C in Sat. Zone (mm)	W.C. in Ground water (mm)
0.16	0.22	4.83	11.41	6.32	0.88	8.57	7.60	49.23	186.24	175.54	402.87	2971.92
0.16	0.22	4.68	11.50	6.32	0.86	8.55	7.58	49.19	186.18	175.56	402.83	2971.92
0.16	0.22	4.54	11.58	6.32	0.84	8.54	7.57	49.17	186.10	175.58	402.79	2971.92
0.16	0.22	4.42	11.66	6.32	0.82	8.52	7.55	49.09	185.98	175.60	402.75	2971.92
0.16	0.22	4.31	11.74	6.32	0.80	8.50	7.53	49.05	185.83	175.62	402.71	2971.92
0.16	0.22	4.15	11.80	6.32	0.78	8.48	7.51	49.63	186.04	175.64	402.68	2971.92
0.16	0.22	4.07	11.87	6.32	0.76	8.47	7.49	49.31	186.06	175.65	402.65	2971.92
0.16	0.22	3.98	11.95	6.32	0.74	8.45	7.48	49.12	185.96	175.67	402.62	2971.92
0.16	0.22	3.90	12.02	6.32	0.72	8.43	7.46	49.00	185.78	175.68	402.59	2971.92
0.16	0.22	3.78	12.08	6.32	0.70	8.41	7.44	49.54	185.93	175.69	402.57	2971.92
0.16	0.22	3.71	12.14	6.32	0.69	8.40	7.42	49.25	185.92	175.71	402.55	2971.92
0.16	0.22	3.65	12.21	6.32	0.67	8.38	7.41	49.08	185.79	175.72	402.53	2971.92
0.16	0.22	3.55	12.27	6.32	0.65	8.36	7.39	49.59	185.98	175.73	402.51	2971.92
0.16	0.22	3.50	12.33	6.31	0.64	8.34	7.37	49.29	185.99	175.74	402.49	2971.92
0.16	0.22	3.44	12.39	6.31	0.62	8.33	7.35	49.10	185.87	175.75	402.47	2971.92
0.16	0.22	3.39	12.46	6.31	0.60	8.31	7.34	48.99	185.69	175.75	402.46	2971.92
0.16	0.22	3.31	12.51	6.31	0.59	8.29	7.32	49.54	185.84	175.76	402.44	2971.92
0.16	0.22	3.27	12.57	6.31	0.57	8.27	7.30	49.25	185.82	175.77	402.43	2971.92
0.16	0.22	3.23	12.62	6.31	0.56	8.26	7.28	49.10	185.78	175.77	402.42	2971.92
0.16	0.22	3.16	12.66	6.31	0.55	8.24	7.27	49.62	186.05	175.78	402.40	2971.92
0.16	0.22	3.13	12.71	6.31	0.53	8.22	7.25	49.32	186.15	175.79	402.39	2971.92
0.16	0.22	3.09	12.77	6.31	0.52	8.20	7.23	49.14	186.13	175.79	402.38	2971.92
0.16	0.22	3.06	12.82	6.31	0.51	8.19	7.22	49.04	186.04	175.80	402.37	2971.92
0.16	0.22	3.03	12.88	6.31	0.49	8.17	7.20	48.97	185.91	175.80	402.37	2971.92
0.16	0.22	2.97	12.92	6.31	0.48	8.15	7.18	49.55	186.13	175.80	402.36	2971.92
0.16	0.22	2.95	12.97	6.31	0.47	8.13	7.17	49.28	186.19	175.81	402.35	2971.92
0.16	0.22	2.92	13.02	6.31	0.46	8.12	7.15	49.12	186.16	175.81	402.34	2971.92
0.16	0.22	2.90	13.07	6.31	0.45	8.10	7.13	49.02	186.05	175.81	402.34	2971.92
0.16	0.22	2.88	13.13	6.31	0.44	8.08	7.12	48.96	185.91	175.82	402.33	2971.92
0.16	0.22	2.83	13.17	6.31	0.42	8.06	7.10	49.54	186.13	175.82	402.33	2971.92
0.16	0.22	2.82	13.20	6.31	0.41	8.05	7.08	49.30	186.28	175.82	402.32	2971.92
0.16	0.22	2.80	13.25	6.31	0.40	8.03	7.07	49.15	186.32	175.83	402.32	2971.92
0.16	0.22	2.78	13.29	6.31	0.39	8.01	7.05	49.06	186.31	175.83	402.31	2971.92
0.16	0.22	2.76	13.34	6.31	0.38	7.99	7.03	49.01	186.27	175.83	402.31	2971.92
0.16	0.22	2.75	13.39	6.31	0.37	7.98	7.02	48.97	186.20	175.83	402.31	2971.92
0.16	0.22	2.73	13.44	6.31	0.37	7.96	7.00	48.95	186.12	175.83	402.30	2971.92
0.16	0.22	2.72	13.49	6.31	0.36	7.94	6.98	48.94	186.04	175.83	402.30	2971.92
0.16	0.22	2.70	13.54	6.31	0.35	7.93	6.97	48.95	186.02	175.84	402.30	2971.92
0.16	0.22	2.69	13.58	6.31	0.34	7.91	6.95	48.96	186.02	175.84	402.29	2971.92
0.16	0.22	2.67	13.63	6.31	0.33	7.89	6.94	48.96	186.01	175.84	402.29	2971.92
0.16	0.22	2.66	13.67	6.31	0.32	7.87	6.92	48.96	186.01	175.84	402.29	2971.92
0.16	0.22	2.65	13.72	6.31	0.31	7.86	6.90	48.96	186.01	175.84	402.29	2971.92
0.16	0.22	2.64	13.76	6.31	0.31	7.84	6.89	48.96	186.01	175.84	402.29	2971.92

Water Fraction Root zone	Water Fraction Unsat. zone	EC Top Soil (dS/m)	EC Rootzone (dS/m)	EC Unsat. zone (dS/m)	EC Saturated zone (dS/m)	EC Ground water (dS/m)	EC Drain Water (dS/m)	W.C. in Topsoil (mm)	W.C. in Rootzone (mm)	W.C. in Unsat. Zone(mm)	W.C in Sat. Zone (mm)	W.C. in Ground water (mm)
0.16	0.22	2.63	13.80	6.31	0.30	7.82	6.87	48.98	186.09	175.84	402.28	2971.92
0.16	0.22	2.62	13.83	6.31	0.29	7.81	6.86	49.00	186.18	175.84	402.28	2971.92
0.16	0.22	2.60	13.87	6.31	0.28	7.79	6.84	49.01	186.27	175.84	402.28	2971.92
0.16	0.22	2.59	13.90	6.31	0.28	7.77	6.82	49.01	186.36	175.85	402.28	2971.92
0.16	0.22	2.59	13.94	6.31	0.27	7.75	6.81	49.02	186.46	175.85	402.28	2971.92
0.16	0.22	2.68	14.07	6.31	0.26	7.74	6.79	45.64	185.03	175.85	402.28	2971.92
0.16	0.22	2.77	14.26	6.31	0.26	7.72	6.78	43.12	182.75	175.85	402.28	2971.92
0.16	0.22	2.87	14.49	6.31	0.25	7.70	6.76	41.09	179.98	175.85	402.27	2971.92
0.15	0.22	2.97	14.75	6.31	0.24	7.69	6.75	39.37	176.90	175.85	402.27	2971.92
0.15	0.22	3.07	15.03	6.31	0.24	7.67	6.73	37.84	173.63	175.85	402.27	2971.92
0.15	0.22	3.18	15.32	6.31	0.23	7.65	6.72	36.46	170.32	175.85	402.27	2971.92
0.14	0.22	3.30	15.63	6.31	0.23	7.64	6.70	35.14	166.93	175.85	402.27	2971.92
0.14	0.22	3.43	15.96	6.31	0.22	7.62	6.69	33.85	163.52	175.85	402.27	2971.92
0.14	0.22	3.56	16.30	6.31	0.22	7.60	6.67	32.57	160.10	175.85	402.27	2971.92
0.14	0.22	3.70	16.65	6.31	0.21	7.59	6.65	31.32	156.76	175.85	402.27	2971.92
0.13	0.22	3.86	17.01	6.31	0.20	7.57	6.64	30.06	153.41	175.85	402.27	2971.92
0.13	0.22	4.03	17.39	6.31	0.20	7.55	6.62	28.80	150.07	175.85	402.27	2971.92
0.13	0.22	4.21	17.79	6.31	0.19	7.54	6.61	27.55	146.73	175.85	402.27	2971.92
0.12	0.22	4.41	18.20	6.31	0.19	7.52	6.59	26.29	143.38	175.85	402.27	2971.92
0.12	0.22	4.63	18.63	6.31	0.19	7.50	6.58	25.06	140.11	175.85	402.27	2971.92
0.12	0.22	4.87	19.07	6.31	0.18	7.49	6.56	23.84	136.84	175.85	402.27	2971.92
0.12	0.22	5.13	19.54	6.31	0.18	7.47	6.55	22.61	133.57	175.85	402.26	2971.92
0.11	0.22	5.38	19.96	6.31	0.17	7.46	6.53	21.54	130.73	175.85	402.26	2971.92
0.11	0.22	5.48	20.12	6.31	0.17	7.44	6.52	21.16	129.73	175.85	402.26	2971.92
0.11	0.22	5.57	20.27	6.31	0.16	7.42	6.51	20.81	128.78	175.85	402.26	2971.92
0.11	0.22	5.67	20.41	6.31	0.16	7.41	6.49	20.47	127.88	175.85	402.26	2971.92
0.11	0.22	5.75	20.54	6.31	0.16	7.39	6.48	20.16	127.05	175.85	402.26	2971.92
0.11	0.22	5.84	20.67	6.31	0.15	7.37	6.46	19.86	126.26	175.85	402.26	2971.92
0.11	0.22	5.92	20.79	6.31	0.15	7.36	6.45	19.58	125.51	175.85	402.26	2971.92
0.11	0.22	6.00	20.91	6.31	0.14	7.34	6.43	19.32	124.82	175.85	402.26	2971.92
0.11	0.22	6.08	21.02	6.31	0.14	7.33	6.42	19.08	124.17	175.85	402.26	2971.92
0.11	0.22	6.15	21.12	6.31	0.14	7.31	6.40	18.85	123.55	175.85	402.26	2971.92
0.11	0.22	6.23	21.23	6.31	0.13	7.29	6.39	18.62	122.96	175.85	402.26	2971.92
0.11	0.22	6.30	21.32	6.31	0.13	7.28	6.37	18.42	122.42	175.85	402.26	2971.92
0.11	0.22	6.35	21.39	6.31	0.13	7.26	6.36	18.26	122.00	175.85	402.26	2971.92

FIGURE 6.6.



Daily Rainfall and Irrigation 08/Apr/2000 - 15/Sep/2000
Daily Rainfall, Irrigation (mm)
Daily Water Table Depth (m)
6
5
4
3
2
1
0
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
08/Apr/2000
19/May/2000
29/Jun/2000
09/Aug/2000
Date
Rainfall - 3.drr
Irrigation - 3.drr
Water Table Depth - 3.drr

FIGURE 6.7.

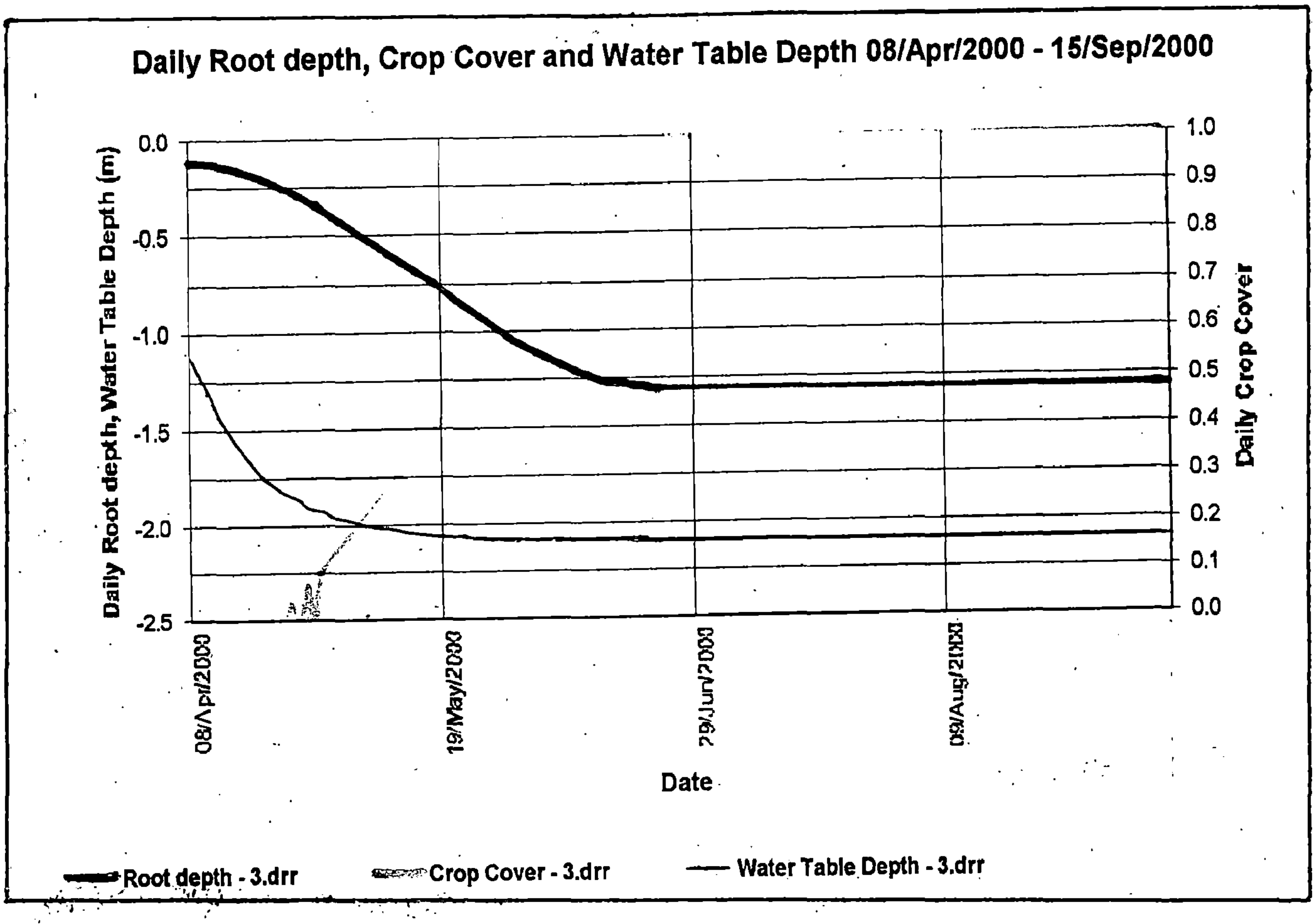
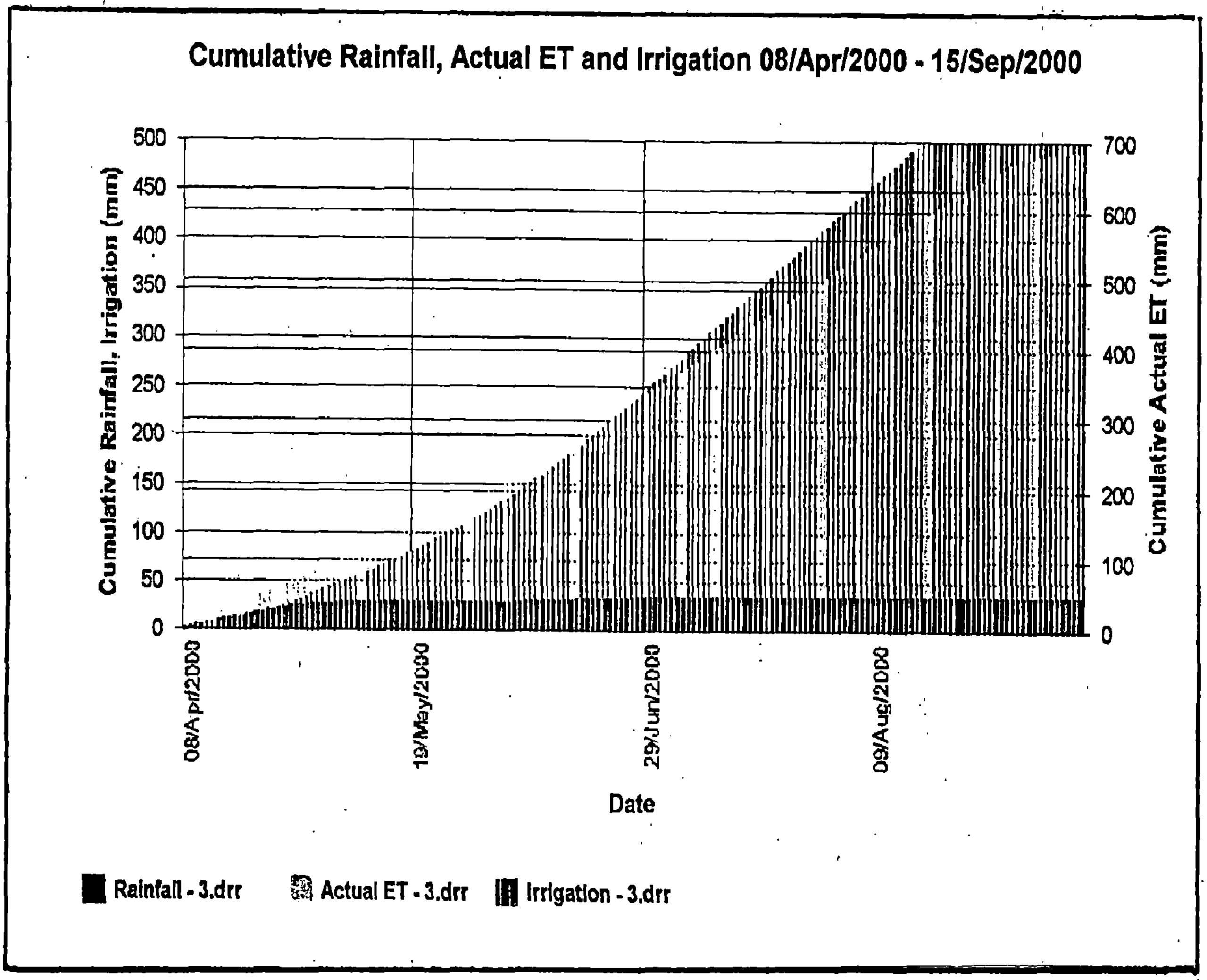

Daily Root depth, Crop Cover and Water Table Depth 08/Apr/2000 - 15/Sep/2000
Daily Root depth, Water Table Depth (m)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
Daily Crop Cover
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
08/Apr/2000
19/May/2000
29/Jun/2000
09/Aug/2000
Date
Root depth - 3.drr
Crop Cover - 3.drr
Water Table Depth - 3.drr

FIGURE 6.8.



Cumulative Rainfall, Actual ET and Irrigation 08/Apr/2000 - 15/Sep/2000
Cumulative Rainfall, Irrigation (mm)
500
450
400
350
300
250
200
150
100
50
0
Cumulative Actual ET (mm)
700
600
500
400
300
200
100
0
08/Apr/2000
19/May/2000
29/Jun/2000
09/Aug/2000
Date
Rainfall - 3.drr
Actual ET - 3.drr
Irrigation - 3.drr