STUDY OF CROPPING PATTERN IN IRRIGATED COMMAND

A DISSERTATION

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

By
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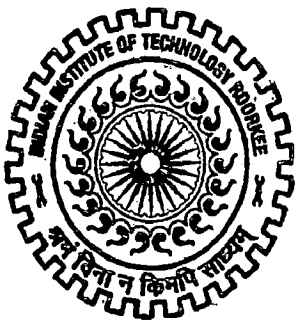

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CANDIDATE'S DECLARATION

I hereby declare that the dissertation titled **"STUDY OF CROPPING PATTERN IN IRRIGATED COMMAND"** which is being submitted in partial fulfillment of the requirement for the award of Degree of **MASTER OF TECHNOLOGY IN IRRIGATION WATER MANAGEMENT** at department of Water Resources Development and Management (WRD&M), Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period of 1-06-2004 to 30-06-2005 under the supervision and guidance of **Dr. Deepak Khare** and **Professor Raj pal Singh,** WRD&M, IIT, Roorkee.

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

Place: Roorkee.
Dated: June, 2005

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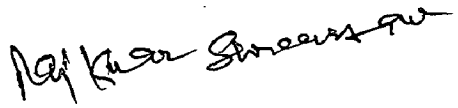

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S.No.	Symbol	Description
1.	I	Month
2.	J	Crop
3.	P_j	Price of crop (Rs. /Quintal)
4.	Y_j	Yield of crop (Quintal /ha)
5.	E_j	Expenditure on cultivation (Rs /ha)
6.	A_j	Area under j^{th} Crop
7.	C_P^C	Equivalent uniform annual capital cost canal (Rs/ ha-m.)
8	C_C	Capacity of canal (ha-m)
9.	C_P	Equivalent uniform annual cost of ground water pumping system (Rs/ ha-m.)
10.	C_G	Capacity of ground water pumping (ha-m.)
11.	C_P^D	Equivalent Uniform Annual Cost of Drainage System (Rs/ ha-m)
12.	C_D	Capacity of Drainage (ha-m.)
13.	C_P^F	Annual capital cost of flood protection system (Rs/ ha-m)
14.	C_P^L	Annual capital cost of land levelling system (Rs/ ha-m.)
15.	T_{IA}	Total irrigated area available for cultivation
16.	C_{OM}	Monthly operation and maintenance cost of canal (rs/ ha-m.)
17.	C_i	Diversion from canal in any month I (Rs. ha-m.)
18.	G_{OM}	Monthly operation and maintenance cost of ground water pumping system (rs/ ha-m.)
19.	G_{ti}	Ground water pumpage through tubewell system for irrigation during ith month (ha-m.)

20	G_{si}	Ground water pumpage through tubewell system directly into drainage system.
21.	D_{OM}	Monthly operation and maintenance cost of drainage system (rs/ ha-m.).
22.	D_i	Drainage diverted in any month (ha-m.)
23	T_{CA}	Total cropped area (Ha)
24.	B_{ij}	Land use coefficient
25.	G_D	Annual ground water draft
26.	AET	Annual evaporation from water table (ha-m.)
27.	NIR	Net irrigation requirements
28.	FIR	Field irrigation requirements
29	GIR	Gross irrigation requirements
30	ETo	Reference crop evapotranspiration (mm/day)
31	ET_{crop}	Crop evapotranspiration (mm/day)
32.	P	Mean Daily Percentage of Total Annual Day Time Hours
33.	W_{ij}	Water requirements of i^{th} crop in j^{th} month
34	Kc	Crop coefficient
35.	C	Adjustment factor which depends on minimum relative humidity, sunshine hours and day time wind estimates
36	D	Depth of water tables (m)
37	R_D	Depth of root zone (m)
38	SW	Surface water
39	GW	Ground water
40	ha	Hectare
41	ha-m	Hectare meter

ABSTRACT

Due to the growing agricultural, industrial & social needs, the optimal utilization of water resources has gained a remarkable importance in the recent years. It is therefore, necessary to maximize the net benefits from the cropping activity in an area by optimal conjunctive use of the surface and ground water. The present study is a small effort in this regard.

A conjunctive use irrigation planning model has been formulated in the present study for the area of Chandok branch canal of Eastern Ganga canal irrigation project. Linear programming technique has been used to maximize the net annual irrigation benefit from surface and ground water. The objective function of the optimal conjunctive use planning model incorporates net benefits from the considered twelve crops, capital costs and operation and maintenance costs of surface water and ground water pumping systems. It is subjected to a set of constraints namely, crop area constraints, crop water requirement constraints, Ground Water Pumping Constraints and constraints for crop management and socio-economic needs.

The effect of variation in the following factors on the objective function has been analyzed.

(i) Cropping pattern

(ii) Ground Water Pumping Draft and

(iii) Surface Water Supply

Sixteen Runs have been taken on computer and on the basis of these, monthly optimal allocation of surface water, ground water and the area under the crops has been arrived at. It is observed that by making conjunctive use of surface and ground water, the net annual benefit may be substantially increased.

INTRODUCTION

1.1 General

Water resources of a country constitute one of its most vital assets. It is a primary input for agriculture, industry and civil life. India being an agricultural country, the rate of food production is indicative of economical development of a country. The potential development of food production depends upon the available water resources. The water resources thus play an important role in healthy and economic growth of a country and , hence their utilization needs to be scientifically planned and managed keeping in view the future demands which are to increase manifold for domestic, irrigation and industrial purposes.

When use of some resources magnifies, it adds new problems and efforts are required to optimize the use of that particular resources. It is in thus context that joint operation and economic use of surface and ground water through coordinated development and economic utilization i.e. conjunctive use becomes essential. This can achieved by planning and management of water on a basin wide scale incorporating assessment of the regions water resources, the knowledge of their quantity, quality, distribution, the degree of fluctuations along with an evaluation of land uses and their effect on stream flow.

1.2 Conjunctive Use

Coordinated and harmonious development of surface and ground water resources for meeting the water requirements, planning water resources development, control and conservation by optimally utilizing the total available water resources is known as conjunctive use.

When surface water and ground water are used conjunctively, various advantages can be obtained viz., the limited water resources are conserved more, with less surface storage, smaller drainage system and smaller surface storage, smaller drainage system and smaller surface distribution system can be adopted.

The conjunctive use is a result of interaction between the surface water and ground water resources and its scope includes.

- Recharge of ground water from natural surface water.
- Artificial and included recharge from surface water to ground water.
- Use of shallow or deep tubewells in canal command areas.
- Use of augmentation tubewells discharging directly into the canal and supplementing the supplies.

Maximum possible benefits can be obtained by planning the modern water resources projects for multipurpose use such as flood damage prevention or reduction, recharging of ground water, irrigation, hydro-electric power generation, domestic and industrial water supply, navigation, conservation and improvement of soil, flow augmentation and water quality control etc.

An essential aspect of conjunctive use planning is Ground Water Modeling. The utilization of ground water for agriculture has attained a lot of importance recently. Ground water has now become an important source of irrigational water because surface water resources in most of the area being fully committed and less surface water diversion schemes are forthcoming. With the linkage of ground water, recirculation of surface water is brought about. On this account, ground water has made a significant contribution in accelerating the agricultural production in India. With the increasing population, in order to increase production in the field of agriculture it has now become important to step up the irrigated agriculture. The conjunctive use planning and management is thus necessary to achieve maximum returns from cropping activities of any areas in addition to the solution of the problems of water logging and water table depletion.

1.3 Systems Approach for Conjunctive Use

The problem of selecting the best alternative, which gives maximum cost benefit ratio, subjected to various constraints including the social and political ones for conjunctive use of surface and ground water can be solved by systems approach. Therefore, the systems approach is being used to solve various problems associated with conjunctive use planning with the advent of computers. Among the extensively used optimization techniques are linear programming is one of the method, which have been used by various research workers for solving the problem of allocating the surface water and ground water resources in optimal manner. Hadley (1962) describe the general linear programming problems as; given a set of 'm' linear inequalities or equalities in 'r' variables, it is aimed to fined non-negative value of these variables

which will maximize or minimize some linear functions of the variables while satisfying the linear constraints.

Linear programming is restrictive as it assumes the objective function and associated constraints to be linear function of decision variables. For non-linear optimization, dynamic programming is used as a optimization technique. Taha (1982) has stated that dynamic programming is a mathematical procedures designed primarily to improve the computational efficiency of solve complex problems by decomposing them into smaller, and hence computations at different stages are linked through recursive computations in a manner that yields a feasible optimal solution to the entire problem when the last stage is reached.

1.4 Objectives of Present Study

The basic objective of the present study is to make optimal conjunctive use of the available surface and ground water resources in the study area, lying in the chnadok branch canal of East Ganga Canal Irrigation System. This is accomplished by maximizing the benefits from irrigation works using surface and ground water conjunctively with the aim to meet the requirements of self-sufficiency in food grains production and to fulfill the socio-economic needs. The overall objectives can be listed as below:

- To study the Chandok branch canal of EGC System
- To study the existing cropping pattern system.
- To formulate the conjunctive use planning models for the study area.
- To workout and suggest an optimum cropping pattern.
- Application of the models of the study area.
- Analysis of the results to obtain optimal cropping pattern and allocation plan of surface water and groundwater.

1.5 Outline of the Thesis

The subsequent chapter of the thesis has been organized as follows:

Chapter 2 deals with review of literature on conjunctive use planning model.

Chapter 3 gives the brief description about the East Ganga canal Irrigation project area. The details of data, which is collected and used for the preparation of objective function and constraints, are included in this chapter.

Chapter 4 deals with the formulation of conjunctive use irrigation planning model to derive at the optimal cropping pattern for the study area.

Chapter 5 deals with analysis and discussion on results obtained after sixteen computers runs. This gives the systematic procedure to get the maximum net benefit of the cropping pattern adopted.

Chapter 6 briefly presents the conclusions based on the analysis for the study area and scope for further study.

REVIEW OF LITERATURE

2.1 General

The optimal cropping pattern study requires determination of area under various crops along with the monthly optimal releases of the surface and ground water. For this optimization techniques like linear programming (LP) and dynamic programming (DP) etc. are usually to derive the optimal polices for the allocation of surface and ground water.

2.2 Review of Literature

This section focuses on some of the important previous studies on conjunctive use planning models are briefly reviewed chronologically.

Nathan Buras (1963) made use of dynamic programming model for the utilization of aquifers in conjunction with surface reservoirs. A system consisting of a dam An aquifer was analyzed from the point of view of its optimal operation. For the given hydrological data the following three problems were solved:

(a) The determination of design criteria for the dam and for the ground water recharges facilities.

(b) The determination of the extent of the areas to be serviced by the system and

(c) The establishment of an operating policy that specifies the drafts from the reservoir and pumpages from the aquifer.

Roger and smith (1970) formulated a linear programming model to aid in the planning of irrigation projects. The model presents the interactions of a surface water and ground water system within the economic context of irrigation management. It selects the canal, tubewells and surface drainage capacities, the project size and the cropping pattern.

The system is subjected to certain constraints on continuity of the river flow, capacity of canals, tubewells and drainage channels, mining of ground water, crop water requirements, and availability of land of different soil types, along with the

inclusion of surface reservoirs, recharge facilities, water quality considerations and salinity intrusion.

Young and Bredehoeft (1972) have presented a **simulation model** to aid in the solution of the river basins where aquifers are intimately associated with streams and unrestricted development of ground water can reduce stream flows. The model is composed of a hydrologic model that represents the response of the stream aquifer system to changes in river flows, diversions and pumping and treats stream flow as a stochastic input. The model is also composed of an economic model that represents the response of irrigation water users to variations in water supply and cost. All theses indices were incorporated into a decision framework to assess the net income of the water resources system considering alternative management schemes.

Lakshminarayana and Rajagopalan (1977) have applied a **linear programming model** to Bari Doab in Punjab for a set of deterministic input data that gives water releases from two sources, canals and tubewells to meet crop requirements and also giving optimal allocation of irrigated land to different crops so as to maximize returns from irrigation activity subject to a set of constraints.

Duckstein and Terrance (1978) have used a control model of the salinity and water-logging in the shepparten-kerrang area of Murray river in Australia. This conjunctive use control scheme represents an element of the general salinity problem with the aim to find a control policy, which minimizes the sum of pumping costs and crop losses due to salinity and water logging.

Sinha and Charyulu_ (1980) formulated a **linear programming model** considering the existing irrigation system of Gomti Kalyani Doab to determine the optimal cropping pattern by allocating the cultivated areas to the various crops and maximizing the net benefits from the conjunctive use of surface water and ground water resources.

Kashyap and Chandra (1982) have developed a non **linear programming model** for arriving at an optimal conjunctive use policy incorporating the spatially and temporally distributed ground water withdrawals for a given pattern of surface water availability and spatially distributed cropping pattern. The model has been used for the study of Daha areas of India. The monthly ground water withdrawals and areas under seven feasible crops were determined and the objective function representing the net benefits from agricultural activity was maximized subject to 36 constraints.

Rakesh kumar (1992) developed conjunctive use irrigation planning model for the area between Eastern Yamuna canal and Yamuna river. **Linear Programming Techniques** were used to maximize the net annual irrigation benefit from surface and ground water. The objective function of the net benefits from the considered fifteen crops was subjected to a set of constraints to arrive at the optimum cropping pattern of the region under consideration.

Wills, Finnay et al., (1992) presented a non-linear **conjunctive use model** in which he considered the production cost including the distribution cost of river water. The cost of ground water considered as non-linear because the lift is dependent on the withdrawls. In this study, net benefits from the production of three crops were maximized.

Matsukawa, Finnay et.al., (1992) developed **conjunctive use model,** which incorporates the hydraulics of surface water and ground water system, water supply, hydropower and ground water cost and objectives function of maximizing benefit. Constraints of the planning model included hydropower production limits, water grading constraints on the combined surface and ground water.

Maurya (1997), attempt a groundwater model to study the ground water fluctuation for Omkareshwar area. The model was based on Integrated Finite Difference Model of Tyson & Weber (1964) It also [present the Cost Economics of groundwater resources for the study area.

Ehsanolah Malek-Mohammadi (1998), carried out a work for developing irrigation system. In this work, surface reservoir capacity, groundwater and spring withdrawal, delivery system capacities (including canals, pumping stations and tunnels), hectares of land to be developed for irrigation and cropping pattern are considered as interacting parts of the system besides cost due to drainage, land leveling and irrigation network construction. The system is optimized by means of a chance constraint optimization model. The model uses mixed integer linear programming to maximize the net benefit associated with the development. Results generated by the application of the model, along with the sensitivity analysis, provide a tool to select the optimum design considering the varieties of criteria involved

Getachew Belaineh et.al., (1998) present a **simulation/optimization model** that integrates linear reservoir decision rules, detailed simulations of stream/aquifer system flows, conjunctive use of surface and groundwater, and delivery via branch canals to water users. State variables, including aquifer hydraulic head stream flow

and surface water/aquifer interflow, are represented through discredited convolution integrals and influence coefficients. Results of application to a hypothetical study area under several scenarios indicate that the more details used to represent the physical system, the better the conjunctive management.

Pamela G. Emch and William W-G. Yeh (1998) developed a model for managing water use within a coastal region. Two conflicting objectives are considered: cost effective allocation of surface water and groundwater supplies and minimization of salt-water intrusion. Optimal control of the system is examined by studying the response of these objectives to changes in groundwater pumping rates and transfer of surface water between sources and users. The objectives, some of the constraints and the groundwater flow equations are formulated as non-linear functions of the decision variables. The flow model simulates the flow of the groundwater using quasi three-dimensional finite difference model based on the sharp interface assumption. The multi objective aspect of the problem is solved using constraint method.

Tracy Nishikawa (1998) has developed a **simulation-optimization model** for optimal management of the city of Santa Barbara's water resources during a drought. The model which, link s groundwater simulation with linear programming, has a planning horizon of 5 years. The objective is to minimize the cost of water supply subject to: water demand constraints, hydraulic head constraints to control sea water intrusion, and water capacity constraints. The decision variables are monthly water deliveries from surface water and groundwater. The drought of 1947-51 is the city's worst drought on record, and simulated surface water supplies for this period were used as a basis for testing optimal management of current water resources under drought conditions. This simulation- optimization model. was applied using three reservoir operation rules. In addition, the model's sensitivity to demand, carryover [the storage of water in one year for use in a later year(s)], head constraints, and capacity was tested.

2.3 Concluding Remarks

The literature review reveals that in conjunctive use model, system approach and its frame works of mathematical models have been widely used by various investigators.

The Dynamic Programming was applied for conjunctive use in the early stages (Buras, 1963: Burt, 1964; Aron, 1969), but the unsuitable of this approach is related to the regional analysis, because of dimensionality problem resulting from the large number of state variables associated with groundwater modeling.

Simulation models have given solution to these problems by incorporating full scale distributed parameters, but it only always the comparison of direct maximization or minimization of a particular objective. An array of feasible solution is obtained by this technique, from which a near optimal solution is identified.

The model based on Non-Linear Programming by Wills et. al (1989) allows the most general formulation, but computer requirement and the convergence rate of the algorithm are major obstacles in the solution of large scale practical problems.

Linear Programming (LP) models used by many investigators have given satisfactory solution of conjunctive use planning problems. However, they have a limitation of linearising the objective function and constraint. The Linear Programming model proposed by Roger and Smith (1970) used by many subsequent investigators viz,. Khare (1994) seems to have an edge over other LP formulations considering the derived result.

The mathematical models of different varieties are available which can solve complex problem involving complexity and extensive data requirements; however these models are still unknown to the practicing engineers and planner, particularly in developing countries. It is not always certain that the result obtained from sophisticated and expensive models would much better then those obtained from less detailed models related to conjunctive use. By considering above discussion, attempt has been made to study conjunctive use management by using Linear Programming model for allocation policies, and study possibilities of different cropping pattern in the study area.

THE STUDY AREA AND DATA ACQUISITION

3.1 General

The area selected for optimal cropping pattern chandok branch of Eatern Ganga Canal that includes seven distributaries; Sabalgarh Dy, Mabndawali Dy, Raipur khas Dy, Nagal Dy, Mandawar Dy, Maheswary Dy. Chandok Branch takes off from main canal of the Eastern Ganga Canal System at ch. 0+30.775km.

3.2 Historical Background

The EGC system (Fig. 3.1) commissioned as far back as has its origin from the mythological river Ganga. This system comprises of 6142.82 km main and Branch canals 155.17 km and watercourses 1489.00 km and 1.05 lacs hect. Of culturable area, the total length of canal is 54.2 km from head to 0.5 km and from 2 km to tail the section of main canal would be lined,.From 0.5 km to 2 km the alignment passes through hilly terrain and consists twin RCC barrels. The capacity of the canal at head will 164.3 cumecs (5800 cusecs) out of which about 27 cumecs (950 cusecs) is before operating the silt ejector located at 0.4 km of canal and the remaining is for utilization in the proposed commanded for rice irrigation. from June to September. The distributaries are to offtake from the main canal to irrigate some smaller doabs.

(a) Chandok Branch pt of offtake 32.6 km of main canal

(b) Najibabad Branch pt of offtake 44.6 km of main canal

(c) Nehtaur Branch pt of offtake 46.6 km of main canal

(d) Nagina Branch pt of offtake 54.2 km of main canal

The gross command area of Eastern Ganga Canal works out to 7,44,456 acres and the culturable commanded area 5,73,891 acres. The proposed area for rice irrigation at the rate of 45% of CCA workout to 2,58,251 acres.

For the present study Chandok branch of the EGC is considered.Chandok branch and its distribution system shall irrigate the Ganga–Malin doab. Gross command area and culturable area for this doab is 1,14,156 and 95632 acres respectively. The rice area to be irrigate in this doab is 43034 acres. The length of channels including branch, distributories and minors would be nearly 280 km. The

head discharge of chandok branch is 22.4 cumecs (790 cusecs). It has been worked out an outlay factor of 55 at head of the branch canal.

3.3 Location

The head works of the proposed scheme is located in district Bijnor of Uttar Pradesh. The main canal with a head discharge of 5800 Cusecs would take off from the left bank of River Ganga Canal lies almost entirely in district Bijnor and partly in Moradabad district.

3.3 Topography of the command

The command area of the system is not undulating except in small pockets here and there land shaping done farmers own labour and bullocks. The proposed command area of the Eastern Ganga Canal lying almost in District Bijnor is already under cultivation and habituated. The monsoon surplus of river Ganga from June to September shall be diverted to this canal for utilization in the proposed command of the project. The main canal would pass through hilly terrain from km 0.5+2.0 and sufficient space is not available between the toe of hill and the Ganga River Khadir in this reach for construction an open channel.

3.4 Climate

The climate of the command of Eastern Ganga Canal system is tropical monsoon climate. It is characterized by general wetness of the air. These are three district seasons in the area. Hot summer from March to the middle of June and the wet monsoon from May to June to the end of October follow the winter season from November to the end of February.

Temperature in the project area remains high (35^0c) during the dry months of May and June 80% annual rainfall occurs in the months of June, July and August. The rainfall data of study area is 1000mm. The average annual rainfall during the month of June to October is about 850mm. Temperature and humidity is high through the year. The mean maximum monthly temperature ranges 31.14^0c and the mean minimum monthly temperature ranges from 7.02^0c to 12.03^0c. The mean monthly relative humidity ranges from ৬৪% to ৭২%. The details of data are given in Table ৪.2.

The rain gauge area established in nearly the command is at Roorkee and Muzaffaernagar, where the daily observation of rainfall and other

climatically data are taken. The monthly abstract for eighteen years (i.e. 1986-2004) of one rain gauge station suited at Roorkee WRD&M (vicinity of the command area) is furnished in Table 4.3 other climatically parameters such as Temperature, humidity, wind velocity, sunshine hours, number of rainy in a month along with month mean rainfall for the WRD&M Roorkee station in furnished month wise.

3.5 Ground Water Table

The depth of ground water table in the month of Oct. and Nov. are very deep in the areas Nagal, Bijnor and Kiratpur ranging from about 7.6m to 17.4m They are especially very deep in the area around Nagal where they range 17 to 18m. In the area around Nagina, Chandpur and Mandawali ground water table vary from about 3.8m to 6.42m.

3.6 Soil

The soil in the command of EGC is generally light loamy soil except in the northern areas of the Malin chhoya, chhoyan-ban, Ban-Gangan and Gangan kho doabs falling in najibabad, Kiratpur and Kotwali blocks. The loamy soil is most of the command and very suitable for rice cultivation. The road borrows pit show that the soil is generally sandy loam. In some reaches it is mixed with clay also. The soil in the rest of the reach of the main canal from 29km to tail generally consists of light (loam soil) or Domat.

3.7 Rainfall

The rainfall pattern of the command the perusal of which would indicate that annual rainfall in the area proposed to be commanded by the project varies from 850 mm to 1000mm. The rainfall is however unevenly distributed during the rainy season the spells of dry weather are encountered.

3.8 Hydrology

River Ganga has two tributaries Bhagirathi and Alakhnanda, which combine together at dewprayag to form gangariver. Ganga has its sources in the Himalayan glaciers and in this a snow fed river. There is a Ganga site on river ganga at Raiwala at about 8 km upstream of Bhimgoda weir where Ganges are observed and are connected to the corresponding discharges observed at Bhimgoda weir. No major

stream joins river Ganga between Raiwala and Bhimgoda and discharge can be taken as equal.

3.9 Present Situation of Project

The present situation of the cropping pattern of chandok branch canal of EGC command is described in this section. The cropping patterns and land occupation intensities are shown in table;

S.N.	Name of the crops	With project % area	Without project % area
1.	Rice	24.87	25.73
2.	Wheat	34.82	11.44
3.	Maize	2.24	2.86
4.	Barley	1.74	2.86
5.	Jwar	17.9	8.58
6.	Gram	4.97	11.44
7.	Pea	1.99	10.86
8.	Groundnut	4.93	11.44
9.	Potato	0.59	5.15
10.	Berseem	0.27	0.51
11.	Bajra	2.68	0.57
12.	sugarcane	16.31	8.58

This project is established for only the rice crop. The cropping pattern shows that area under rice crop is only 24.87% of total CCA. Farmers are more moves towards the sugarcane. Due to various reason listed below farmers are not growing rice;

- It requires more water throughout the period.
- Uncertainty of water distribution among the farmers.
- Only head reach farmers can get the water in time.
- A particular type of top level fields is needed where water can be stagnated to equal depth.
- There is acute shortage of labour at the time of sowing, weeding, puddlig and

harvesting of crops. This may be the major reason for not coming up for rice crop in this command.

- The net benefit of sugarcane is more than rice, wheat, so farmers are more growing sugarcane being cash crop.
- Due to shortage to cold storage facility farmers are not growing potato crops.
- Lackness of knowledge about fertilizers, weedcites, pesticides dose, depth of water use in crops.
- The agriculture extension service is ineffective in this region.

Salient feature of EGC system

S.N.	ITEM	PROJECT PROPOSALS
1.	Source of Supply	: RIVER GANGA
2.	Location of Head Works	:Left bank of Existing Bhimgoda Barrage across River Ganga at Haridwar
3.	Command of the project	District Bijnore,Haridwar and Jyotiba Fule Nagar, Bounded between Ganga on west, River Khoh on South and Ram Ganga feeder Channel on south
4.	Gross Command Area	: 3.01 Lac. Hect
5.	Cultural Command Area	: 2.33 Lac. Hect
6.	Proposed Rice Irrigation	: 45% of C.C.A.
7.	Proposed area of Rice	: 1.05 Lac. Hect
8.	Peak Water requirement	: 137.4 Cumecs
9.	Total Peak requirement including	: 164.3 Cumecs Silt Ejector requirements
10.	Head works	: 3*18 meter wide sluice bays.
11.	Pond level	: 293.70 m max. ; 290.20m min
12.	**MAIN CANAL**	
	(a) Head regulator	: 4 bays of 11.0 meter wide each with three 2 meter thick piers.
	(b) Head discharge	: 164.30 Cumecs Including silt ejector

(c) Length	:	48.55 Km
Lining		
Boulder lining & Tile lining	:	32.50 Km
Tunnel, Cut & Cover	:	1.005 Km
Unlined		15 Km
(d) Land		
Total permanent land	:	503 Hect
Forest Land	:	327 Hect
Cultivated Land	:	176 Hect
13. **BRANCHES**		
(a) No. of Branches	:	5
(b) Total Length	:	155.17 Km
(c) Total permanent Land	:	984.00 Hect
Forest Land	:	15 Hect
Cultivated Land	:	969 Hect
14. **DISTRIBUTION SYSTEM**		
(a) Total length	:	489Hect
(b) Total permanent land	:	3114 Hect
15. **DRAIN**		
(a) Total length	:	432 Km
(b) Cost	:	Rs 1603.80 Lacs
16. **WATER COURSES**		
(a) Total length	:	4450 Km
(b) Cost	:	4263.90 Lac
17. Cost of project at 7/04 price level	:	751 52 Crore
18. Cost of project per Hect. of irrigation	:	Rs 71573.00
19. **AGRICULTURAL PRODUCTION**		
(a) Additional Yield in Rice	:	1730 Lac Qtl
(b) Additional Yield in sugarcane	:	185.7 Lac Qtl
(c) Cost of additional production	:	25652.00 Crores
20. BENEFIT COST RATIO	:	1.65 : 1
21. YEAR OF COMPLETION	:	2006 - 2007

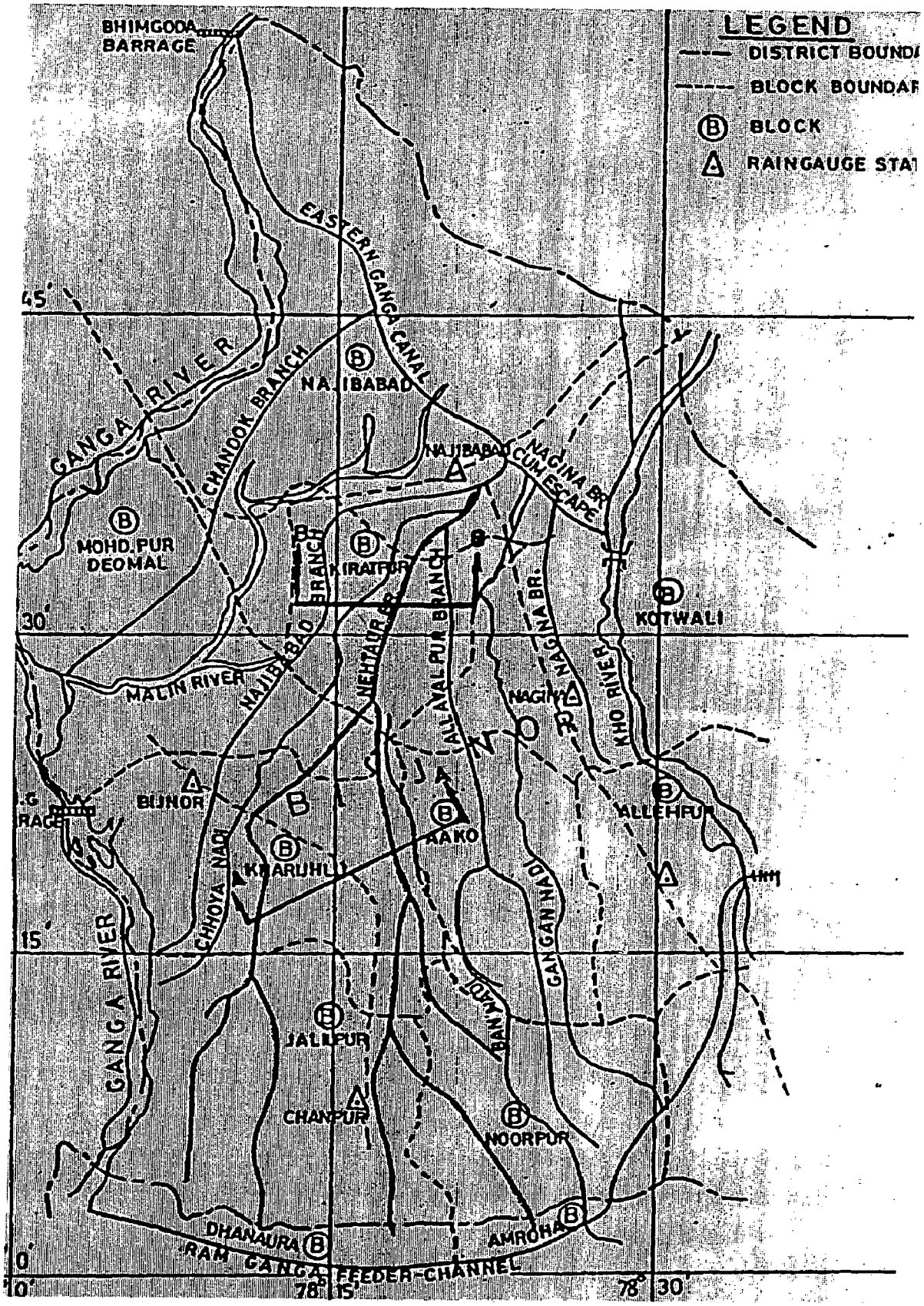


Fig 3.1 Eastern Ganga Canal System

COJUNCTIVE USE IRRIGATION PLANNING MODEL

4.1 General

In this chapter, a conjunctive use irrigation planning model has been formulated for maximizing the net benefits i.e. profit from irrigation works after accounting for annual equivalent uniform capital costs and monthly operation and maintenance costs of canal water supply system, ground water pumpage system and drainage system. The model also incorporates the investments on land leveling and flood protection works.

4.2 Objective Function

The general form of objective function can be expressed as below,

Maximum net benefit =

Benefit from irrigation works	—	Capital cost of irrigation works	—	Operation and maintenance cost of irrigation works

Maximum Net benefit =

$$\sum_{j=1}^{I}(P_j Y_j - E_j)A_J - [C_P^C C_C + C_P^G C_G + C_P^D C_D + (C_P^F + C_P^{L)})T_{IA} + \sum_{i=1}^{J}[C_{OM} C_i + G_{OM}(G_{ti} + G_{S)})D_{OM} D_i] \quad \text{--- 4.1}$$

Where

j = crop

P_j = Price of j^{th} crop (Rs. /Quintal)

Y_j = Yield ofj^{th} crop (Quintal /Hectare)

E_j = Expenditure on cultivation of j^{th} crop (Rs /Hectare)

A_j = Area under jth crop

C_P^C = Equivalent uniform annual capital cost canal (Rs/ha.m.)

C_C = Capacity of canal (ha.m.)

C_P^G = Equivalent uniform annual cost of ground water pumping system (Rs/ ha.m.)

C_G = Capacity of ground water pumping system (ha.m.)

C_P^D = Equivalent uniform annual cost of drainage system (Rs/ ha.m.)

C_D = Capacity of drainage (ha.m.)

C_P^F = Annual Capital cost of flood protection system (Rs/ ha.m.)

C_P^L = Annual Capital cost of land levelling system (Rs/ ha.m.)

T_{IA} = Total irrigated area available for cultivation

C_{OM} = Monthly operation and maintenance cost of canal (Rs/ ha.m.)

C_i = Diversion from canals in any month i (Rs. ha.m.)

i = Month

G_{OM} = Monthly operation and maintenance cost of ground water pumping system (Rs/ ha.m.)

G_{ti} = Ground water pumpage through tubewell system for irrigation during i^{th} month (ha.m..)

G_{si} = Ground water pumpage through tubewell system directly into drainage system.

D_{OM} = Monthly operation and maintenance cost of drainage system (Rs/ ha.m.).

D_i = Drainage diverted in any month (ha.m.)

The equation 4.1 is general from of the objective function. However for the present study the objective function is as follows:

$$\text{Max. (Net. benefit)} = \sum_{j=1}^{J} (P_j Y_j - E_j) A_j - [(C_P^C C_C + C_G C_P^G + \sum_{j=1}^{I} (C_{OM} C_i + G_{OM} G_{ti})] \quad \text{--- 4.2}$$

4.3 Constraints

The objective function is subject to the following constraints.

4.3.1 Crop area constraints

Sum of area under various crops in a month cannot exceed the total irrigated area, available for cultivation, i.e.

$$\sum_{j=1}^{J} B_{ij} A_j \leq T_{IA} \quad \text{----------4.3}$$

Where,

B_{ij} =Land use coefficient for j^{th} crop in ith month

T_{IA} = Total irrigated area available for cultivation.

4.3.2 Crop water requirements constraints

Water requirements of various crops are met in each month and they cannot exceed the monthly surface and ground water diversions.

$$\sum_{j=1}^{J} A_j W_{ij} \leq (C_i + G_{ti})$$

$$\text{or,} \quad (\sum A_j W_{ij}) - C_i - G_{ti} \leq 0 \qquad \text{---------} \qquad 4.4$$

Where,

W_{ij} =water requirement for j^{th} crop in i^{th} month.

4.3.3 Ground water pumping constraints

Ground water pumped in a year should not exceed the annual ground water draft.

$$\sum_{i=1}^{I} G_{ti} <= G_D \qquad \text{---------} \qquad 4.5$$

Where,

G_D = Annual ground water draft.

4.3.4 Constraint for crop management and socio-economic needs

$$A_j > p'.T_{IA} \qquad \text{----------} \qquad 4.6$$

Where,

p'= percentage of total irrigated area allotted to j^{th} crop.

4.4 Formulation of the conjunctive use model

This section deals with various calculation of objective function and constraints of the area under study. For the smooth fitting of the model, few assumptions are made which are described in subsequent paragraph.

4.4.1 Assumptions

The following assumptions have been made in the study :

(i) The canal water supply is available for the five months.

(ii) Adequate power and diesel will be available for running the pumps at required capacity and time.

(iii) There exists adequate natural drainage in the area and there are no expenditures on drainage provisions.

(iv) There are no investments on land leveling and flood protection works in the Study area.

(v) The area is free from water logging, water salinity and leaching problems.

(vi) There is no ground water pumpage through tubewells directly into drainage system.

(vii) The yield of the crops included in the study has been assumed as fixed on the basis of sample survey of the study area and the information are available from land record office, Bijnor.

4.4.2 Data input

The present section describes the data input to the model (described in section 4.2 and 4.3)The list of variables, namely crops variables (X_1, X_2, X_3----------X12), monthly surface water diversion variables (X_{13} ,X_{14} ,X_{15} ----------X_{24}), monthly ground water with drawl variables (X_{25}, X_{26}, X_{27}----------X_{36}) has been given in Appendix 1.

4.4.2.1 Benefit from irrigation works

For calculation of benefits from irrigation works 12 crops have been selected on the basis of the statistics of crops grown in the study area. Optimal inputs of fertilizers and water use for high yielding varieties of crop as well as the expenditures on weedicides, insecticides and pesticides, plant protection, nursery preparation (where applicable), irrigation charges, land revenue, capital charges of implements and machinery (including depreciation and interest on capital), tractor ploughing, expenditures on harvesting and threshing have been taken into account. Benefits from bye-product of the crops (where applicable) have also been considered. The detailed calculation of net annual benefits from irrigation works are given in table 4.1. the values assumed in this table are reasonable and realistic since these are based on field survey and information available from land record office,Bijnor. Benefits for the selected crops listed in Table-4.1 have been introduced in the objective Function of the model, Eq (1) chapter - 4 and the resulting expression is given in Appendix-2.

4.4.2.2 Capital and o&m costs of irrigation works

As per the EGC system the total capital cost of chadok branch canal would be 125000 MRs so the Annual capital cost required to work out the unit cost can be computed using the following formulae.

$$\text{Annual capital cost, } A = \frac{C\,(1+i)^n}{(1+i)-1} \qquad \text{----------} \qquad 4.7$$

Where,

A = Annual capital cost (Rs.)

C = Total capital cost (Rs.)

i = rate of interest (%)

n = Useful life (Years)

So, the annual capital cost with 10% rate of interest and 25 Years as useful life to be, A = 1373.13 lakhs.

With 130 days of canal operation in a year,

the volume of water = 24867.64 ha-m.

∴ Unit cost = 5522.15 Rs/ ha-m.

Adding 1% as O/M cost

Total unit cost = 6074.34 Rs/ ha-m.

4.4.2.2 Capital & O&M cost of ground water

For the same study area a relationship was established for obtaining the unit cost of ground water system in terms of depth to water table as under. (Khare ,1994)

Considering capital costs alone

$$CFC = 50.21 * d_w + 11.34.57 \quad \text{----------} \quad 4.8$$

Considering O & M costs alone

$$CFO = 116.79 * d_w + 428.91 \quad \text{----------} \quad 4.9$$

Considering capital costs alone

$$CFT = 167.00 * d_w + 1563.48 \quad \text{----------} \quad 4.10$$

Where, d_w is the depth to water table (m).

CFC is Capital cost function

CFO is O & M cost function

CFT is Total cost function

4.4.2.4 Constraints

The details of the input data for the various constraints are as follows:

4.4.2.4.1 Crop area constraint

The crop area constraint is given by Eq. 4.3. The crop calendar based on the existing practice of crop cultivation in the study area has been adopted on the basis of the sample survey of the area and as per information available from EGC system S.D.O office Bijnor. The details of the crop area constraint equation are given in Appendix – 3 (A).

Net Annual benefits for various crops (Rs. Hectare) Sheet – 1

S.N.	Description	Unit	Rate per unit (Rs)	1. Berseem		2. Pea		3.Potato	
				No of units	Cost	No of units	Cost	No of units	Cost
(A)	EXPENSE								
1	Human Labour	Day	100.00	20.00	2000.00	5.00	500.00	100.00	10000.00
2	Tractor charge (ploughing)	Ha	1000.00	2.00	2000.00	4.00	4000.00	6.00	6000.00
3	Seeds	kg		35*25	875.00	90*40.0	3690	15*2000	30000
4	Insecticites/pesticites	L.s.							
5	Fertilizers								
	(a) D.A.P.	kg	10.00	45.00	450.00	40.00	400.00	150.00	1500.00
	(b) N.P.K.	kg	8.00	45.00	360.00	45.00	360.00		
	(C) Seperphosphate	kg	5.00					80.00	400.00
	(d) Muriate of Potash	kg	5.00						
	(e)Urea	kg	6.00	20.00	120.00	20.00	120.00	80.00	480.00
6	Plant protection	L.s.							
7	Nursary Protection	L.s.							
8	Irrigation charges (canal/Tubewell)	L.s.			125	150			
9	Land Revenue	L.s.				100			60.00
10	Capital charge of implements $machinery (including depreciation $ interest on capital)	L.s.			120	120			
11	Harvesting $ Threshing								
	(a) Human labour	day	100.00	20.00	2000	15.00	1500.00	60.00	6000.00
	(b)Bullock labour	day	250.00						
	(C) Tractor charge	Ha	1100.00			1.00	1100.00		
12	Interest @ 12% on items 1 to 7 for crop period				406.35		634.90		3386.60
13	Transportation Charges				4000.00		1100.00		6000.00
14	Total Expanses (Rs)				12456.35		13404.90		63826.60
(B)	**BENEFITS**								
1	Yield of main product (quintals)			550.00		17.00		350.00	
2	Price per quintals of main products				50.00		1500.00		300.00
3	Value of yield of main product (Rs)				27500		25500		105000
4	Yield of bye products(quintal)								
5	Price per quintal of bye products								
6	Value of Yield of bye products(Rs)								
7	Total Benefits (Rs)				27500		25500		105000
8	Net Benefits(Rs)				15043.65		12095.10		41173.40

Net Annual benefits for various crops (Rs. Hectare) Sheet – 2

S.N.	Description	Unit	Rate per unit (Rs)	4. Rice		5. Bajara		6. Groundnut	
				No of units	Cost	No of units	Cost	No of units	Cost
(A)	EXPENSE								
1	Human Labour	Day	100.00	15.00	1500	4.00	400	15.00	1500
2	Tractor charge (ploughing)	Ha	1000.00	5.00	5000	4.00	4000	3.00	3000
3	Seeds	kg		7.5*100	750	20*20.0	400	35.0*120	4200
4	Insecticites/pesticites	L.s.			500				
5	Fertilizers								
	(a) D.A.P.	kg	10.00	50.00	500	30.00	300	100.00	1000
	(b) N.P.K.	kg	8.00						
	(C) Seperphosphate	kg	5.00	50.00	250				
	(d) Muriate of Potash	kg	5.00			30.00	150		
	(e)Urea	kg	6.00	100.00	600	50.00	300	70.00	420
6	Plant protection	L.s.							
7	Nursary Protection	L.s.							
8	Irrigation charges (canal/Tubewell)	L.s.			250		250.00		400.00
9	Land Revenue	L.s.			150		150.00		200.00.
10	Capital charge of implements $machinery (including depreciation $ interest on capital)	L.s.			150		120.00		100.00
11	Harvesting $ Threshing								
	(a) Human labour	day	100.00	5.00	500.00	15.00	1500.00	4.00	400
	(b)Bullock labour	day	250.00			6.00	1500.00		
	(C) Tractor charge	Ha	1100.00	2.00	2200.00				
12	Interest @ 12% on items 1 to 7 for crop period				637.00		388.50		708.40
13	Transportation Charges				360.00		360.00		350.00
14	Total Expanses (Rs)				13347.00		9818.50		12078.40
(B)	**BENEFITS**								
1	Yield of main product(quintals)			45.00		30.00	30.00	40.00	
2	Price per quintals of main products				600.00		750.00		700.00
3	Value of yield of main product (Rs)				27000		22500		28000
4	Yield of bye products(quintal)			120.00		70.00	70.00	60.00	—
5	Price per quintal of bye products				25.00		24.00		15.00
6	Value of Yield of bye products(Rs)				3000		1680.00		
7	Total Benefits (Rs)				30000		24180		28000
8	Net Benefits(Rs)				16653.00		14361.50		15921.60

Net Annual benefits for various crops (Rs. Hectare) Sheet – 3

S.N.	Description	Unit	Rate per unit (Rs)	7. Wheat		8. Sugarcane		9. Maize	
				No of units	Cost	No of units	Cost	No of units	Cost
(A)	EXPENSE								
1	Human Labour	Day	100.00	5.00	500.00	25.00	2500.00	5.00	500.00
2	Tractor charge(ploughing)	Ha	1000.00	2.00	2000.00	4.00	4000.00	5.00	5000.00
3	Seeds	kg		11*110	1210.00	0.7*6000	4200.00	40*18.0	720.00
4	Insecticites/pesticites	L.s.			1000.00		2000.00.		500.00
5	Fertilizers								
	(a) D.A.P.	kg	10.00	125.00	1250.00	200.00	2000.00	50.00	500.00
	(b) N.P.K.	kg	8.00						
	(C) Seperphosphate	kg	5.00						
	(d) Muriate of Potash	kg	5.00	100.00	500.00	100.00	500.00	30.00	150.00
	(e)Urea	kg	6.00	125.00	750.00	200.00	1200.00	40.00	240.00
6	Plant protection	L.s.							
7	Nursary Protection	L.s.							
8	Irrigation charges (canal/Tubewell)	L.s.		750.00	750.00		1500.00		600.00
9	Land Revenue	L.s.		250.00	250.00		250.00		150..00
10	Capital charge of implements $machinery (including depreciation $ interest on capital)	L.s.		200.00	200.00		200.00		150.00
11	Harvesting $ Threshing								
	(a) Human labour	day	100.00	20.00	2000.00	150.00	6500.00	70.00	7000.00
	(b)Bullock labour	day	250.00						
	(C) Tractor charge	Ha	1100.00	1.00	1100.00				
12	Interest @ 12% on items 1 to 7 for crop period				504.70	37.03	1008.00		532.70
13	Transportation Charges				1000.00		8000.00		600.00
14	Total Expanses (Rs)				13014.70		31858.00		16492.70
(B)	**BENEFITS**								
1	Yield of main product(quintals)			50.00		1000.00		70.00	
2	Price per quintals of main products				500.00		130.00		360.00
3	Value of yield of main product (Rs)				25000		130000		25200
4	Yield of bye products(quintal)			220.00		300.00		150.00	
5	Price per quintal of bye products				20.00		20.00		15.00
6	Value of Yield of bye products(Rs)				4400		6000		2250
7	Total Benefits (Rs)				29400		136000		27450
8	Net Benefits(Rs)				16385.30		104142.00		10957.30

Net Annual benefits for various crops (Rs. Hectare) Sheet – 4

S.N.	Description	Unit	Rate per unit (Rs)	10. Barley		11. Gram		12. Jowar	
				No of units	Cost	No of units	Cost	No of units	Cost
(A)	EXPENSE								
1	Human Labour	Day	100.00	5.0	500	5.0	500	5.00	500.00
2	Tractor charge (ploughing)	Ha	1000.00	4.0	4000	3.0	3000	5.00	5000.00
3	Seeds	kg		25*55	1375	35*4.5	135	9*110	990.00
4	Insecticites/pesticites	L.s.							
5	Fertilizers								
	(a) D.A.P.	kg	10.00	80	800	100.0	1000	125.00	1250.00
	(b) N.P.K.	kg	8.00						
	(C) Seperphosphate	kg	5.00						
	(d) Potash	kg	5.00					100.00	500.00
	(e)Urea	kg	6.00	40	240	50.0	300	125.00	750.00
6	Plant protection	L.s.							
7	Nursary Protection	L.s.							
8	Irrigation charges (canal/Tubewell)	L.s.		100	100	500.0	750.0	750.00	750.00
9	Land Revenue	L.s.		250	250	250.0	250.0	250.00	250.00
10	Capital charge of implements $machinery (including depreciation $ interest on capital)	L.s.		200	200	200.0	200.0	200.00	200.00
11	Harvesting $ Threshing								
	(a) Human labour	day	100.00	25	2500	25.0	2500	20.00	2000.00
	(b)Bullock labour	day	250.00						
	(C) Tractor charge	Ha	1100.00	0.5	550	0.5	1500	0.50	550.00
12	Interest @ 12% on items 1 to 7 for crop period				484.05		345.45		629.30
13	Transportation Charges				500.00		1000.00		500.00
14	Total Expanses (Rs)				11499.05		11480.45		13869.30
(B)	**BENEFITS**								
1	Yield of main product(quintals)			45.00		10.00		45.00	
2	Price per quintals of main products				400		2000		400.00
3	Value of yield of main product (Rs)				18000		20000		18000.00
4	Yield of bye products(quintal)			250.00		200.00		225.00	
5	Price per quintal of bye products				25		25		30.00
6	Value of Yield of bye products(Rs)				6250		5000		6750.00
7	Total Benefits (Rs)				24250.00		25000.00		24750.00
8	Net Benefits(Rs)				12750.95		13519.55		10880.70

4.4.2.4.2 Crop water requirement

Crop water requirement is defined as the quantity of water utilized by the plant during its life time; this water may be supplied either entirely by rainfall, entirely by irrigation or by a combination of both. The water requirement of a chosen cropping pattern is compared with the available water resources to determine the maximum cropping intensity and extent of irrigable area.

Following steps are to be involved in estimation of crop requirements :

(a) Estimation of monthly reference crop evapotranspiration (ETo) ,(Table 4.4)

(b) Estimation of crop coefficient (Kc), [Table 4.5a-h]

(c) Estimation of crop water requirements, [Table 4.6a-h]

- **Cropping Pattern**

This section limited to a discussion of cropping pattern in relation to water availability and assumes that farmers will continue to plant rice in preference to other crops with lower water requirements.

In general terms the annual cropping pattern can be divided into three seasons:

(i) Monsoon rice July- November

(ii) Pre- monsoon rice March – June

(ii) Winter season crop December – February/March.

The main rainy season is from July to September and farmers expect to crop 100% of their land with monsoon rice. The peak irrigation requirement for monsoon rice is normally in late September and October. When rainfall is much reduced, although in some circumstances the peak may be in June to July.

- **Reference Crop Evapotranspiration (ETo)**

Reference crop evapotranspiration (ETo) represents the rate of evapotranspiration of an extended surface of an 8 to 15 cm tall green grass cover, actively growing completely shading the ground and not short of water.

There are several methods of calculating ETo, the best review of these is provided by FAO irrigation and drainage paper No. 24 "Crop Water requirements". The four methods presents presented,

- Blaney-Criddle,
- Radiation,
- Modified Penman and
- Pan Evaporation method,

Using the main daily climatic data for 30 or 10 days periods. ETo is expressed in mm/day and represents the mean value over that period. Primarily the choice of method must be based on the type of climatic data available and on the accuracy required in determining water needs.

Climatic data needed for the different methods are:

Method	Temperature	Humidity	Wind	Sunshine	Radiation	Evaporation	Environ
Blaney-criddle	*	0	0	0			0
Radiation	*	0	0	*	(*)		0
Penman	*	*	*	*	(*)		0
Pan evaporation		0	0			*	*

* Measured data; 0 estimated data; (*) if available, but not essential.

Concerning accuracy, only approximate possible errors can be given since no base line type of climate exists. The modified Penman method would offer the best results with minimum possible error of plus or minus 10% in summer, and up to 20% under low evaporative conditions. The pan method can be graded next with possible error of 155 depending on the location the plan. The radiation method, in extreme conditions, involves a possible error of up to 20% in summer. The blanney-Criddle method should only be applied for periods of one month or longer; in humid, windy, mid-latitude winter condition an over and under prediction of up to 25% has been noted.

Formula of the modified penman method is

$$ETo = [W.Rn + (1-W).f(u).(e_a-e_{d)}]$$

CALCULATION OF ETo BY MODIFIED PENMAN METHOD

C.1 Reference crop Evapotranspiration (ETo)

The form of the equation is

$$Eto = C\,[W.\,Rn + (1-W).f(u).(e_a-e_d)]$$

Where,

e_a = Saturation vapour pressure at mean temperature in m/bar

e_d = actual vapour pressure $e_a * RH_{mean}/10$ (m/bar)

f(u) = wind function

f(u) =0.27(1+u/100), where u is 24 hour wind run in km/day at 2 m height.

R_n = total net radiation in mm/day or

$R_n = 0.75\ R_s - R_{nl}$ where,

R_s = incoming short wave radiation in mm/day either measured or obtained from

$R_s = (0.25 + 0.50\ n/N)\ R_a$

R_a = extra- terrestrial radiation in mm/day (Table No. 10)

n = mean actual sunshine duration in hour /day

N = maximum possible sunshine duration in hour /day

R_{nl} = net long wave radiation in mm/day and

$R_{nl} = f(T).f(n/N).f(e_d)$

where,

f (T) = function of temperature (table 12)

$f(e_d)$ = function of actual vapour pressure (Table 13)

f(n/N) = function of the ratio of the sunshine duration (Table 14)

w = temperature and altitude dependent weighing (Table 15)

C = adjustment factor for ratio U day/Unight , for RH_{max} and R_s (Table 16).

The estimation is carried out in five steps:

(i) Calculation of saturation deficit ($e_a - e_d$)

(ii) Estimation of the wind function f(u)

(iii) Calculation of net radiation (R_n)

(iv) Estimation of weighing factor

(v) Estimation of the adjustment factor

C.2 Calculation of the Saturation Deficit ($e_a - e_d$)

Calculation of e_a

The mean maximum and minimum temperature for each month are calculated and averaged to give the mean monthly temperature (T_{mean})

Using T_{mean} in table 9 (FAO No.33) gives e_a in millimeters.

Calculation of e_d

Generally humidity data is recorded at 0840 hours and 1740 hours each day. For practical purposes the average of these two reading can be taken as the daily mean relative humidity and the average of the daily figures as the monthly mean (RH_{mean}). Then

$$e_d = RH_{mean} * \frac{e_a}{100}$$

C.3 Estimation of the wind function f(u)

(a) Station with Record Wind Speed

Wind function f(u) is defined as

$$(f(u) = 0.27(1 + \frac{U}{100})$$

Where, U is 24- hour wind run in km/day at 2-m height. Where wind data are not collected at 2-m height, the approximate correction for wind measurements taken at different heights are given below:

Measurement height m	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0
Correction factor	1.35	1.15	1.06	1.0	0.93	0.88	0.85	0.83

(b) Station where wind Records are not Kept

Due to topography and limited data it has not been possible to derive a model for the country as a whole. Therefore a subjective estimate has to be made taking into account local experiences, wind data from the nearest station and topography. table C.1 gives values of f(u) for several wind strengths.

Table C.1 Variation of f(u) with Wind Run

Wind	Range of wind run (km/day)	Average (km/day)	f(u)
Light	<175	85	0.50
Moderate	175-425	300	1.08
Strong	426-700	560	1.79
Very strong	>700	800	2.43

C.4 Calculation of Net Radiation (Rn)

Derive Total Radiation (Ra)

This figure in millimeters per day equivalent evaporation is obtained from Table 10 and depends on the latitude of the station and the time of the year. Calculate Ratio of Actual Sunshine hours to Maximum Possible Sunshine Hours (n/N)

(a) Where sunshine records are kept from the records calculate the average daily sunshine hours per month. The figure from mean daily maximum possible sunshine hours is obtained from Table 11 The ratio n/N can then be calculated.

(b) Where sunshine records are not available.

The following equation is used to derive n/N in these situations.

$$n/N = A + BP + CP^2$$

Where, P = monthly precipitation in millimeters, and A, B,and c are constants which depend on the geographical location and the elevation of the site being analyses.

C.5 Weighing factor (W)

The value of the weighing factor (W) is derived from the Table No. 15 (FAO No. 33), which relates to T_{mean} and elevation.

C.6 Adjustment factor (C)

The adjustment factor can be taken as 1.0.

- **Crop coefficient (Kc)**

To an account for the of the crop characteristics on crop water requirements, crop coefficient (Kc) are presented to relate ETo to crop evapotranspiration of a disease free crop grow in large fields under optimum soil water and fertility conditions and achieving full production potential under the given growing environment.

ET crop can be found by

ETc = Kc*ETo

Factor affecting the value of crop coefficient (Kc) are mainly crop characteristics, crop planting or sowing data, rate of crop development, length of growing season and climatic conditions. Information about crop planting and sowing season along with initial, crop development, mid season and late period has been collected by sample survey of the study area.

For determination of Kc following steps have been followed :

(i) Initial stage: - This is the period from sowing transplanting to the ground cover of about 10 %.

(ii) Crop development stage: crop development stage and last until the ground cover is 60%.

(iii) Mid season stage: start in the end of crop development and last with the growing grain formation.

(iv) Late season stage: This starts from grain formation for the date of harvesting.

- **Land preparation requirement**

The estimates of water requirements for land preparation can be critical as they generally cause a peak in irrigation demand, principally for the pre-monsoon rice crop. The water is applied to make tillage cashier and to saturate the soil prior to planting. For paddy crops water is also required to flood the fields.

The land preparation process for pre-monsoon rice is to add about 50 mm of water to the field prior to ploughing. After 1 to 2 weeks a further 100 mm is added for puddling of the fields and to provide about 20 mm depth of water during transplanting. For crop calendars starting with monsoon rice, this requirement can be met in part by rainfall and a total of only 110 mm is needed over the up to transplanting. Where monsoon rice is grown following pre-monsoon rice, the requirement is further reduced as the soil is easier to prepare and it is possible for farmers to have the fields ready for transplanting in two weeks; the requirements is taken to be 55 mm. The water applied until transplanting subject to evaporation losses. Thereafter the losses are included in the land preparation requirement. For non-paddy crops the much lower land preparation requirements are assumed to be met from soil moisture storage, except in the case of wheat for which 60 mm is applied to improve germination.

In summary, land preparation requirements in millimeters over 15 days periods are:

Periods (15- days)

Paddy Rice	1st	2nd	3rd	4th
Pre- monsoon	75	75	50	50
Follow paddy	55	50	50	-
Monsoon (first crop)	55	55	50	50
Dryfood crops Wheat	60	-	-	-
All other	-	-	-	-

4.4.2.4.3 Deep percolation losses

Deep percolation losses are only explicitly considered in the calculation of requirement for paddy rice. In the case of dry-foot crops deep percolation is indirectly allowed for in the field efficiency factor.

The estimates of deep percolation losses for rice can have a major impact on the overall calculation of irrigation requirements, and field measurement is desirable whenever possible.The estimates of deep percolation losses for different soil categories which can be used in the absence of field measurements is given in the table:

Estimated deep percolation Losses (mm/day)

Soil Texture	Newly Irrigated	Long Term Irrigated
Sand, loamy sand	>20	>20
Sandy loam	20	10
Very fine sandy loam, Silty loam sandy clay loam	10	5
Silty clay loam, clay loam, silty clay, clay	5	2

Effective Rainfall

Precipitation falling during the growing period of a crop that is available to meet the evapotranspiration needs of the crop is called effective rainfall. It does not include precipitation lost through deep percolation below the root zone or the water lost as surface runoff. Since there are no records of effective rainfall available, it is necessary to estimates the portion of total Rainfall that can be effective. An approximate procedure for arriving at effective rainfall is given as follows:

P_e = Effective Rainfall (mm)

P_e = 0.8-25 if P>75 mm/month

P_e = 0.6P-10 if P<75 mm/month.

For the crop, other than rice USDA method is used.

4.4.2.4.5 Net irrigation Requirement

In summary, the elements in the calculation of the net irrigation requirement are:

Paddy:

Crop evapotranspiration + Land preparation + Evaporation + Deep percolation - Effective rainfall.

Dry-foot Crops:

Crop evapotranspiration+ Land preparation for wheat - Effective rainfall.

Field Irrigation Requirements

Basin irrigation for dry-foot crops can be reasonably efficient given good management. However, it is still difficult to apply the desired amount of irrigation to the furthest corner of the field without considerable over supply to the crop closest to the supply point. This over supply is regarded as a loss from the system and is expressed as field irrigation efficiency.

This efficiency depends on several factors including basin size, soil type, size of irrigation stream, the skill of the farmers and so on.

Generally, application efficiency ranging 50-70% i.e. water stored in root zone / water applied to field is taken for the calculation of field irrigation requirement (FIR).

$$FIR = \frac{NIR}{\text{field Irrigation efficiency}\,(0.75)}$$

- **Gross Irrigation Requirement**

Conveyance efficiency relates to the main and secondary canals and dependent on seepage losses, management efficiency and losses due to rotation.

Gross irrigation requirement at the head works or at the point of diversion, which include all field, losses, conveyance and operational losses are worked out assuming the conveyance efficiency ranging between 70-80% (i.e. water received at field gate /water released at project head).

$$GIR = \frac{FIR}{0.80}$$

4.4.2.4.6 Ground Water pumping Constraint :

The ground water pumping constraint is given by Eq. 4.5 Chapter – 4.

4.4.2.4.7 Constraint for Crop Management and Socio-economic Needs :

This constraint is given by Eq. 4.6 Chapter – 4 Based upon crop management practices and socio-economic needs. This equation is given in Appendix – 3 (D).

Table No. 4.1 crop Calendar

S.N	Name of the crops	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Paddy						0.0	0.8	0.4	0.5	0.2		
2	Wheat	0.1	0.2	0.1	0.0							0.2	0.1
3	Maize							0.0	0.1	0.2	0.1		
4	Barley	0.07	0.02								0.04	0.18	0.16
5	Jowar								0.24	0.39	0.27	0.05	
6	Gram	0.14	0.11	0.00							0.02	0.06	0.11
7	Pea	0.1	0.1								0.18	0.1	0.1
8	Groundnut							0.0	0.1	0.2	0.2	0.0	
9	Potato	0.1	0.0									0.1	0.2
10	Berseem	0.1	0.2	0.4	0.2							0.2	0.2
11	Bajara								0.1	0.2	0.3	0.1	
12	Sugarcane	0.1	0.1	0.2	0.2	0.4	0.5	0.3	0.3	0.4	0.2	0.0	0.0

Table No. 4.2 Climate data

Month	year	Monthly Mean min Temp °c	Monthly Mean Max Temp °c	Monthly Mean Temp °c	Monthly mean relative humidity RH (%) Morning	Afternoon	Average	Monthly mean wind vel(km/day)	Monthly mean sun shine hr/day	Monthly rainfall (mm)	No. of rainy days in a months
	1999	8.30	12.60	10.00	74.85	64.54	69.695	16.13	3.7	74.4	4
January	2000	8.10	12.70	10.00	78.9	66.97	72.935	12.45	5.7	50.2	4
	2001	6.00	12.40	9.20	71.6	59.32	65.46	17.16	4.36	13.8	3
	2002	6.30	12.10	9.20	72.43	53.93	63.18	14.94	6.64	16.7	3
	2003	6.40	10.00	8.20	83.94	68.65	76.295	6.65	3	18.6	2
	Average	7.02	11.96	422.32	76.34	62.68	69.51	13.47	4.68	34.74	3.20
	1999	9.80	15.40	12.60	73.96	49.13	61.545	18.07	6.92	0	0
February	2000	7.90	15.40	11.65	67.89	48.32	58.105	25.48	6.93	74.8	5
	2001	8.90	17.12	13.01	58.14	39.3	48.72	33.75	7.7	5	2
	2002	9.20	16.00	12.60	71.15	50.38	60.765	27.39	6.9	79.7	6
	2003	9.60	15.40	12.50	77	46.5	61.75	21.89	6.83	84	3
Average		9.08	15.86	12.47	69.63	46.73	58.18	25.32	7.06	48.70	3.20
	1999	12.90	23.80	18.35	46.73	31.8	39.265	39.35	9.5	0	0
	2000	12.30	22.40	17.35	52.99	38.62	45.805	39.13	9.23	9.6	3
March	2001	12.80	22.40	17.60	51.63	35.93	43.78	42.74	8.5	19.4	4
	2002	14.10	22.00	18.05	66.77	42.33	54.55	33.61	8.9	12.2	1
	2003	13.40	20.10	16.75	70.3	45.09	57.695	33.35	8.81	17.4	3
Average		13.10	22.14	17.62	57.68	38.75	48.22	37.64	8.99	11.72	2.20
	1999	17.80	30.90	24.35	37.24	12.33	24.785	30.77	11.6	0	0
	2000	18.10	29.60	23.85	41.12	39.97	40.545	40.9	11.12	0	0
April	2001	17.70	28.50	23.10	44.97	39.07	42.02	39.87	9.13	11.6	2
	2002	18.60	28.60	23.60	52.69	31.24	41.965	43.1	10.2	15.6	3
	2003	18.10	28.10	23.10	60.52	41.32	50.92	31.73	9.8	3.6	1
	Average	18.06	29.14	23.60	47.31	32.79	40.05	37.27	10.37	6.16	1.20

Table 4.2 (contd)

Month	year	Monthly Mean Max	Monthly Mean	Monthly mean relative humidity RH (%)			Monthly mean wind	Monthly mean sun	Monthly rainfall	No.of rainy days in a
		Temp °c	Temp °c	Morning	Afternoon	Average	vel(km/day)	shine hr/day	(mm)	months
May	1999	23.10	33.00	43.05	32.94	37.995	47.97	10.97	33	4
	2000	24.10	31.60	57.68	47.34	52.51	33.32	9.48	101.2	6
	2001	24.10	32.30	50.77	38.25	44.51	67.45	10.35	42.4	3
	2002	24.20	31.80	56.15	39.98	48.065	69.42	11.37	45.2	4
	2003	21.40	32.00	60.44	45.59	53.015	40.58	11.21	11.8	2
Average		23.38	32.14	53.62	40.82	47.22	51.75	10.68	46.72	3.80
June	1999	31.90	15.95	57.91	43.54	50.73	26.32	4.70	245.20	14.00
	2000	28.80	14.40	71.48	67.91	69.70	42.63	8.83	358.60	10.00
	2001	31.30	15.65	69.34	64.28	66.81	37.77	8.25	222.00	13.00
	2002	31.80	15.90	64.57	55.07	59.82	45.97	10.60	91.80	7.00
	2003	32.10	16.05	69.95	61.10	65.53	49.07	10.38	58.40	5.00
Average		31.18	15.59	66.65	58.38	62.52	40.35	8.55	195.20	9.80
July	1999	29.70	14.85	75.50	70.38	72.94	26.32	4.70	245.20	14.00
	2000	29.50	14.75	79.00	76.62	77.81	46.19	6.24	380.00	20.00
	2001	30.50	15.25	77.39	72.01	74.70	27.97	7.64	289.40	14.00
	2002	32.00	16.00	73.50	59.52	66.51	32.00	8.63	39.40	2.00
	2003	30.20	15.10	77.24	65.88	71.56	39.19	7.48	224.00	13.00
	Average	30.38	15.19	76.53	68.88	72.70	34.33	6.94	235.60	12.60
August	1999	29.70	14.85	76.89	67.26	72.08	16.61	5.80	182.60	17.00
	2000	29.70	14.85	79.45	76.67	78.06	27.58	6.87	463.00	15.00
	2001	30.70	15.35	75.13	68.42	71.78	24.68	8.92	159.80	7.00
	2002	29.50	14.75	77.10	64.10	70.60	30.06	7.50	258.20	12.00
	2003	29.00	14.50	79.77	66.33	73.05	25.61	7.69	282.80	15.00
Average		29.72	14.86	77.67	68.56	73.11	24.91	7.36	269.28	13.20

Table no. 4.2 (contd)

Month	year	Monthly Mean Max Temp °c	Monthly Mean Temp °c	Monthly mean relative humidity RH (%) Morning	Afternoon	Average	Monthly mean wind vel(km/day)	Monthly mean sun shine hr/day	Monthly rainfall (mm)	No.of rainy days in a months
September	1999	29.00	14.50	75.28	68.32	71.80	14.57	5.40	101.20	7.00
	2000	28.80	14.40	72.11	66.03	69.07	24.17	8.11	91.00	6.00
	2001	30.40	15.20	67.85	56.24	62.05	22.77	9.65	0.00	0.00
	2002	27.20	13.60	77.20	65.53	71.37	19.23	7.05	403.60	14.00
	2003	27.50	13.75	78.41	68.04	73.23	21.30	6.19	139.30	10.00
Average		28.58	14.29	74.17	64.83	69.50	20.41	7.28	147.02	7.40
October	1999	27.10	13.55	62.58	54.37	58.48	7.61	9.10	4.60	1.00
	2000	27.40	13.70	63.76	54.73	59.25	16.06	9.50	0.00	0.00
	2001	26.80	13.40	67.49	52.87	60.18	14.90	8.70	2.60	1.00
	2002	25.30	12.65	70.73	47.71	59.22	9.48	9.40	18.60	1.00
	2003	24.50	12.25	72.35	54.82	63.59	13.81	9.14	0.00	0.00
Average		26.22	13.11	67.38	52.90	60.14	12.37	9.17	5.16	0.60
November	1999	21.90	10.95	58.63	47.50	53.07	5.63	9.40	0.00	0.00
	2000	21.90	10.95	64.74	54.71	59.73	10.83	7.60	0.00	0.00
	2001	21.20	10.60	63.70	57.21	60.46	13.43	8.84	1.80	1.00
	2002	19.10	9.55	75.43	48.81	62.12	4.23	8.80	0.00	0.00
	2003	19.10	9.55	76.42	60.08	68.25	12.87	7.23	3.00	1.00
Average		20.64	10.32	67.78	53.66	60.72	9.40	8.37	0.96	0.40
December	1999	17.20	8.60	66.06	49.07	57.57	0.10	8.60	3.40	1.00
	2000	15.75	7.88	63.78	46.97	55.38	10.81	7.83	0.00	0.00
	2001	15.60	7.80	71.96	59.94	65.95	12.45	7.27	0.60	1.00
	2002	14.90	7.45	76.30	52.33	64.32	7.23	7.63	16.00	1.00
	2003	14.80	7.40	85.40	61.50	73.45	20.00	4.95	15.00	1.00
Average		15.65	7.83	72.70	53.96	63.33	10.12	7.26	7.00	0.80

Table no. 4.3 MONTHLY RAINFALL AT ROORKEE(WRDTC DEMONSTRATION FARM) STATION Un it: mm

year/mon	Jan	Feb	Mar	Apr	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
1986	20.00	58.00	19.20	8.50	48.40	94.00	91.3	43.30	8.00	10.40	18.60	419.70
1987	33.00	33.00	17.40	5.40	92.60	33.60	206.4	27.20	5.00	0.00	10.20	463.80
1988	1.00	20.30	63.30	11.40	59.80	481.00	439.1	261.40	0.00	0.00	14.20	1351.50
1989	112.20	4.40	1.80	2.20	37.20	260.40	274.1	255.80	0.00	11.00	34.00	993.10
1990	4.40	100.50	24.00	3.00	22.60	343.10	332.7	202.40	2.00	14.20	70.40	1119.30
1991	100.50	23.40	15.40	2.00	123.20	252.40	172.1	221.10	0.00	0.00	0.00	910.10
1992	23.40	0.00	0.00	0.00	43.80	151.80	457.4	160.20	0.00	2.60	0.00	839.20
1993	0.00	29.10	110.60	0.00	41.70	177.60	131	300.40	0.00	0.00	0.00	790.40
1994	9.00	57.40	0.00	31.30	35.00	633.20	348	11.00	0.00	0.00	0.00	1124.90
1995	29.00	45.40	6.00	0.00	128.20	356.00	446.5	116.40	2.80	0.00	1.30	1131.60
1996	57.20	93.60	8.40	0.00	61.00	158.00	434.6	354.00	60.00	0.00	0.00	1226.80
1997	33.80	3.00	5.80	66.40	34.00	328.20	242.5	68.80	64.40	36.00	86.20	969.10
1998	20.00	28.90	82.00	80.00	74.40	250.60	405.9	192.00	149.50	0.00	0.00	1283.30
1999	74.40	0.00	0.00	0.00	245.20	245.20	182.6	101.20	4.60	0.00	0.00	853.20
2000	50.20	74.80	9.60	0.00	358.60	380.00	463	91.00	0.00	0.00	3.40	1430.60
2001	13.80	5.00	19.40	11.60	222.00	289.40	159.8	0.00	2.60	1.80	0.60	726.00
2002	16.70	79.70	12.20	15.60	91.80	39.40	258.2	403.60	18.60	0.00	16.00	951.80
2003	18.60	84.00	17.40	3.60	58.40	224.00	282.8	139.30	0.00	3.00	15.00	846.10
Average	**34.3**	**41.1**	**21.95**	**13.4**	**98.8**	**261.0**	**296**	**163.84**	**17.64**	**4.39**	**14.99**	**967.4**

[Table No.4.5a] **CALCULATION OF COEFFICIENT (Kc)**

Name of crop: **Pea** Crop period:15th Oct to 15th Feb

Number of growth stage: 5

Number of days per growth stage: 24

Crop Development stage	value of crop coefficient(Kc)	Average value of kc
Initial stage	0.4-0.5	0.45
Crop Development stage	0.7-0.85	0.775
Mid season	1.05-1.2	1.125
Late season	1.0-1.15	1.075
At harvest	0.95-1.1	1.025

Month	No. of days	Growth stage	Crop coefficient		Kc
			As per G.S.	As per month	
Oct	16	1	0.45	16*0.45/16	0.45
November	8	1	0.45	(8*0.45+22*0.775)/30	0.68
	22	2	0.775		
December	2	2	0.775	(2*0.775+26*1.125+3*1.075)/31	1.10
	26	3	1.125		
	3	4	1.075		
Jan	22	4	1.075	(22*1.075+9*1.025)/31	1.06
	9	5	1.025		
February	15	5	1.025	15*1.025/15	1.025

[Table No. 4.5b] **CALCULATION OF COEFFICIENT (Kc)**

Name of crop: **Potato** Crop period: 1st Nov to 10th Feb

Number of growth stage: 5

Total No. of days 110 days

Number of days per growth stage: 22

Crop Development stage	value of crop coefficient(Kc)	Average value of kc
Initial stage	0.4-0.5	0.45
Crop Development stage	0.7-0.8	0.775
Mid season	1.05-1.2	1.125
Late season	0.85-0.95	0.9
At harvest	0.7-0.75	0.725

Month	No. of days	Growth stage	Crop coefficient		Kc
			As per G.S.	As per month	
November	22	1	0.45	(22*0.45+8*0.75)/31	0.51
	8	2	0.75		
December	15	2	0.75	(15*0.75+16*1.125)/31	0.95
	16	3	1.125		
Jan	6	3	1.125	(6*1.125+22*0.90+3*.725)/31	0.93
	22	4	0.9		
	3	5	0.725		
February	19	5	0.725	19*0.725/19.	0.725

[Table No. 4.5c] **CALCULATION OF COEFFICIENT (Kc)**

Name of crop: **Maize** Crop period: 2nd july to 10th oct

Number of growth stage: 5

Total No. of days: 98 days

Number of days per growth stage: 19.60

Crop Development stage	value of crop coefficient(Kc)	Average value of kc
Initial stage	0.3-0.5	0.4
Crop Development stage	0.7-0.85	0.772
Mid season	1.05-1.2	1.125
Late season	0.8-0.95	0.875
At harvest	0.55-0.6	0.575

Month	No. of days	Growth stage	Crop coefficient	
			As per G.S.	As per month
July	19	1	0.4	19*0.4+9*0.772)/28
	9	2	0.772	
August	10	2	0.772	(10*0.772+19*1.125+2*0.875)/31
	19	3	1.125	
	2	4	0.875	
September	17	4	0.875	(17*0.875+13*0.575)/ 30
	13	5	0.575	
October	10	5	0.575	10*0.575/10

[Table No. 4.5d] **CALCULATION OF COEFFICIENT (Kc)**

Name of crop: **Groundnut** Crop period: 1st july to 7th Nov

Number of growth stage: 5 Total No. of days: 98 days

Number of days per growth stage: 26days

Crop Development stage	value of crop coefficient(Kc)	Average value of kc
Initial stage	0.4-0.5	0.45
Crop Development stage	0.7-0.8	0.75
Mid season	0.95-1.1	1.025
Late season	0.75-0.85	0.8
At harvest	0.55-0.6	0.575

Month	No. of days	Growth stage	Crop coefficient		Kc
			As per G.S.	As per month	
July	26	1	0.45	(0.45*26+4*0.75)/30	0.5
	4	2	0.75		
August	21	2	0.75	(21*0.75+1.025*100/31	0.84
	10	3	1.025		
September	15	3	1.025	(15*1.025+15*0.80)/30	0.66
	15	4	0.8		
October	12	4	0.8	(12*0.80+19*0.575)/31	0.575
	19	5	0.575		
November	7	5	0.575	7*0.575/7	0.575

[Table No. 4.5 e] **Calculation of Crop Coefficient**

Name of the crop: Sugarcane **Crop period : March to Feb**

Number of growth stage: 5 Total no of days :365

Number of days per growth stage: 73

Crop Development stage	Value of crop coefficient (kc)	Average value of kc
Initial stage	0.4-0.5	0.45
Crop development.	0.7-1.0	0.85
Mid season	1.0-1.3	1.15
Late season	0.75-0.80	0.78
At harvest	0.5-0.6	0.55

Month	No. of days	Growth stage	Crop Coefficient		Kc
			As per G.S	As Per month	
March	31	1	0.45	31*0.45/31	0.45
April	30	1	0.45	30*0.45/30	0.45
May	12	1	0.45	(12*0.45+19*0.85)/31	0.70
	19	2	0.85		
June	30	2	0.85	30*0.85/30	0.85
July	24	2	0.85	(24*0.85+6*1.15)/30	0.92
	6	3	1.15		
August	31	3	1.15	31*1.15/31	1.15
Sep	30	3	1.15	30*1.15/*30	1.15
Oct	5	3	1.15	(5*1.15+26*0.78)/31	0.84
	26	4	0.78		
Nov	30	4	0.78	30*0.78/30	0.78
Dec	17	4	0.78	(17*0.78+14*0.55)/31	0.68
	14	5	0.55		
Jan	31	5	0.55	31*0.55/31	0.55
Feb	28	5	0.55	28*0.55/28	0.55

[Table No. 4.5f] CALCULATION OF COEFFICIENT (Kc)

Name of crop: **Wheat** Crop period: 20th Nov to 3rd

Number of growth stage: 5

Total no. of days : 135

Number of days per growth stage: 27

Crop development stage	Value of crop coefficient (kc)	Average value of Kc
Initial stage	0.3-0.4	0.35
Crop development	0.7-0.8	0.75
Mid season	1.05-1.2	1.15
Late season	0.85-0.75	0.80
At harvest	0.2-0.25	0.22

Month	No. of days	Growth stage	Crop coefficient		Kc
			As per G.S.	As per month	
November	10	1	0.35	10*0.35/10	0.35
December	16	1	0.35	(16*0.35+15*0.75)/31	0.54
	15	2	0.75		
January	12	2	0.75	(12*0.75+19*1.15)/31	1.00
	19	3	1.15		
February	8	3	1.15	(8*1.15+20*0.80)/28	0.90
	20	4	0.80		
March	7	4	0.80	(7*0.80+24*0.22)/31	0.34
	24	5	0.22		
April	3	5	0.22	3*0.22/3	0.22

[Table No. 4.5 g] **CALCULATION OF COEFFICIENT (Kc)**

Name of crop: Berseem

Crop period: 1st Jul to 28th oct

Number of growth stage: 5

Total no. of days : 120

Number of days per growth stage: 24

Crop development stage	Value of crop coefficient (kc)	Average value of Kc
Initial stage	0.3-0.4	0.35
Crop development	0.7-0.75	0.725
Mid season	1.0-1.15	1.075
Late season	0.75-0.80	0.775
At harvest	0.50-0.55	0.525

Month	No. of days	Growth stage	Crop coefficient		Kc
			As per G.S.	As per month	
July	24	1	0.35	(24*0.35+6*0.725)/30	0.43
	6	2	0.725		
August	17	2	0.725	(17*0.725+14*1.075)/31	0.88
	14	3	1.075		
September	10	3	1.075	(10*1.075+20*0.775)/30	0.88
	20	4	0.775		
October	4	4	0.775	(4*0.775+24*0.525)/28	0.56
	24	5	0.525		

[Table 4.5h] **CALCULATION OF COEFFICIENT (Kc)**

Name of crop: Paddy Crop period: 1 th June to 19 th oct

Number of growth stage: 5 Total no. of days: 126

Number of days per growth stage: 25.2

Crop development stage	Value of crop coefficient (kc)	Average value of Kc
Initial stage	1.0-1.15	1.12
Crop development	1.10-1.50	1.30
Mid season	1.10-1.30	1.20
Late season	0.95-1.05	1.00
At harvest	0.95-1.05	1.00

Month	No. of days	Growth stage	Crop coefficient		Kc
			As per G.S.	As per month	
June	16	1	1.12	16*1.12/16	1.12
July	9	1	1.12	(9*1.12+22*1.30)/31	1.25
	22	2	1.30		
August	4	2	1.30	(4*1.3+25*1.2+2*1)/31	1.2
	25	3	1.20		
	2	4	1.00		
September	24	4	1.00	(24*1.0+6*1.0) 30	1.00
	6	5	1.00		
October	19	5	1.00	19*1.0/19	1.00

Table No. 4.6a

CROP WATER REQUIREMENT SHEET

Crop : Berseem		Date of sowing: March								
S.N.	Particulars	Units	Jan	Feb	Mar	Apr	Nov	Dec	Total	Remarks
1	75% Reliable rainfall (p)	mm	4.0	13.0	7.5	2.0	0.00	0.00	26.50	
2	Effective rainfall (p_e)	mm	0.0	0.0	0.0	0.0	0.00	0.00	0.00	
3	ETo/day	mm	2.55	3.99	6.50	8.80	4.07	3.03	-	
4	ETo/months	mm	79.1	111.7	201.5	264.0	122.10	93.90	-	
5	No of days in month for water requirements by crop	Days	31	28	31	15	30	31	166	From crop duration mentioned at top
6	Days of growth up to mid of month	%	77	106	136	159	15	46	-	Cumulative days from start up to mid of current month
7	Percentage of growth up to mid of month	-	46.4	63.8	81.9	95.8	9	28	-	S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	1.13	1.13	1.13	1.13	0.35	1.05	-	
9	Consumptive use (ETc)	mm	88.90	125.70	226.70	148.50	42.74	98.63	731.17	S.N. 6*S.N. 5*S.N. 8
10	Requirements for land preparation	mm	-	-	-	-	75.00	-	75.00	
11	Seepage and percolation@ 3mm/day	mm	-	-	-	-	-	-	0.00	During major part of monsoon only irrigation.ie June to September
12	Total requirement	mm	88.93	125.70	226.70	148.50	117.70	98.63	806.16	S.N. 9+S.N. 10+S.N.11
13	Net irrigation Requirement (NIR)	mm	88.93	125.70	226.70	148.50	117.70	98.63	806.16	S.N.12-S.N.2
14	Field irrigation Requirement (FIR)	mm	118.60	167.60	302.30	198.00	157.00	131.50	1075.00	S.N.13/0.75
15	Gross irrigation Requirement (GIR)	mm	148.20	209.50	377.80	247.50	196.20	164.40	1343.60	S.N.14/0.80

Table No. 4.6b

CROP WATER REQUIREMENT SHEET

Crop : Bajara		Date of sowing: July			Soil type : Sandy loam			
S.N.	Particulars	Units	Aug	Sep	Oct	Nov	Total	Remarks
1	75% Reliable rainfall (p)	mm	187.0	60.00	0.00	0	247.00	
2	Effective rainfall (p_e)	mm	125.3	44.60	0.00	0	169.90	
3	ETo/day	mm	6.60	6.07	5.74	4.07	22.48	
4	ETo/months	mm	204.60	182.10	177.90	12.1	576.70	
5	No of days in month for water requirements by crop	Days	25	30	31	14	100.00	From crop duration mentioned at top
6	Days of growth upto mid of month	%	13	43	74	88		Cumulative days from start up to mid of current month
7	Percentage of growth up to mid of month	-	13.0	43.0	74.0	88		S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	0.21	0.70	1.02	0.63		
9	Consumptive use (ETc)	mm	34.65	127.47	181.50	35.90	379.52	S.N. 3*S.N. 5*S.N. 8
10	Requirements for land preparation	mm	100.00	0.00	0.00	0	100.00	
11	Seepage and percolation@ 3mm/day	mm	1.04	3.82	5.44	1.08	11.39	During major part of monsoon only irrigation.ie june to September
12	Total requirement	mm	135.69	131.29	186.94	36.97	490.90	S.N. 9+S.N. 10+S.N.11
13	Net irrigation requirement (NIR)	mm	10.39	86.69	186.94	36.97	321.00	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	13.85	115.59	249.26	49.30	428.00	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	17.32	144.49	311.57	61.62	570.67	S.N.14/0.80

Table No. 4.6c CROP WATER REQUIREMENT SHEET

Crop : paddy		Date of sowing: March			Crop period :15th june to 19th oct						Soil type : Sandy loam	
S.N.	Particulars	Units	Jun		Jul			August	Sep	Oct	Total	Remarks
1	75% Reliable rainfall (p)	mm	40.0		150.0			187.00	60.00	0.00	437.00	
2	Effective rainfall (p_e)	mm	29.8		104.0			125.30	44.60	0.00	303.70	
3	ETo/day	mm	8.25		7.00			6.60	6.07	5.74		
4	ETo/months	mm	247.5		217.00			204.60	182.10	177.90		
			NURSERY			FIELD						
5	No of days in month for water requirements by crop	Days	15-19 5 DAYS	20-30 11 DAYS	1-23 23 DAYS	19-23 5 DAYS	24-31 8 DAYS	31	30	19	132	From crop duration mentioned at top
6	Days of growth upto mid of month	%	-	6.0	23	-	4	24	54	79		cumulative days from start upto mid of current month
7	Percentage of growth up to mid of month	-	-	-	-	-	3.175	19	43	63		S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	0.85		0.92			1.15	1.15	0.84		
9	Consumptive use (ETc)	mm	35.06	77.14	148.10	32.20	51.52	235.30	209.40	91.61	880.33	S.N. 6*S.N. 5*S.N. 8
10	Requirements for land preparation	mm	400.00	-	-	400.00	-	-	-	-	800.00	
11	Seepage and percolation@ 3mm/day	mm	25.00	55.00	115.00	25.00	40.00	155.00	150.00	95.00	660.00	during major part of monsoon only irrigation.ie June to September
12	Total requirement	mm	460.10	132.10	263.10	457.20	91.52	390.30	359.40	186.60	2340.32	S.N. 9+S.N. 10+S.N.11
13	Net irrigation requirement (NIR)	mm	(460.1+132.1-29.8)/20=28.1		263.1/20+457.2+91.52-104=457.9			265.00	314.80	186.60	1252.40	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	37.47		610.50			353.32	419.80	248.80	1669.89	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	46.84		763.13			441.70	524.70	311.00	2087.37	S.N.14/0.80

Table No. 4.6d

CROP WATER REQUIREMENT SHEET

Crop : **Maize** Date of sowing: March Soil type : Sandy loam

S.N.	Particulars	Units	Jul	Aug	Sep	Oct	Total	Remarks
1	75% Reliable rainfall (p)	mm	150.0	187.0	60.00	0.00	397.00	
2	Effective rainfall (p_e)	mm	104.0	125.3	44.60	0.00	273.90	
3	ETo/day	mm	7.0	6.60	6.07	5.74	-	
4	ETo/months	mm	217.0	204.60	182.10	177.90	-	
5	No of days in month for water requirements by crop	Days	28.0	31	30	10	99	From crop duration mentioned at top
6	Days of growth up to mid of month	%	28.0	59	89	99	-	cumulative days from start up to mid of current month
7	Percentage of growth up to mid of month	-	28.3	59.6	89.9	100.0	-	S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	0.52	1.00	0.74	0.58	-	
9	Consumptive use (ETc)	mm	101.92	204.60	134.75	33.01	474.28	S.N. 3*S.N. 5*S.N. 8
10	Requirements for land preparation	mm	0.00	0.00	0.00	0.00	0.00	
11	Seepage and percolation@ 3mm/day	mm	3.06	6.14	4.04	0.00	13.24	during major part of monsoon only irrigation.ie june to september
12	Total requirement	mm	104.98	210.74	138.80	33.01	487.52	S.N. 9+S.N. 10+S.N.11
13	Net irrigation requirement (NIR)	mm	0.98	85.44	94.20	33.01	213.62	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	1.30	113.92	125.60	44.01	284.82	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	1.63	142.40	156.99	55.01	356.03	S.N.14/0.80

Table No. 4.6e
Crop : **Wheat**

CROP WATER REQUIREMENT SHEET
Date of sowing: March

S.N.	Particulars	Units	Jan	Feb	Mar	Apr	Nov	Dec	Total	Remarks
1	75% Reliable rainfall(p)	mm	4	13	7.5	2	0	0	472	
2	Effective rainfall(pe)	mm	0	0	0	0	0	0	304	
3	ETo/day	mm	2.55	3.99	6.5	8.8	4.1	3	-	
4	ETo/months	mm	79.1	112	202	264	12	94	-	
5	No of days in month for water requirements by crop	Days	31	28	31	3	11	31	135	From crop duration mentioned at top
6	Days of growth up to mid of month	%	68	96	127	130	6	37		Cumulative days from start up to mid of current month
7	Percentage of growth up to mid of month	-	52.3	73.8	98	100	4.6	28		S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	1.00	0.90	0.35	0.22	0.35	0.54		
9	Consumptive use (ETc)	mm	79.1	101	71	5.81	16	51	322	S.N.3*S.N.5*S.N.8
10	Requirements for land preparation	mm	0	0	100	0	0	0	100	
11	Seepage and percolation@ 3mm/day	mm	0	0	0	0	0	0	366	During major part of monsoon only irrigation.ie June to September
12	Total requirement	mm	79.1	101	171	5.81	16	51	422	S.N. 9+S.N. 10+S.N.11
13	Net irrigation requirement (NIR)	mm	79.1	101	171	5.81	16	51	422	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	105	134	227	7.74	21	68	563	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	132	168	284	9.68	26	85	704	S.N.14/0.80

Table No. 4.6f

CROP WATER REQUIREMENT SHEET

Crop : **Gram**

Date of sowing:22th October

Soil type : Sandy loam

S.N.	Particulars	Units	Jan	Feb	Mar	Oct	Nov	Dec	Total	Remarks
1	75% Reliable rainfall (p)	mm	4.0	13.0	7.5	0.00	0.00	0.00	24.50	
2	Effective rainfall (p_e)	mm	0.0	0.0	0.0	0.00	0.00	0.00	0.00	
3	ETo/day	mm	2.55	3.99	6.50	5.74	4.07	3.03	-	
4	ETo/months	mm	79.1	111.7	201.5	177.90	12.10	93.90	-	
5	No of days in month for water requirements by crop	Days	31	28	7	8	30	31	135	From crop duration mentioned at top
6	Days of growth up to mid of month	%	100	128	135	8	38	69	-	Cumulative days from start up to mid of current month
7	Percentage of growth up to mid of month	-	74.1	94.8	100.0	6	28	51	-	S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	1.07	0.78	0.40	0.20	0.30	0.70	-	
9	Consumptive use (ETc)	mm	84.58	87.14	18.20	9.18	36.63	65.75	301.49	S.N. 6*S.N. 5*S.N.3
10	Requirements for land preparation	mm	-	-	-	-	-	-	-	
11	Seepage and percolation@ 3mm/day	mm	-	-	-	-	-	-	-	During major part of monsoon only irrigation.ie June to September
12	Total requirement	mm	84.58	87.14	18.20	9.18	36.63	65.75	301.49	S.N. 9+S.N.10+S.N.11
13	Net irrigation requirement (NIR)	mm	84.58	87.14	18.20	9.18	36.63	65.75	301.49	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	112.78	116.19	24.27	12.25	48.84	87.67	401.99	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	140.97	145.24	30.33	15.31	61.05	109.59	502.48	S.N.14/0.80

Table No. 4.6g

CROP WATER REQUIREMENT SHEET

Crop : **Jowar**

Date of sowing: July

Soil type : Sandy loam

S.N.	Particulars	Units	Jul	Aug	Sep	Oct	Nov	Total	Remarks
1	75% Reliable rainfall (p)	mm	150.0	187.0	60.00	0.00	0.00	397.00	
2	Effective rainfall (p_e)	mm	104.0	125.3	44.60	0.00	0.00	273.90	
3	ETo/day	mm	7.0	6.60	6.07	5.74	4.07	-	
4	ETo/months	mm	217.0	204.60	182.10	177.90	12.10	-	
5	No of days in month for water requirements by crop	Days	16.0	31	30	31	15	123	From crop duration mentioned at top
6	Days of growth up to mid of month	%	16.0	47	77	108	123	-	cumulative days from start up to mid of current month
7	percentage of growth up to mid of month	-	13.0	38	63	88	100	-	S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	0.26	0.85	1.05	0.90	0.52	-	
9	Consumptive use (ETc)	mm	29.12	173.91	191.21	160.15	31.75	586.13	S.N. 6*S.N. 5*S.N. 3
10	Requirements for land preparation	mm	-	-	-	-	-		
11	Seepage and percolation@ 3mm/day	mm	93.00	93.00	90.00	-	-	276.00	During major part of monsoon only irrigation.ie june to september
12	Total requirement	mm	93.00	266.91	281.21	160.15	31.75	833.01	S.N. 9+S.N. 10+S.N.11
13	Net irrigation requirement (NIR)	mm	0.00	141.61	236.61	160.15	31.75	570.11	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	0.00	188.81	315.47	213.53	42.33	760.14	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	0.00	236.02	394.34	266.91	52.91	950.18	S.N.14/0.80

Table No. 4.6h
Crop : **Barley**

CROP WATER REQUIREMENT SHEET
Date of sowing: October

Soil type : Sandy loam

S.N.	Particulars	Units	Jan	Feb	Oct	Nov	Dec	Total	Remarks
1	75% Reliable rainfall (p)	mm	4.0	13.0	0.00	0.00	0.00	17.00	
2	Effective rainfall (p_e)	mm	0.0	0.0	0.00	0.00	0.00	0.00	
3	ETo/day	mm	2.55	3.99	5.74	4.07	3.03	-	
4	ETo/months	mm	79.1	111.7	177.90	12.10	93.90	-	
5	No of days in month for water requirements by crop	Days	30	10	15	30	30	115	From crop duration mentioned at top
6	Days of growth up to mid of month	%	105	115	15	45	75	-	Cumulative days from start up to mid of current month
7	Percentage of growth up to mid of month	-	0.9	1.0	0.1	0.4	0.7	-	S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	0.53	0.25	0.27	0.88	1.09	-	
9	Consumptive use (ETc)	mm	40.55	9.98	23.25	107.45	98.63	279.84	S.N. 6*S.N. 5*S.N. 3
10	Requirements for land preparation	mm	-	-	-	-	-	-	
11	Seepage and percolation@ 3mm/day	mm	-	-	-	-	-	-	During major part of monsoon only irrigation.ie June to September
12	Total requirement	mm	40.55	9.98	23.25	107.45	98.63	279.84	S.N. 9+S.N. 10+S.N.11
13	Net irrigation Requirement (NIR)	mm	40.55	9.98	23.25	107.45	98.63	279.84	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	54.06	13.30	31.00	143.26	131.50	373.12	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	67.58	16.63	38.75	179.08	164.38	466.40	S.N.14/0.80

Table No. 4.6i

CROP WATER REQUIREMENT SHEET

Crop : **Potato**

Date of sowing: March

S.N.	Particulars	Units	Jan	Feb	Nov	Dec	Total	Remarks
1	75% Reliable rainfall (p)	mm	4	13	0	0	472	
2	Effective rainfall (pe)	mm	0	0	0	0	304	
3	ETo/day	mm	2.55	3.99	4.07	3.03		
4	ETo/months	mm	79.1	111.7	12.1	93.9		
5	No of days in month for water requirements by crop	Days	31	18	30	31	365	From crop duration mentioned at top
6	Days of growth up to mid of month	%	77	95	15	46	233	Cumulative days from start upto mid of current month
7	Percentage of growth up to mid of month	-	70	86.36	13.6	41.8		S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	0.93	0.725	0.51	0.95		
9	Consumptive use (ETc)	mm	73.5	52.07	62.3	89.2	277	S.N.3*S.N. 5*S.N. 8
10	Requirements for land preparation	mm						
11	Seepage and percolation@ 3mm/day	mm	2.21	1.562	1.87	2.68	8.31	During major part of monsoon only irrigation.ie June to September
12	Total requirement	mm	75.7	53.63	64.1	91.9	285	S.N. 9+S.N. 10+S.N.11
13	Net irrigation requirement (NIR)	mm	75.7	53.63	64.1	91.9	285	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	101	71.51	85.5	123	381	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	126	89.39	107	153	476	S.N.14/0.80

Table No. 4.6j CROP WATER REQUIREMENT SHEET

Crop : **Pea** Date of sowing: March Soil type : Sandy loam

S.N.	Particulars	Units	Oct	Nov	Dec	Jan	Feb	Total	Remarks
1	75% Reliable rainfall (p)	mm	0	0	0	4	13	472	
2	Effective rainfall (pe)	mm	0	0	0	0	0	303.7	
3	ETo/day	mm	5.74	4.07	3.03	2.55	3.99	-	
4	ETo/months	mm	177.9	122.1	93.9	79.1	111.7	-	
5	No of days in month for water requirements by crop	Days	16	30	31	31	13	121	From crop duration mentioned at top
6	Days of growth up to mid of month	%	8	38	69	100	113		cumulative days from start up to mid of current month
7	Percentage of growth up to mid of month	-	6.66	31.66	57.5	83.33	94.16		S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	0.45	0.69	1.1	1.06	1.025		
9	Consumptive use (ETc)	mm	41.328	84.25	103.32	83.79	53.17	365.86	S.N.3*S.N. 5*S.N. 8
10	Requirements for land preparation	mm	0	0	0	0	0	0	
11	Seepage and percolation@ 3mm/day	mm	1.24	2.53	3.10	2.51	1.60	10.98	during major part of monsoon only irrigation.ie June to September
12	Total requirement	mm	42.57	86.78	106.42	86.31	54.76	376.84	S.N. 9+S.N. 10+S.N.11
13	Net irrigation requirement (NIR)	mm	42.57	86.78	106.42	86.31	54.76	376.84	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	56.757	115.7	141.9	115.1	73.016	502.45	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	70.946	144.6	177.37	143.8	91.27	628.06	S.N.14/0.80

Table No. 4.6j

CROP WATER REQUIREMENT SHEET

Crop : **Groundnut**

Date of sowing: July

Soil type : Sandy loam

S.N.	Particulars	Units	Jul	Aug	Sep	Oct	Nov	Total	Remarks
1	75% Reliable rainfall (p)	mm	150.0	187.0	60.00	0.00	0	397.00	
2	Effective rainfall (p_e)	mm	104.0	125.3	44.60	0.00	0	273.90	
3	ETo/day	mm	7.0	6.60	6.07	5.74	4.07	29.48	
4	ETo/months	mm	217.0	204.60	182.10	177.90	12.1	793.70	
5	No of days in month for water requirements by crop	Days	31.0	31	30	31	7	130.00	From crop duration mentioned at top
6	Days of growth up to mid of month	%	31.0	62	92	123	130	-	Cumulative days from start up to mid of current month
7	Percentage of growth up to mid of month	-	23.8	47.7	70.8	94.6	100	-	S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	0.50	0.84	0.92	0.66	0.535	-	
9	Consumptive use (ETc)	mm	108.50	171.86	167.53	117.44	15.24	580.58	S.N. 3*S.N. 5*S.N. 8
10	Requirements for land preparation	mm	0.00	0.00	0.00	0.00	0	0.00	
11	Seepage and percolation@ 3mm/day	mm	3.26	5.16	5.03	3.52	0.46	17.42	During major part of monsoon only irrigation.ie June to September
12	Total requirement	mm	111.76	177.02	172.56	120.96	15.70	598.00	S.N. 9+S.N. 10+S.N.11
13	Net irrigation requirement (NIR)	mm	7.76	51.72	127.96	120.96	15.70	324.10	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	10.34	68.96	170.61	161.28	20.93	432.13	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	12.93	86.20	213.26	201.61	26.17	576.17	S.N.14/0.80

Table No. 4.6k

CROP WATER REQUIREMENT SHEET

Crop : **Sugarcane** Date of sowing: March Crop period :12 months Soil type : Sandy loam

S.N.	particulars	Units	Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Remarks
1	75% Reliable rainfall(p)	mm	4.0	13.0	7.5	2.0	8.5	40.0	150.0	187.0	60.00	0.00	0.00	0.00	472.00	
2	Effective rainfall(p_e)	mm	0.0	0.0	0.0	0.0	0.0	29.8	104.0	125.3	44.60	0.00	0.00	0.00	303.70	
3	ETo/day	mm	2.55	3.99	6.50	8.80	9.73	8.25	7.0	6.60	6.07	5.74	4.07	3.03	-	
4	ETo/months	mm	79.1	111.7	201.5	264.0	301.6	247.5	217.0	204.60	182.10	177.90	12.10	93.90	-	
5	No of days in month for water requirements by crop	Days	31	28	31	30	31	30	31.0	31	30	31	30	31	365	From crop duration mentioned at top
6	Days of growth up to mid of month	%	322	350	16	46	77	107	138.0	169	199	230	260	291	-	Cumulative days from start up to mid of current month
7	Percentage of growth up to mid of month	-	88.0	96.0	4.0	12.0	21.0	29	38.0	46	55	63	71	80	-	S.N. 6/(crop period)*100
8	Crop coefficient (Kc)	mm	0.55	0.55	0.45	0.45	0.70	0.85	0.92	1.15	1.15	0.84	0.78	0.68	-	
9	Consumptive use (ETc)	mm	43.48	61.45	90.68	118.80	211.10	210.40	199.60	235.29	209.42	149.50	95.24	63.87	1688.83	S.N. 6*S.N. 5*S.N. 8
10	Requirements for land preparation	mm	-	-	100.00	-	-	-	-	-	-	-	-	-	100.00	
11	Seepage and percolation@ 3mm/day	mm	-	-	-	-	-	90.00	93.00	93.00	90.00	-	-	-	366.00	During major part of monsoon only irrigation . June to sep
12	Total requirement	mm	43.48	61.45	190.70	118.80	211.10	300.40	292.60	328.29	299.42	149.50	95.24	63.87	2154.85	S.N. 9+S.N. 10+S.N.11
13	Net irrigation requirement (NIR)	mm	43.48	61.45	100.00	118.80	211.10	270.60	188.60	202.99	254.82	149.50	95.24	63.87	1655.52	S.N.12-S.N.2
14	Field irrigation requirement (FIR)	mm	57.97	81.93	133.30	158.40	281.50	360.80	251.50	270.65	339.75	199.30	127.00	85.16	2347.26	S.N.13/0.75
15	Gross irrigation requirement (GIR)	mm	72.46	102.40	166.70	198.00	351.90	451.00	314.40	338.32	424.69	249.10	158.70	106.50	2934.17	S.N.14/0.80

Tabe No 4.6 I **Gross irrigation requirement per hectare**

Name of the crops	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Paddy						0.047	0.763	0.442	0.525	0.211		
Wheat	0.132	0.168	0.118	0.010							0.151	0.085
Maize							0.002	0.142	0.157	0.055		
Barley	0.068	0.017								0.039	0.179	0.164
Jowar								0.236	0.394	0.267	0.053	
Gram	0.141	0.105	0.003							0.015	0.061	0.110
Pea	0.071	0.145								0.177	0.144	0.091
Groundnut							0.013	0.086	0.213	0.202	0.026	
Potato	0.126	0.008									0.107	0.153
Berseem	0.148	0.210	0.378	0.248							0.196	0.164
Bajara								0.143	0.219	0.312	0.062	
Sugarcane	0.072	0.102	0.167	0.198	0.352	0.451	0.314	0.338	0.425	0.249	0.015	0.0

Calculation for ET_o

Items / Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Maxm Temp°c	11.96	15.86	22.14	29.14	32.14	31.18	30.38	29.72	28.6	26.2	20.64	15.65
Minm Temp ° c	7.02	9.08	13.1	18.06	23.38	24.53	26.06	25.26	23.3	18.2	12.3	8
Avg Temp° c	9.49	12.47	17.62	23.6	27.76	27.855	28.22	27.49	25.95	22.2	16.47	11.83
Mean Relative Humidity (%)	69.5	58.19	48.22	40.05	47.2	62.5	72.7	73.1	69.5	60.0	60.7	63.3
Sunshine Hours (Actual) n	4.7	7.05	8.99	10.37	10.7	10.7	6.94	7.4	7.28	9.2	8.4	7.26
Maxm Possible sunshine hours N	10.45	11.1	12	12.9	13.6	14	13.9	13.2	12.4	11.5	10.6	10.2
Wind Speed (Km/day)	13.5	25.32	37.64	37.27	51.75	40.35	34.3	24.91	20.41	12.4	9.4	10.12
Wind Speed day (m/sec)	0.16	0.29	0.44	0.43	0.60	0.47	0.40	0.29	0.24	0.14	0.11	0.12
Saturation Vapour Pressure e_a (mbar)	11.90	14.5	20.14	29.12	37.4	37.5	38.31	36.73	33.51	26.74	18.76	13.85
Actual Vapour Pressure e_d (mbar)	8.27	8.41	9.71	11.66	17.65	23.44	27.85	26.85	23.29	16.04	11.39	8.77
e_a-e_d	3.63	6.09	10.43	17.46	19.75	14.06	10.46	9.88	10.22	10.70	7.37	5.08
Extra terrestrial radiatian, Ra mm/day	8.93	10.8	13.17	15.23	16.5	16.95	16.78	15.7	13.95	11.7	9.6	8.43
f(T)	12.6	13.2	14.12	15.3	16.22	16.27	16.34	16.2	15.89	15.04	13.89	13.07
f(ed)	0.22	0.216	0.2	0.19	0.152	0.12	0.11	0.115	0.124	0.16	0.193	0.212
f(n/N)	0.51	0.68	0.77	0.82	0.81	0.65	0.55	0.61	0.63	0.82	0.81	0.74
Rnl	1.41	1.94	2.20	2.38	2.00	1.27	0.99	1.14	1.25	1.97	2.17	2.05
Rs=(0.25+0.5n/N)Ra	4.24	6.13	6.17	9.93	10.62	10.71	8.38	8.33	7.58	7.61	6.20	5.11
Rn=.75Rs-Rnl	1.77	2.66	3.97	5.06	5.96	5.79	5.31	5.11	4.44	3.73	2.48	1.78
Weighting Factor, W	0.55	0.60	0.67	0.73	0.77	0.78	0.78	0.77	0.75	0.72	0.65	0.59
1-W	0.45	0.40	0.34	0.27	0.23	0.23	0.22	0.23	0.25	0.28	0.35	0.41
Wind Function f(u) =0.27(1+U/100)	0.98	1.01	1.05	1.05	1.08	1.06	1.04	1.01	1.00	0.98	0.98	0.98
Adjustment Factor C	0.99	0.98	1.03	1.02	1.03	1.05	1.07	1.06	1.04	1.02	0.99	0.98
Eto mm/day	**2.55**	**3.99**	**6.50**	**8.80**	**9.77**	**8.31**	**7.00**	**6.60**	**6.09**	**5.74**	**4.07**	**3.04**
Nos. of day in month	31	28	31	30	31	30	31	31	30	31	30	31
ETo mm/month	**79.13**	**111.71**	**201.42**	**263.99**	**302.91**	**249.30**	**217.11**	**204.47**	**182.62**	**177.85**	**122.10**	**94.12**

Table 15 Values of Weighting Factor (W) for the Effect of Radiation on ETo at Different Temperatures and Altitudes

Temperature °C	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
W at altitude m																				
0	0.43	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77*	.78	.80	.82	.83	.84	.85
500	.45	.48	.51	.54	.57	.60	.62	.65	.67	.70	.72	.74	.76	.78	.79	.81	.82	.84	.85	.86
1000	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.80	.82	.83	.85	.86	.87
2000	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.88
3000	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.88	.88	.89

Table 16 Adjustment Factor (c) in Presented Penman Equation

	RHmax = 30%				RHmax = 60%				RHmax = 90%			
Rs mm/day	3	6	9	12	3	6	9	12	3	6	9	12
Uday m/sec	Uday/Unight = 4.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.79	.84	.92	.97	.92	1.00	1.11	1.19	.99	1.10	1.27	1.32
6	.68	.77	.87	.93	.85	.96	1.11	1.19	.94	1.10	1.26	1.33
9	.55	.65	.78	.90	.76	.88	1.02	1.14	.88	1.01	1.16	1.27
	Uday/Unight = 3.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.76	.81	.88	.94	.87	.96	1.06	1.12	.94	1.04	1.18	1.28
6	.61	.68	.81	.88	.77	.88	1.02	1.10	.86	1.01	1.15	1.22
9	.46	.56	.72	.82	.67	.79	.88	1.05	.78	.92	1.06	1.18
	Uday/Unight = 2.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.69	.76	.85	.92	.83	.91	.99*	1.05*	.89	.98	1.10*	1.14*
6	.53	.61	.74	.84	.70	.80	.94	1.02	.79	.92	1.05	1.12
9	.37	.48	.65	.76	.59	.70	.84	.95	.71	.81	.96	1.06
	Uday/Unight = 1.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.64	.71	.82	.89	.78	.86	.94*	.99*	.85	.92	1.01*	1.05*
6	.43	.53	.68	.79	.62	.70	.84	.93	.72	.82	.95	1.00
9	.27	.41	.59	.70	.50	.60	.75	.87	.62	.72	.87	.96

Table 9 Saturation Vapour Pressure (ea) in mbar as Function of Mean Air Temperature (T) in °C y

Temperature °C	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ea mbar	6.1	6.6	7.1	7.6	8.1	8.7	9.3	10.0	10.7	11.5	12.3	13.1	14.0	15.0	16.1	17.0	18.2	19.4	20.6	22.0

Temperature °C	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
ea mbar	23.4	24.9	26.4	28.1	29.8	31.7	33.6	35.7	37.8	40.1	42.4	44.9	47.6	50.3	53.2	56.2	59.4	62.8	66.3	69.9

y Also actual vapour pressure (ed) can be obtained from this table using available Tdewpoint data. (Example: Tdewpoint is 18°C; ed is 20.6 mbar)

Table 10 Extra-terrestrial Radiation (Ra) expressed in equivalent evaporation in mm/day

Northern Hemisphere													Lat	Southern Hemisphere											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40°	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
6.9	9.0	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10.0	7.5	6.1	38	17.9	15.8	12.8	9.6	7.1	5.8	6.3	8.3	11.4	14.4	17.0	18.3
7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36	17.9	16.0	13.2	10.1	7.5	6.3	6.8	8.8	11.7	14.6	17.0	18.2
7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34	17.8	16.1	13.5	10.5	8.0	6.8	7.2	9.2	12.0	14.9	17.1	18.2
8.3	10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8	32	17.8	16.2	13.8	10.9	8.5	7.3	7.7	9.6	12.4	15.1	17.2	18.1
8.8	10.7	13.1	15.2	16.5	17.0	16.8	15.7	13.9	11.6	9.5	8.3	30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8	28	17.7	16.4	14.3	11.6	9.3	8.2	8.6	10.4	13.0	15.4	17.2	17.9
9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26	17.6	16.4	14.4	12.0	9.7	8.7	9.1	10.9	13.2	15.5	17.2	17.8
10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24	17.5	16.5	14.6	12.3	10.2	9.1	9.5	11.2	13.4	15.6	17.1	17.7
10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2	22	17.4	16.5	14.8	12.6	10.6	9.6	10.0	11.6	13.7	15.7	17.0	17.5
11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18	17.1	16.5	15.1	13.2	11.4	10.4	10.8	12.3	14.1	15.8	16.8	17.1
12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6	16	16.9	16.4	15.2	13.5	11.7	10.8	11.2	12.6	14.3	15.8	16.7	16.8
12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0	14	16.7	16.4	15.3	13.7	12.1	11.2	11.6	12.9	14.5	15.8	16.5	16.6
12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12	16.6	16.3	15.4	14.0	12.5	11.6	12.0	13.2	14.7	15.8	16.4	16.5
13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3	8	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0
13.9	14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7	6	15.8	16.0	15.6	14.7	13.4	12.8	13.1	14.0	15.0	15.7	15.8	15.7
14.3	15.0	15.5	15.5	14.9	14.4	14.6	15.1	15.3	15.1	14.5	14.1	4	15.5	15.8	15.6	14.9	13.8	13.2	13.4	14.3	15.1	15.6	15.5	15.4
14.7	15.3	15.6	15.3	14.6	14.2	14.3	14.9	15.3	15.3	14.8	14.4	2	15.3	15.7	15.7	15.1	14.1	13.5	13.7	14.5	15.2	15.5	15.3	15.1
15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8	0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

Table 11 Mean Daily Duration of Maximum Possible Sunshine Hours (N) for Different Months and Latitudes

Northern Latitudes / Southern Latitudes	Jan / July	Feb / Aug	Mar / Sept	Apr / Oct	May / Nov	June / Dec	July / Jan	Aug / Feb	Sept / Mar	Oct / Apr	Nov / May	Dec / June
40	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3
35	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8
30	10.4	11.1	12.0	12.9	13.6	14.0	13.9*	13.2	12.4	11.5	10.6	10.2
25	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
20	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
15	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
10	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
5	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

Table 12 Effect of Temperature f(T) on Longwave Radiation (Rnl)

T°C	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
$f(T) = \delta T k^4$	11.0	11.4	11.7	12.0	12.4	12.7	13.1	13.5	13.8	14.2	14.6	15.0	15.4	15.9	16.3*	16.7	17.2	17.7	18.1

Table 13 Effect of Vapour Pressure f(ed) on Longwave Radiation (Rnl)

ed mbar	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
$f(ed) = 0.34 - 0.044\sqrt{ed}$	0.23	.22	.20	.19	.18	.16	.15	.14	.13*	.12	.12	.11	.10	.09	.08	.08	.07	.06

Table 14 Effect of the Ratio Actual and Maximum Bright Sunshine Hours f(n/N) on Longwave Radiation (Rnl)

n/N	0	.05	.1	.15	.2	.25	.3	.35	.4	.45	.5	.55	.6	.65	.7	.75	.8	.85	.9	.95	1.0
$f(n/N) = 0.1 + 0.9n/N$	0.10	.15	.19	.24	.28	.33	.37	.42	.46	.51	.55	.60	.64	.69	.73	.78	.82*	.87	.91	.96	1.0

ANALYSIS OF RESULTS

5.1 General

Parametric study has been carried out for making optimal conjunctive use of surface water and ground water. The present chapter analysis the results of sixteen run of computer, which has been presented in Tabular from in Table 5.1 to 5.16. The effect of variation of the following parameters has been studied.

(a) Variation in cropping pattern when canal system is not existing.

(b) Variation in cropping pattern when canal systems exist.

(c) Variation in cropping pattern with 10% ground water mining.

5.2 Variation in cropping pattern when canal water is not existing.

The net annual benefit from surface and ground water irrigation systems have been analyzed in run – 1.

Run – 1

Details of run -1 are given in Table 5.1 and presented in Fig.5.1. In this run the crop constraints in imposed are based upon the existing pattern of crops cultivated in the study area. The maximum values of net benefit from ground water irrigation works is obtained as Rs. 1325.92 lakhs. It is observed that full ground water draft has been utilized.

5.3 Variation in cropping pattern when canal systems exist.

Run – 2

Details of run -2 are given in Table 5.2 and presented in Fig.5.2. In this run the crop constraints imposed are based upon the existing pattern of crops cultivated in the study area. The maximum value of net benefit from ground water irrigation works is obtained as Rs. 4317.35 lakhs. It is observed that full ground water draft has been utilized. Ground water withdrawal during the month of Jun., Jul., Aug. is not required as per optimal allocation due to surface water availability. The cropping intensity of 113.33% has been achieved as per optimal allocation.

Run - 3

Details of run -3 are given in Table 5.3 and presented in Fig.5.3. In this Run the effect of increase in area under Rice, Sugarcane, Groundnut and decrease in area

under Wheat, Maize, Barley, has been examined. The maximum value of net benefit has increased to Rs. 6288.65 lakhs by 45%. It is observed that full ground water draft has been utilized. Ground water withdrawal during the month of Jun., is not required as per optimal allocation. The cropping intensity of 120.86 % has been achieved as per optimal allocation.

Run - 4

Details of run -4 are given in Table 5.4 and presented in Fig.5.4. In this Run the effect of increase in area under Sugarcane and decrease in area under Groundnut has been examined. The maximum value of net benefit has increased to Rs. 6381.23 lakhs by 1.45%. It is observed that full ground water draft has been utilized and surface water utilized by 83%. Ground water withdrawal during the month of Jun is not required as per optimal allocation. The cropping intensity of 114.16 % has been achieved as per optimal allocation.

Run – 5

Details of run - 5 are given in Table 5.5 and presented in Fig.5.5. In this run the effect of increase in area under Sugarcane and decrease in area under gram has been examined. The maximum value of net benefit has increased to Rs. 6427.88 lakhs by 2.4 %. It is observed that full ground water draft has been utilized and surface water utilized by 86 %. Ground water withdrawal during the month of Jun is not required as per optimal allocation. The cropping intensity of 114.16 % has been achieved as per optimal allocation.

Run - 6

Details of run - 6 are given in Table 5.6 and presented in Fig.5.6. In this run the effect of increase in area under Rice, Sugarcane, Barley and decrease in area under gram pea and groundnut has been examined. The maximum value of net benefit has increased to Rs. 6684.10 lakhs by 3.83 %. It is observed that full ground water draft has been utilized and surface water utilized by 85 %. Ground water withdrawal during the month of June & September is not required as per optimal allocation. The cropping intensity of 129.10 % has been achieved as per optimal allocation.

Run – 7

Details of run - 7 are given in Table 5.7 and presented in Fig.5.7. In this run the effect of increase in area under maize, and decrease in area under sugarcane has been examined. The maximum value of net benefit is obtained to Rs. 6684.00 lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 85 %. Ground water withdrawal during the month of June & September is not required as per optimal allocation. The cropping intensity of 141.66 % has been achieved as per optimal allocation.

Run – 8

Details of run - 8 are given in Table 5.8 and presented in Fig.5.8. In this run the effect of increase in area under sugarcane, by 4.5% decreased in area under Maize, Jwar, pea and Gram has been examined. The maximum value of net benefit has increased to Rs. 6933.00 % lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 88 %. Ground water withdrawal during the month of June & September is not required as per optimal allocation. The cropping intensity of 120.65 % has been achieved as per optimal allocation.

Run – 9

Details of run - 9 are given in Table 5.9 and presented in Fig.5.9. In this run the effect of increase in area under sugarcane, decreased in area under gram has been examined. The maximum value of net benefit has increased to Rs. 6979.00 lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 87 %. ground water withdrawal during the month of June & September is not required as per optimal allocation. The cropping intensity of 118.45 % has been achieved as per optimal allocation.

Run – 10

Details of run - 10 are given in Table 5.10 and presented in Fig.5.10. In this run the effect of increase in area under sugarcane, decreased in area under gram groundnut, potato has been examined. The maximum value of net benefit has increased to Rs. 7018.76 lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 88 %. ground water withdrawal during the month of June & August is not required as per optimal allocation. The cropping intensity of 108.12 % has been achieved as per optimal allocation.

Run – 11

Details of run - 11 are given in table 5.11 and presented in Fig.5.1.. In this run the effect of increase in area under potato by 3% decreased in area under sugarcane, by 0.5 % has been examined. The maximum value of net benefit has increased to Rs. 7097.10 lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 86 %. Ground water withdrawal during the month of June & August is not required as per optimal allocation. The cropping intensity of 109.92 % has been achieved as per optimal allocation.

Run – 12

Details of run - 12 are given in table 5.12 and presented in Fig.5.1.. In this run the effect of increase in area under groundnut by 6 %, sugarcane by 2.3% decreased in area under potato by 6 % has been examined. The maximum value of net benefit has increased to Rs. 7455.40 lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 88 %. ground water withdrawal during the month of June & August is not required as per optimal allocation. The cropping intensity of 115.64 % has been achieved as per optimal allocation.

Run – 13

Details of run - 13 are given in Table 5.13 and presented in Fig.5.1.. In this run the effect of increase in area under Potato by 6 % decreased in area under sugarcane by 2.3% has been examined. The maximum value of net benefit has increased to Rs. 7477.72 lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 89 %. ground water withdrawal during the month of June is not required as per optimal allocation. The cropping intensity of 116.11 % has been achieved as per optimal allocation.

Run – 14

Details of run - 14 are given in Table 5.14 and presented in Fig.5.1.. In this run the effect of increase in area under sugarcane decreased in area under potato has been examined. The maximum value of net benefit has increased to Rs. 7517.44 lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 86 %. ground water withdrawal during the month of June is not required as per

optimal allocation. The cropping intensity of 111.17 % has been achieved as per optimal allocation.

Run – 15

Details of run – 15 are given in Table 5.1 and presented in Fig.5.1. 5. In this run the effect of increase in area under potato groundnut decreased in area under sugarcane has been examined. The maximum value of net benefit has increased to Rs. 7522.35 lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 86 %. ground water withdrawal during the month of June is not required as per optimal allocation. The cropping intensity of 117.04 % has been achieved as per optimal allocation.

Run – 16

Details of run – 16 are given in table 5.16 and presented in Fig.5.1. In this run the effect of increase in area under potato decreased in area under sugarcane has been examined. The maximum value of net benefit has increased to Rs. 8013.00 lakhs. It is observed that full ground water draft has been utilized and surface water utilized by 86 %. ground water withdrawal during the month of June is not required as per optimal allocation. The cropping intensity of 127.28 % has been achieved as per optimal allocation.

Table 5.1 Cropping pattern and allocation of water : without canal (Run - 1)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		Canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	2.86	500.00	Jan	0.000	516.56
2	Wheat	11.44	2000.00	5.72	1000.00	Feb	0.000	638.51
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	201.93
4	Barley	2.86	500.00	2.86	500.00	Apr	0.000	56.28
5	Jwar	8.58	1500.00	8.58	1500.00	May	0.000	47.31
6	Gram	11.44	2000.00	5.72	1000.00	Jun	0.000	83.83
7	Pea	10.86	1900.00	5.72	1000.00	Jul	0.000	434.40
8	Groundnut	11.44	2000.00	5.72	1000.00	Aug	0.000	779.61
9	Potato	5.15	900.00	5.72	1000.00	Sep	0.000	1207.78
10	Berseem	0.51	90.00	0.51	90.00	Oct	0.000	1028.44
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	623.37
12	Sugarcane	8.58	1500.00	0.77	135.00	Dec	0.000	527.91
		100.00	17490.00	47.60	8325.00		0.000	6145.93

Maximum value of net benefits from Irrigation works = Rs.1325.92 lakhs

Annual ground water draft < 6150 H.M.

Utilization of ground water =99.91%

Fig 5.1 Optimal releases of surface and ground water : (Run - 1)

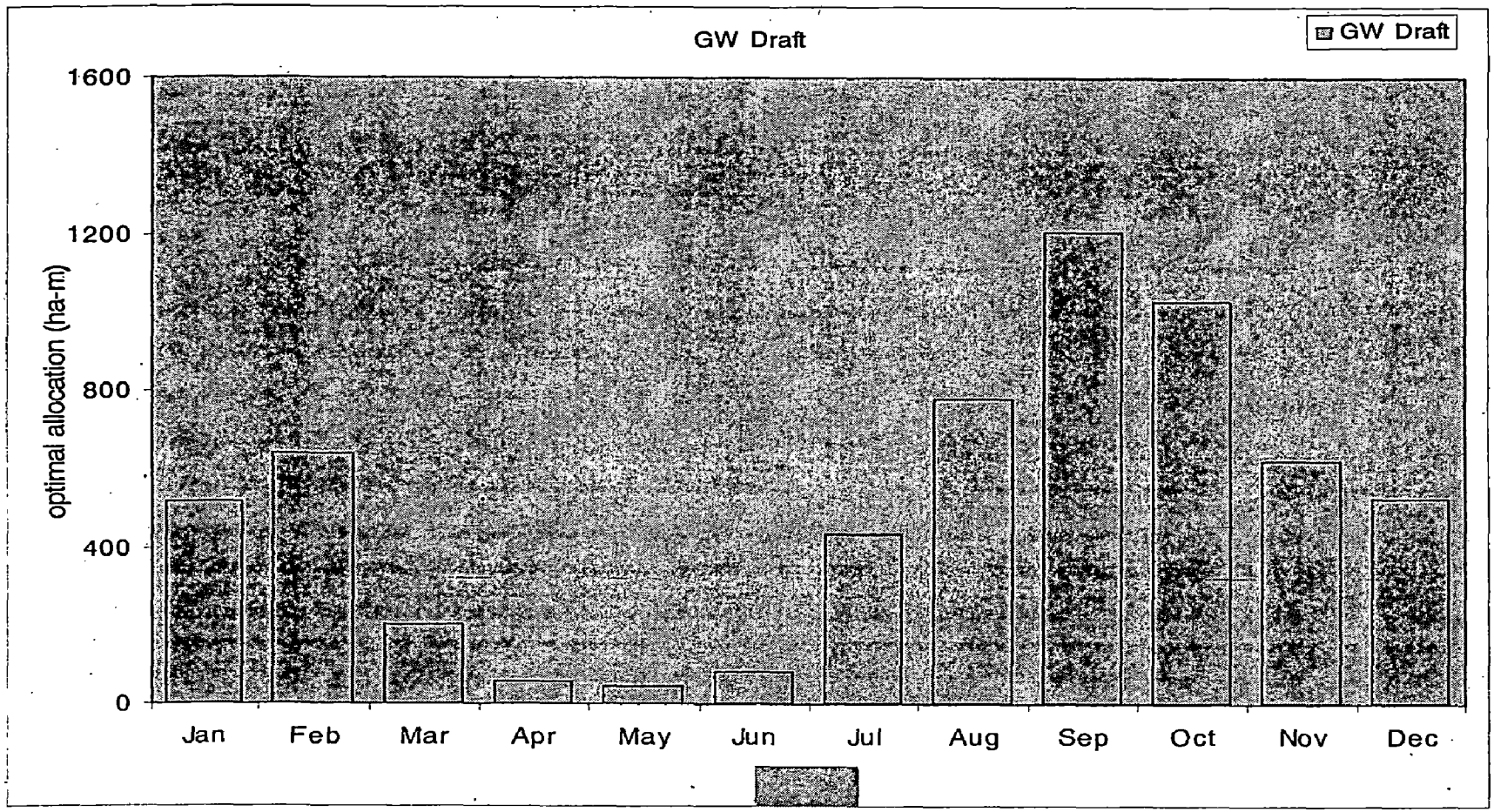


Table 5.2 Cropping pattern and allocation of water under existing condition (Run - 2)								
S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	24.87	4350.00	24.87	4350.00	Jan	0.000	1183.22
2	Wheat	34.82	6090.00	34.82	6090.00	Feb	0.000	1539.41
3	Maize	2.24	391.00	2.24	391.00	Mar	0.000	1212.41
4	Barley	1.74	304.00	1.74	304.00	Apr	0.000	608.40
5	Jwar	17.91	3132.00	17.91	3132.00	May	0.000	998.54
6	Gram	4.97	870.00	4.97	870.00	Jun	1483.940	0.00
7	Pea	1.99	348.00	1.99	348.00	Jul	4201.170	0.00
8	Groundnut	4.93	863.00	4.93	863.00	Aug	3770.460	0.00
9	Potato	0.59	104.00	0.59	104.00	Sep	3732.530	1287.57
10	Berseem	0.27	48.00	0.27	48.00	Oct	0.000	3262.06
11	Bajra	2.68	469.00	2.68	469.00	Nov	0.000	1685.17
12	Sugarcane	16.31	2853.00	16.31	2853.00	Dec	0.000	962.73
		113.33	19822.00	113.33	19822.00		13188.100	12739.51
Maximum value of net benefits from Irrigation works = Rs. 4317.35 lakhs Annual canal water diversions < 24867.64 H.M. (water available at outlet) Annual ground water draft < 14001.00H.M.								

Fig 5.2 Optimal releases of surface and ground water : (Run - 2)

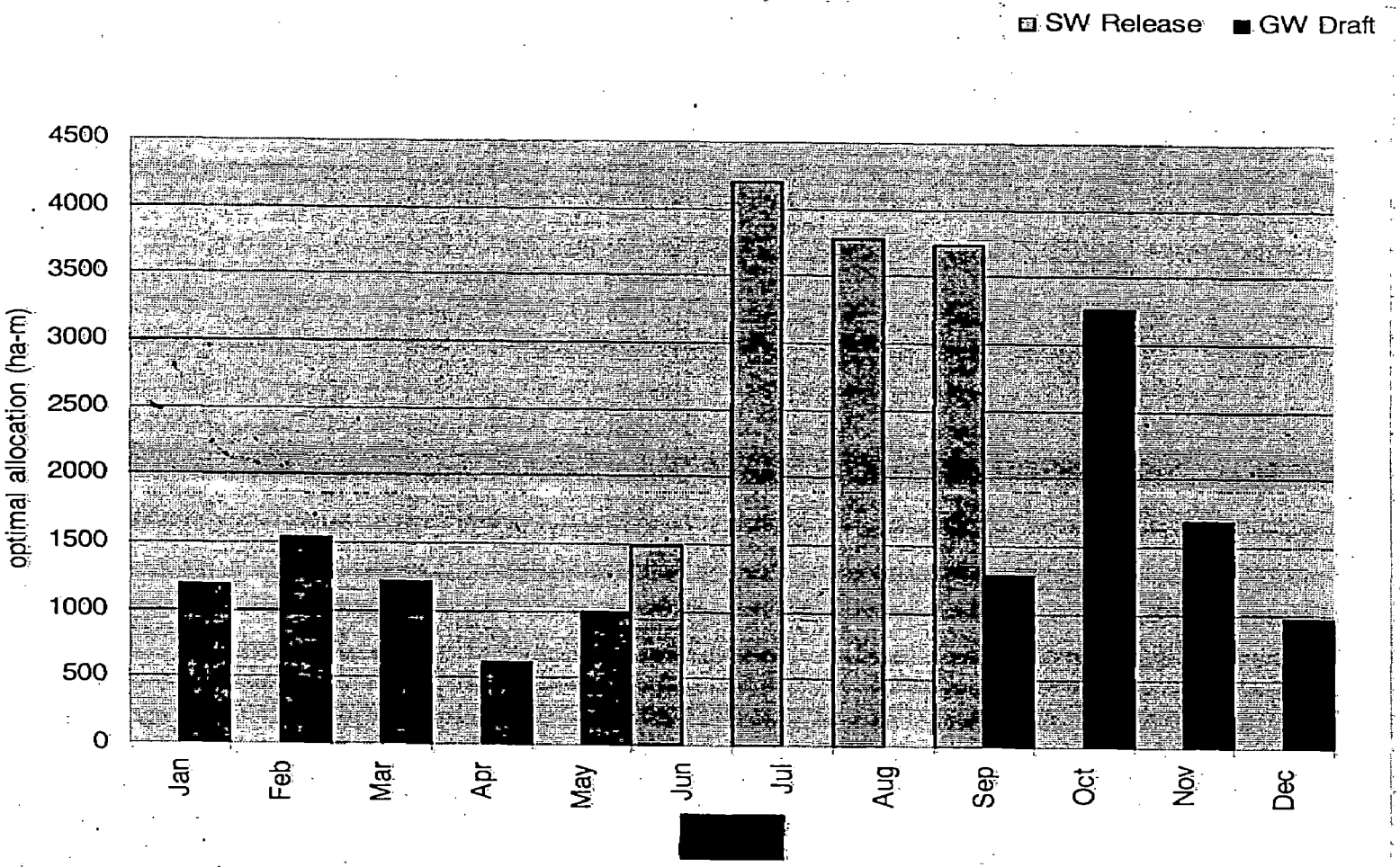


Table 5.3 Alternate cropping pattern with availability of surface water (Run - 3)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	31.45	5500.00	Jan	0.000	1083.69
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1434.99
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1120.28
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	999.08
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	428.45
6	Gram	11.44	2000.00	8.58	1500.00	Jun	2525.460	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	1179.97
8	Groundnut	11.44	2000.00	11.44	2000.00	Aug	4590.000	97.47
9	Potato	5.15	900.00	5.15	900.00	Sep	4590.000	1491.96
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	2093.09
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1599.58
12	Sugarcane	8.58	1500.00	28.87	5049.00	Dec	0.000	1200.39
		100.00	17490.00	120.86	21139.00		19547.370	12728.95

Maximum value of net benefits from Irrigation works = Rs. 6288.65 lakhs

Annual canal water diversions <19547.37 H.M.

Annual ground water draft < 12729 H.M.

Utilization of ground water =99.99%

Fig 5.3 Optimal releases of surface and ground water : (Run - 3)

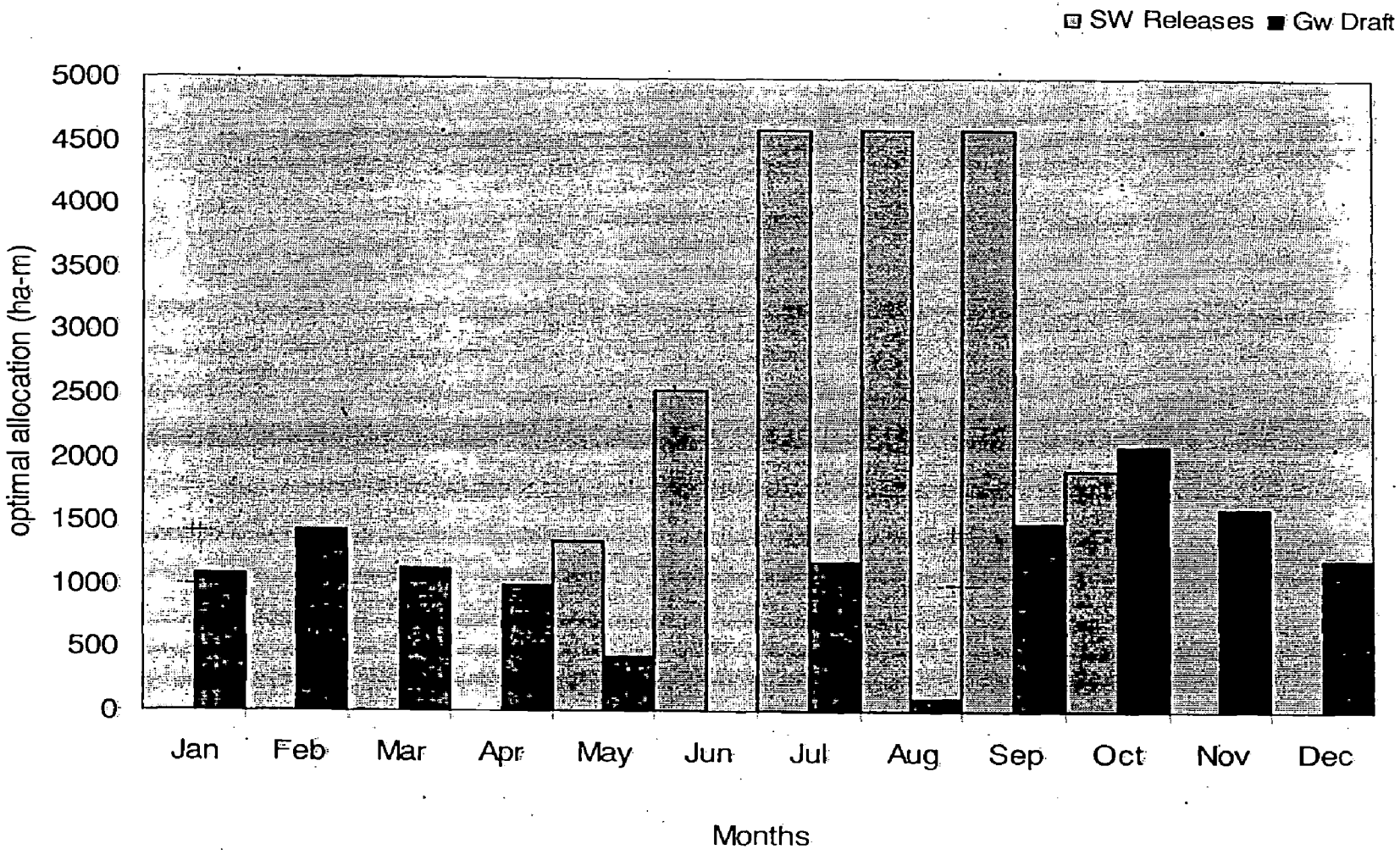


Table 5.4 Alternate cropping pattern with availability of surface water (Run - 4)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	31.45	5500.00	Jan	0.000	1106.60
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1467.71
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1172.65
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	1061.26
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	542.99
6	Gram	11.44	2000.00	8.58	1500.00	Jun	2672.730	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	1263.43
8	Groundnut	11.44	2000.00	2.86	500.00	Aug	4590.000	76.47
9	Potato	5.15	900.00	5.15	900.00	Sep	4590.000	1314.42
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	1871.63
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1618.68
12	Sugarcane	8.58	1500.00	30.74	5377.19	Dec	0.000	1233.11
		100.00	17490.00	114.16	19967.19		19694.640	12728.95

Maximum value of net benefits from Irrigation works = Rs. 6381.23 lakhs

Annual canal water diversions <24867.64 H.M. (water available at outlet)

Annual ground water draft < 12729 H.M.

Utilization of ground water =99.99%

Fig 5.4Optimal releases of surface and ground water: (Run - 4)

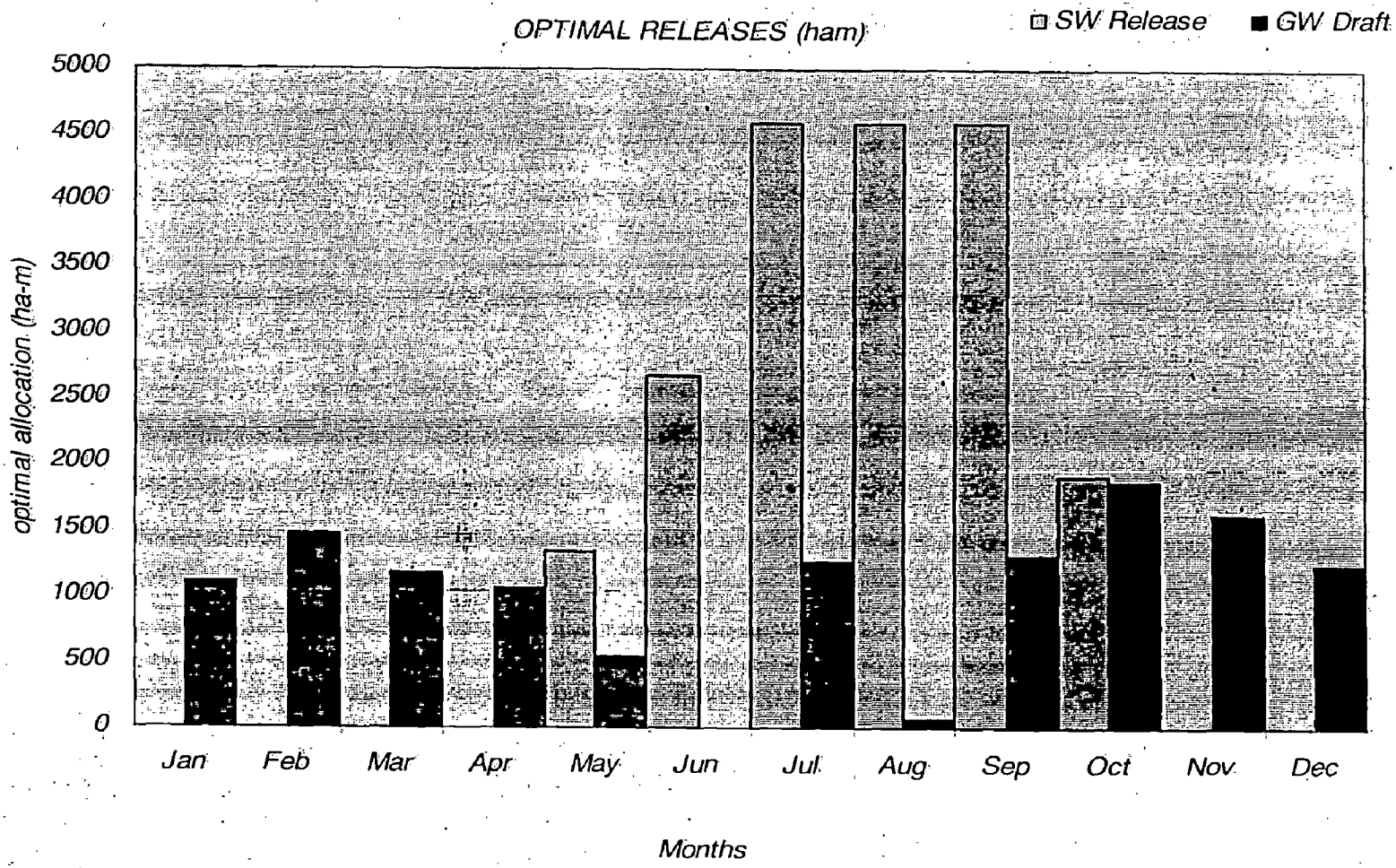


Table 5.5 Alternate cropping pattern with availability of surface water (Run - 5)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	31.45	5500.00	Jan	0.000	1018.32
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1383.60
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1173.86
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	1087.64
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	591.59
6	Gram	11.44	2000.00	4.57	800.00	Jun	2735.210	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	1306.47
8	Groundnut	11.44	2000.00	2.86	500.00	Aug	4590.000	122.29
9	Potato	5.15	900.00	5.15	900.00	Sep	4590.000	1372.73
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	1897.95
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1597.50
12	Sugarcane	8.58	1500.00	31.54	5516.03	Dec	0.000	1177.00
		100.00	17490.00	110.96	19406.03		19757.120	12728.95

Maximum value of net benefits from Irrigation works = Rs. 6427.88 lakhs

Annual canal water diversions <24867.64 H.M. (water available at outlet)

Annual ground water draft < 12729 H.M.

Utilization of ground water =99.99%

Fig 5.5 Optimal releases of surface and ground water: (Run - 5)

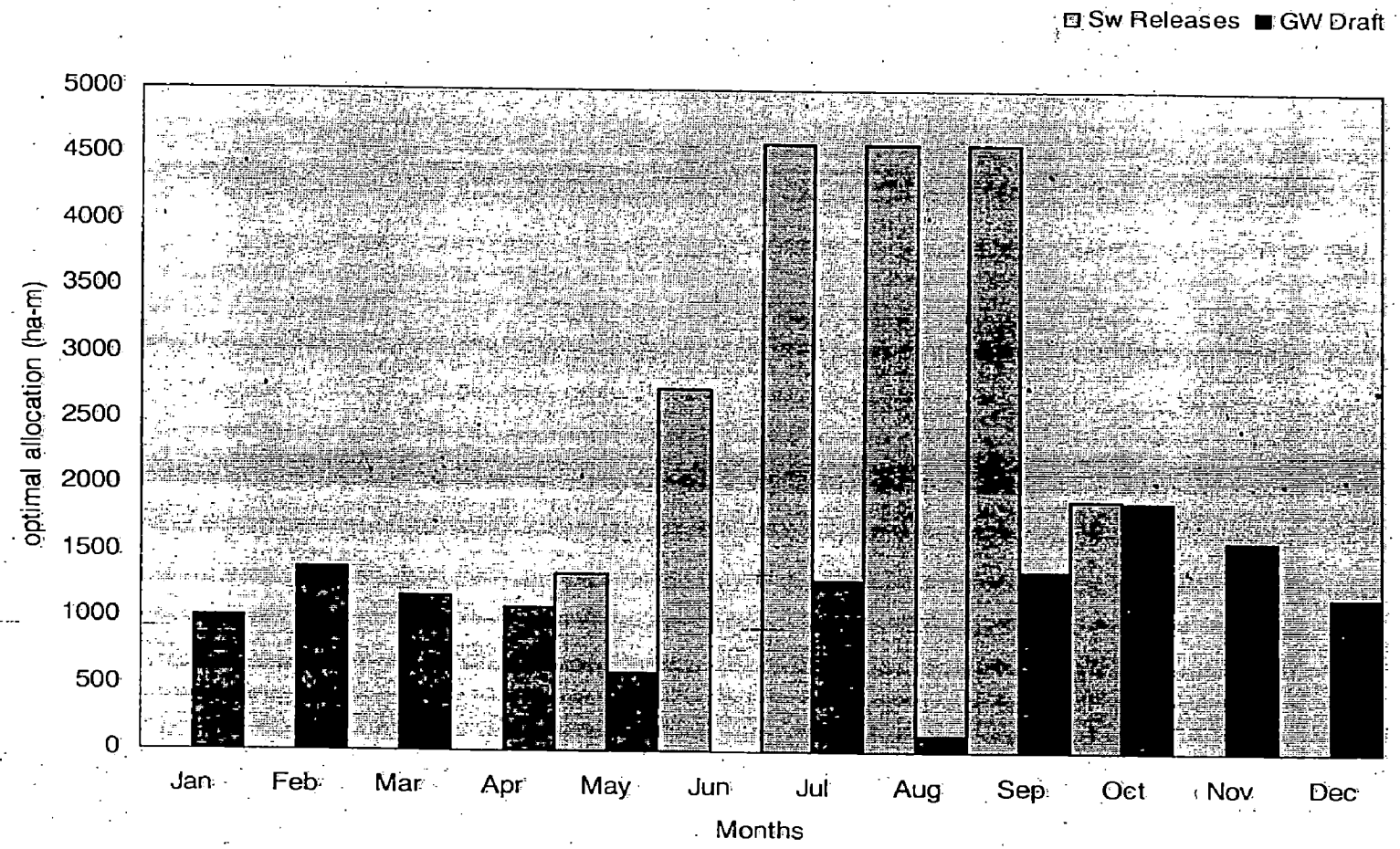


Table5.6 Alternate cropping pattern with availability of surface water (Run - 6)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1360.46
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1761.08
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1203.83
4	Barley	2.86	500.00	2.86	500.00	Apr	0.000	1044.86
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	512.78
6	Gram	11.44	2000.00	17.15	3000.00	Jun	2587.880	0.00
7	Pea	9.72	1700.00	12.58	2200.00	Jul	4590.000	494.66
8	Groundnut	10.29	1800.00	11.44	2000.00	Aug	4326.980	0.00
9	Potato	4.57	800.00	5.15	900.00	Sep	4590.000	1073.16
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	2016.90
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1844.72
12	Sugarcane	11.44	2000.00	30.25	5290.00	Dec	0.000	1416.48
		100.00	17490.00	129.10	22580.00		19346.770	12728.93

Maximum value of net benefits from Irrigation works = Rs. 6684.00 lakhs

Annual canal water diversions <19346.77H.M.

Annual ground water draft < 12729 H.M.

Utilization of ground water = 99.9%

Fig 5.6 Optimal releases of surface and ground water: (Run – 6)

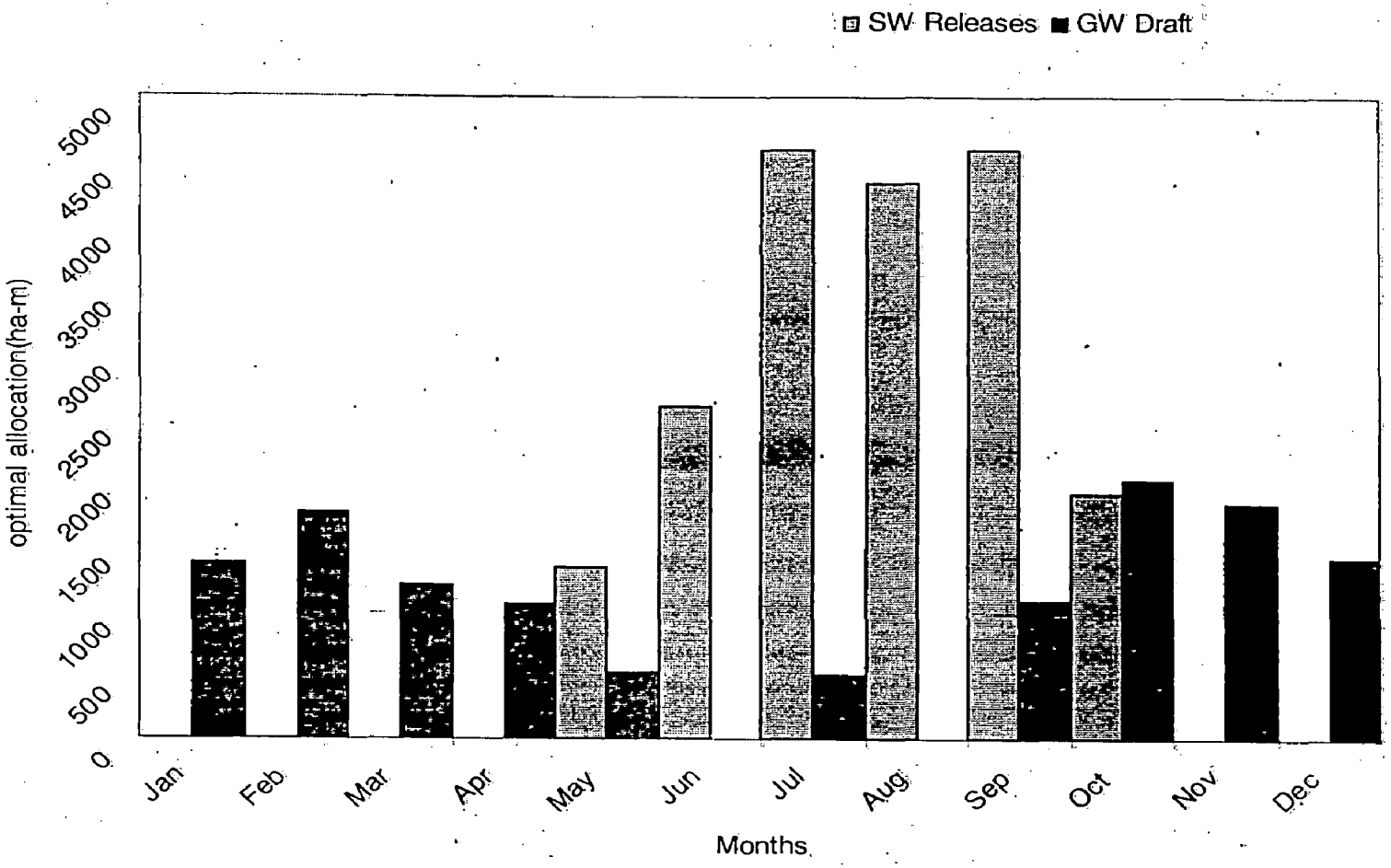


Table5.7 Alternate cropping pattern with availability of surface water (Run - 7)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1344.10
2	Wheat	10.01	1750.00	11.44	2000.00	Feb	0.000	1737.72
3	Maize	0.86	150.00	16.75	2929.39	Mar	0.000	1166.45
4	Barley	2.86	500.00	2.86	500.00	Apr	0.000	1000.47
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	431.00
6	Gram	17.15	3000.00	17.15	3000.00	Jun	2482.000	0.00
7	Pea	12.58	2200.00	12.58	2200.00	Jul	4590.000	424.00
8	Groundnut	11.44	2000.00	11.44	2000.00	Aug	4590.000	0.00
9	Potato	5.15	900.00	5.15	900.00	Sep	4590.000	1339.44
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	2082.31
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1809.68
12	Sugarcane	4.57	800.00	28.91	5057.22	Dec	0.000	1393.00
		100.00	17490.00	141.66	24776.61		19503.910	12728.17

Maximum value of net benefits from Irrigation works = Rs. 6684.00 lakhs

Annual canal water diversions <19503 H.M.

Annual ground water draft < 12729 H.M.

Utilization of ground water = 99.9%

Fig 5.7 Optimal releases of surface and ground water: (Run – 7)

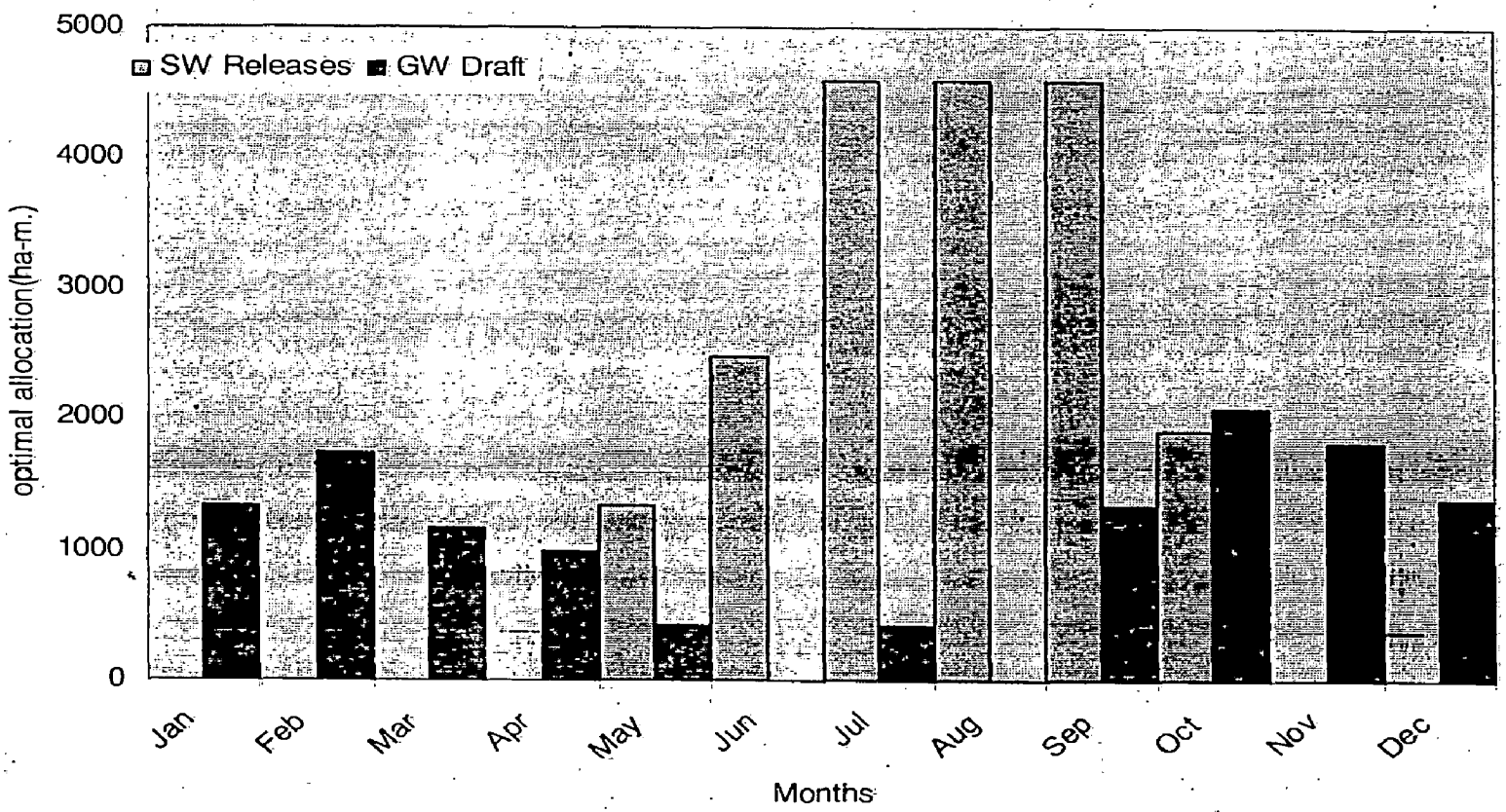


Table 5.8 Alternate cropping patterns with availability of surface water (Run - 8)

S.No.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1186.96
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1533.23
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1257.28
4	Barley	2.86	500.00	2.86	500.00	Apr	0.000	1143.95
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	695.31
6	Gram	11.44	2000.00	11.44	2000.00	Jun	2822.570	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	656.34
8	Groundnut	11.44	2000.00	11.44	2000.00	Aug	4499.090	0.00
9	Potato	5.15	900.00	5.15	900.00	Sep	4590.000	1292.20
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	1962.08
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1722.95
12	Sugarcane	8.58	1500.00	33.23	5812.39	Dec	0.000	1278.63
		100.00	17490.00	120.65	21102.39		19753.570	12728.93

Maximum value of net benefits from Irrigation works = Rs. 6933.00 lakhs

Annual canal water diversions <19753.57 H.M.

Annual ground water draft < 12729 H.M.

Utilization of ground water = 99.9%

Fig 5.8 Optimal releases of surface and ground water: (Run – 8)

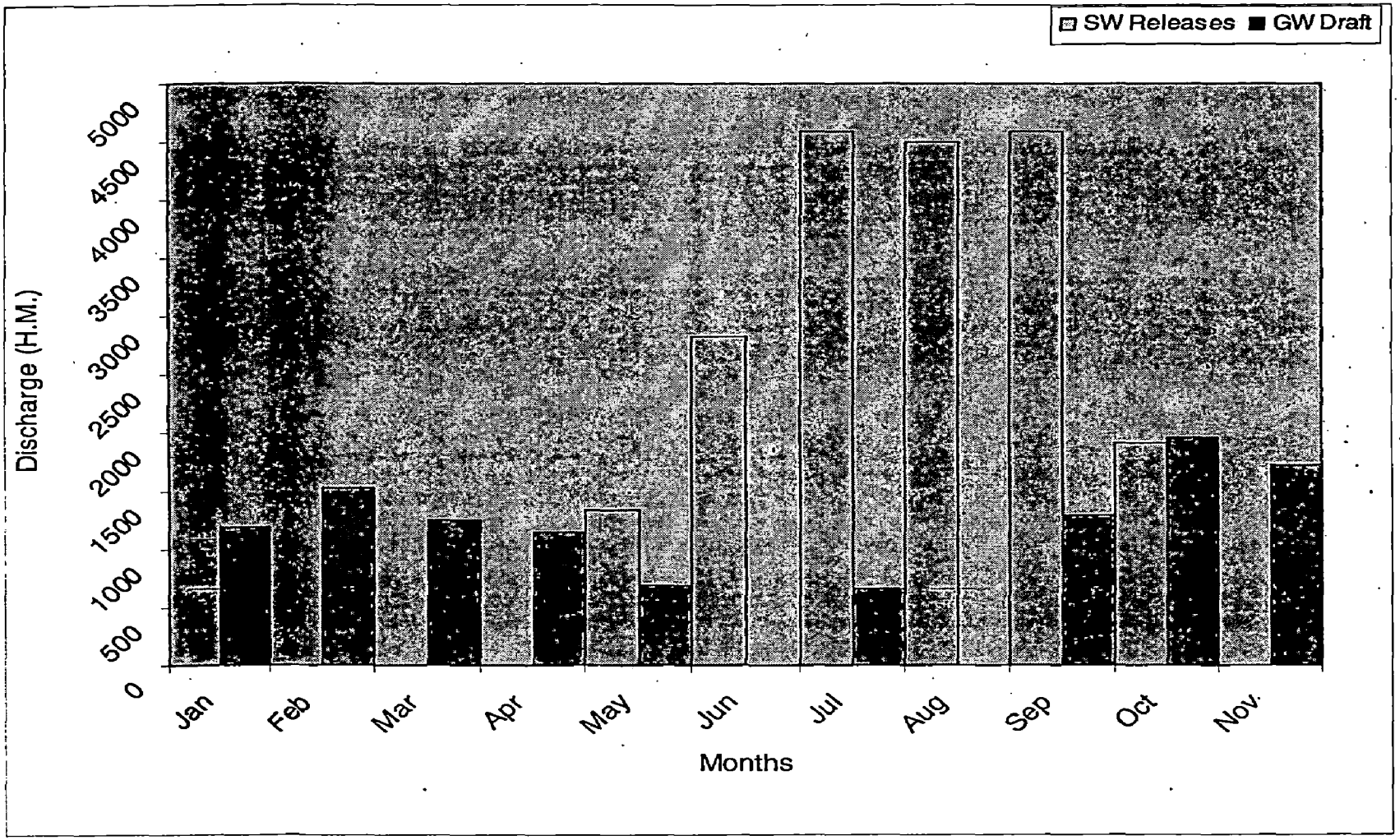


Table 5.9 Alternate cropping pattern with availability of surface water (Run - 9)								
S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1125.06
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1474.72
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1260.65
4	Barley	2.86	500.00	2.86	500.00	Apr	0.000	1165.75
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	735.51
6	Gram	11.44	2000.00	8.58	1500.00	Jun	2874.250	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	691.94
8	Groundnut	11.44	2000.00	11.44	2000.00	Aug	4536.980	0.00
9	Potato	5.15	900.00	5.15	900.00	Sep	4590.000	1340.43
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	1984.64
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1710.18
12	Sugarcane	8.58	1500.00	33.89	5927.22	Dec	0.000	1240.12
		100.00	17490.00	118.45	20717.22		19843.140	12729.00
Maximum value of net benefits from Irrigation works = Rs. 6979.5600 lakhs Annual canal water diversions <19843.00 H.M. Annual ground water draft = 12729 H.M. *Utilization of ground water =100%*								

Fig 5.9 Optimal releases of surface and ground water: (Run – 9)

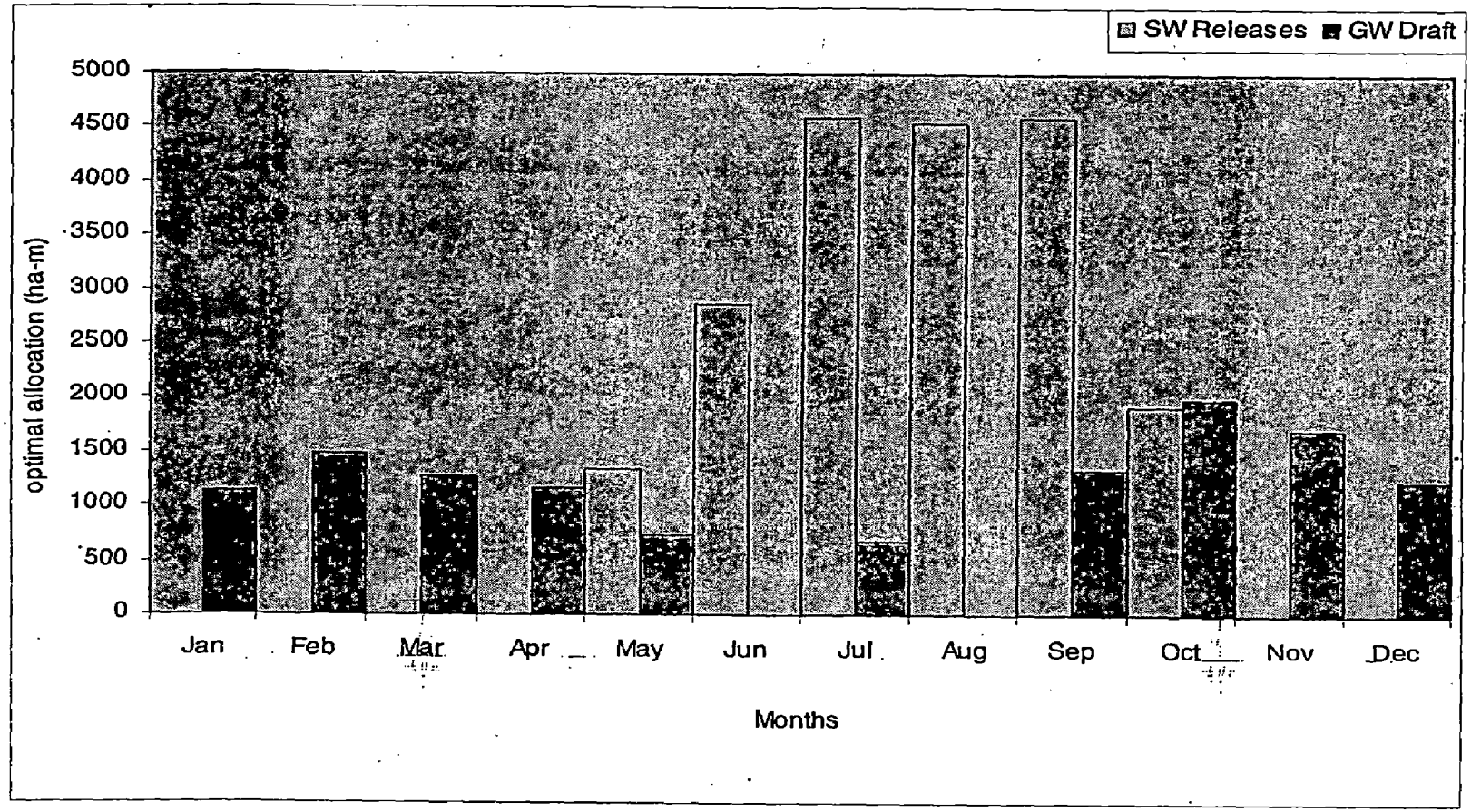


Table 5.10 Alternate cropping pattern with availability of surface water (Run -10)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1033.70
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1442.14
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1318.73
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	1259.67
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	908.48
6	Gram	11.44	2000.00	4.57	800.00	Jun	3096.640	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	827.14
8	Groundnut	11.44	2000.00	2.86	500.00	Aug	4571.070	0.00
9	Potato	5.15	900.00	2.86	500.00	Sep	4590.000	1233.00
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	1805.25
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1693.31
12	Sugarcane	8.58	1500.00	36.71	6421.00	Dec	0.000	1207.54
		100.00	17490.00	108.12	18911.00		20099.620	12728.96

Maximum value of net benefits from Irrigation works = Rs. 7018.76 lakhs

Annual canal water diversions < 24867.64 H.M. (water available at outlet)

Annual ground water draft < 12729 H.M.

Utilization of ground water =99.99%

Fig 5.10 Optimal releases of surface and ground water: (Run – 10)

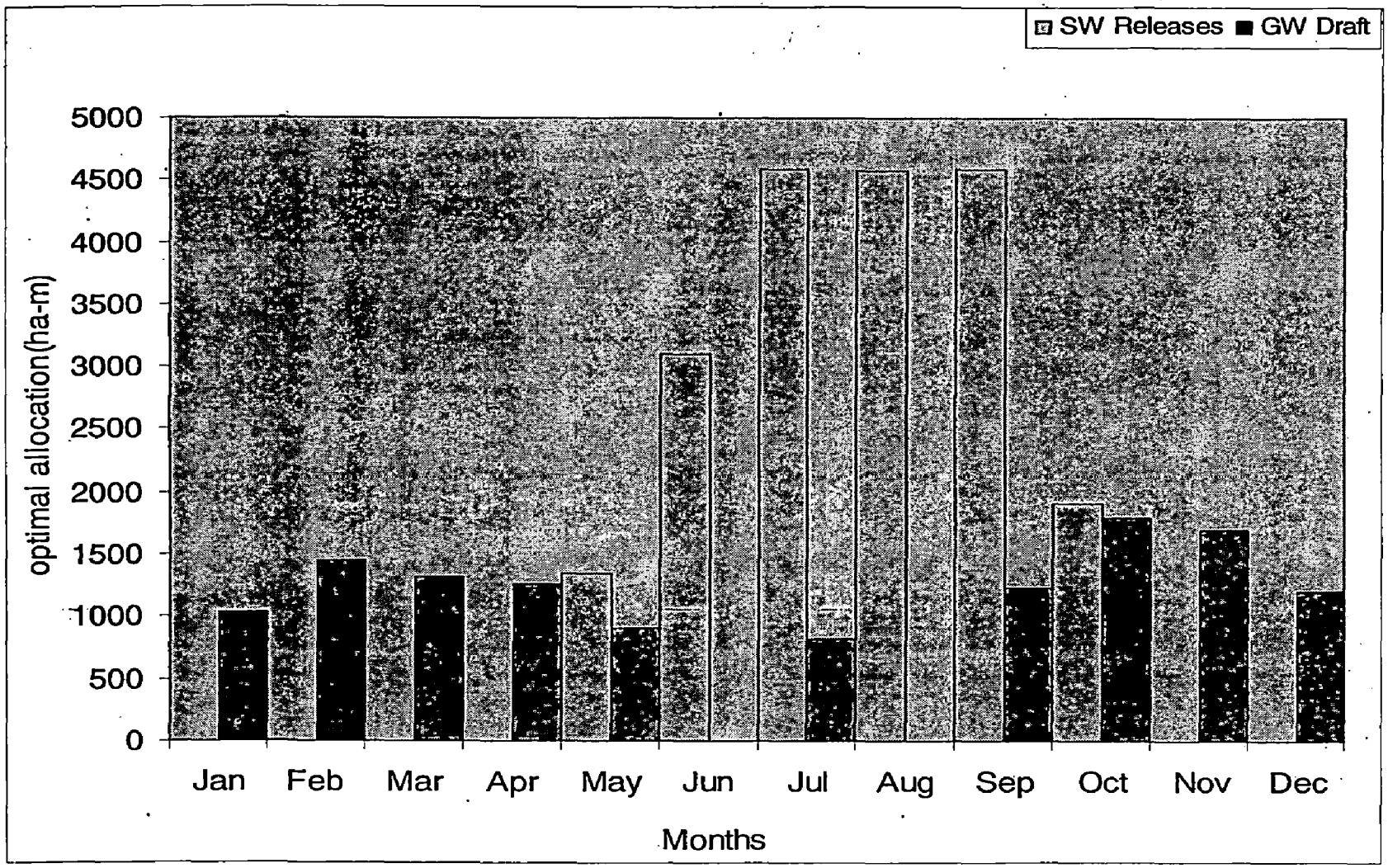


Table 5.11 Alternate cropping pattern with availability of surface water (Run -11)								
S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1075.67
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1465.53
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1304.95
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	1243.31
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	878.34
6	Gram	11.44	2000.00	4.57	800.00	Jun	3057.890	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	800.44
8	Groundnut	11.44	2000.00	2.86	500.00	Aug	4542.650	0.00
9	Potato	5.15	900.00	5.15	900.00	Sep	4590.000	1196.83
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	1784.58
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1720.39
12	Sugarcane	8.58	1500.00	36.22	6335.31	Dec	0.000	1258.93
		100.00	17490.00	109.92	19225.31		20032.450	12728.97
Maximum value of net benefits from Irrigation works = Rs. 7097.84 lakhs Annual canal water diversions < 24867.64 H.M. (water available at outlet) Annual ground water draft < 12729 H.M. Utilization of ground water =99.99%								

Fig 5.11 Optimal releases of surface and ground water: (Run – 11)

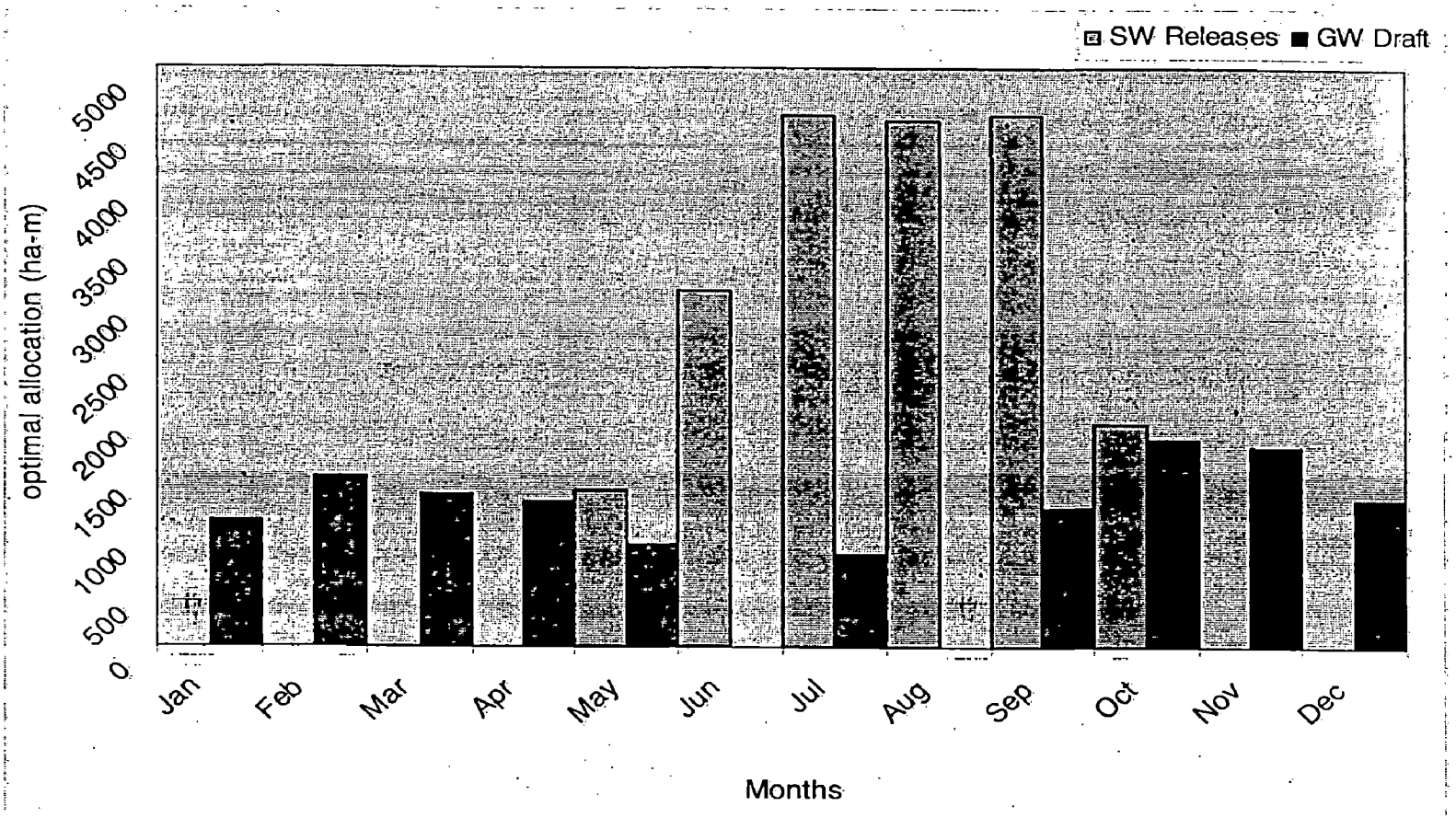


Table 5.12 Alternate cropping pattern with availability of surface water with 10% mining (Run -12)								
S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1055.76
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1473.66
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1369.17
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	1319.57
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	1018.82
6	Gram	11.44	2000.00	4.57	800.00	Jun	3238.510	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	936.87
8	Groundnut	11.44	2000.00	8.58	1500.00	Aug	4590.000	171.11
9	Potato	5.15	900.00	2.86	500.00	Sep	4590.000	1575.41
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	2080.91
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1760.60
12	Sugarcane	8.58	1500.00	38.51	6736.00	Dec	0.000	1239.06
		100.00	17490.00	115.64	20226.00		20260.420	14000.94
Maximum value of net benefits from Irrigation works = Rs. 7455.40 lakhs								
Annual canal water diversions < 24867.64 H.M. (water available at outlet)								
Annual ground water draft < 14001.00H.M.								
Utilization of ground water =99.99%								

Fig 5.12 Optimal releases of surface and ground water: (Run – 12)

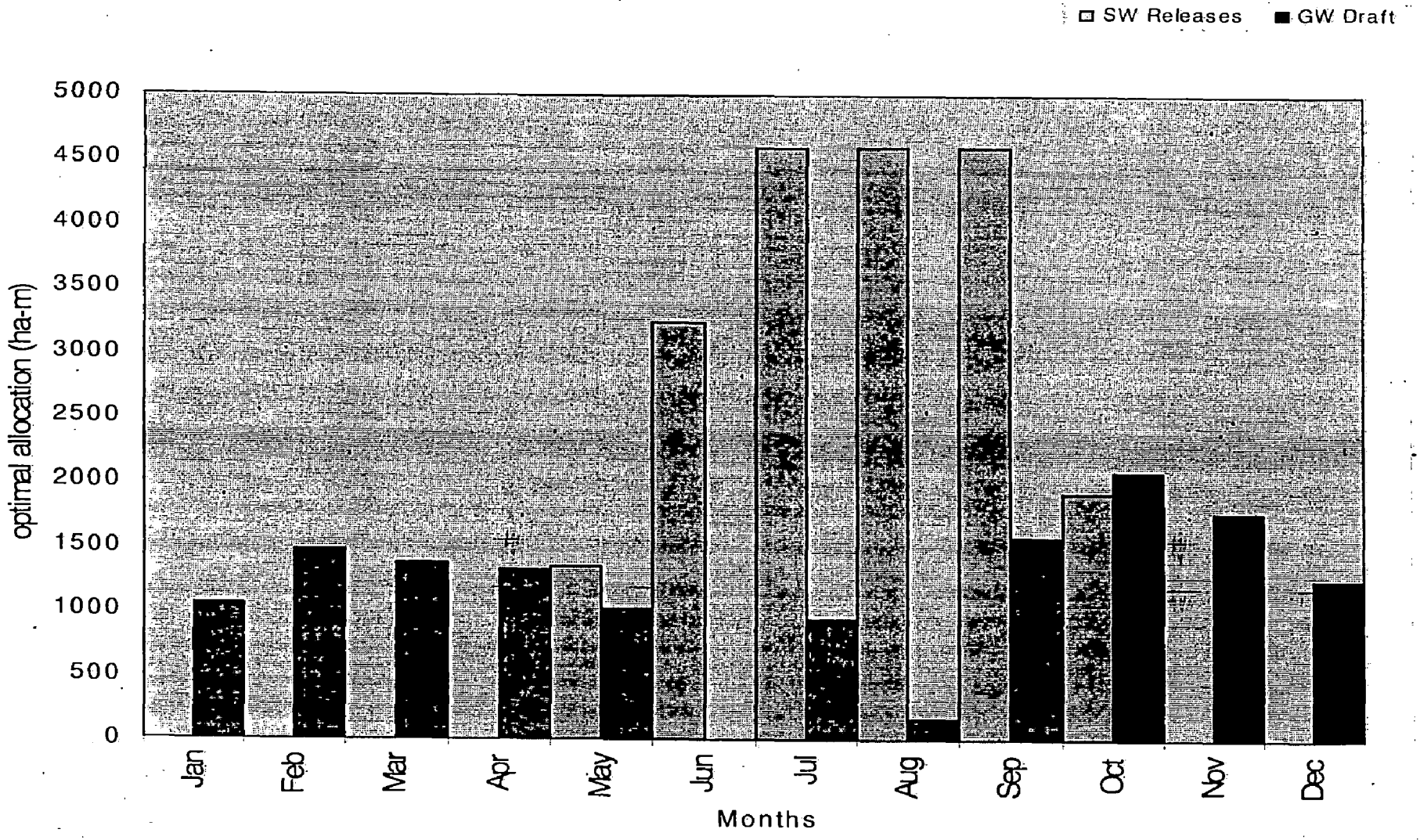


Table 5.13 Alternate cropping pattern with availability of surface water with 10% mining (Run -13)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1066.46
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1479.81
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1366.19
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	1316.03
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	1012.31
6	Gram	11.44	2000.00	4.57	800.00	Jun	3230.140	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	931.11
8	Groundnut	11.44	2000.00	8.58	1500.00	Aug	4590.000	164.97
9	Potato	5.15	900.00	3.43	600.00	Sep	4590.000	1567.60
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	2076.45
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1767.81
12	Sugarcane	8.58	1500.00	38.41	6718.00	Dec	0.000	1252.21
		100.00	17490.00	116.11	20308.00		20252.050	14000.95

Maximum value of net benefits from Irrigation works = Rs. 7477.72 lakhs

Annual canal water diversions < 24867.64 H.M. (water available at outlet)

Annual ground water draft < 14001.00H.M.

Utilization of ground water =99.99%

Fig 5.13 Optimal releases of surface and ground water: (Run – 13)

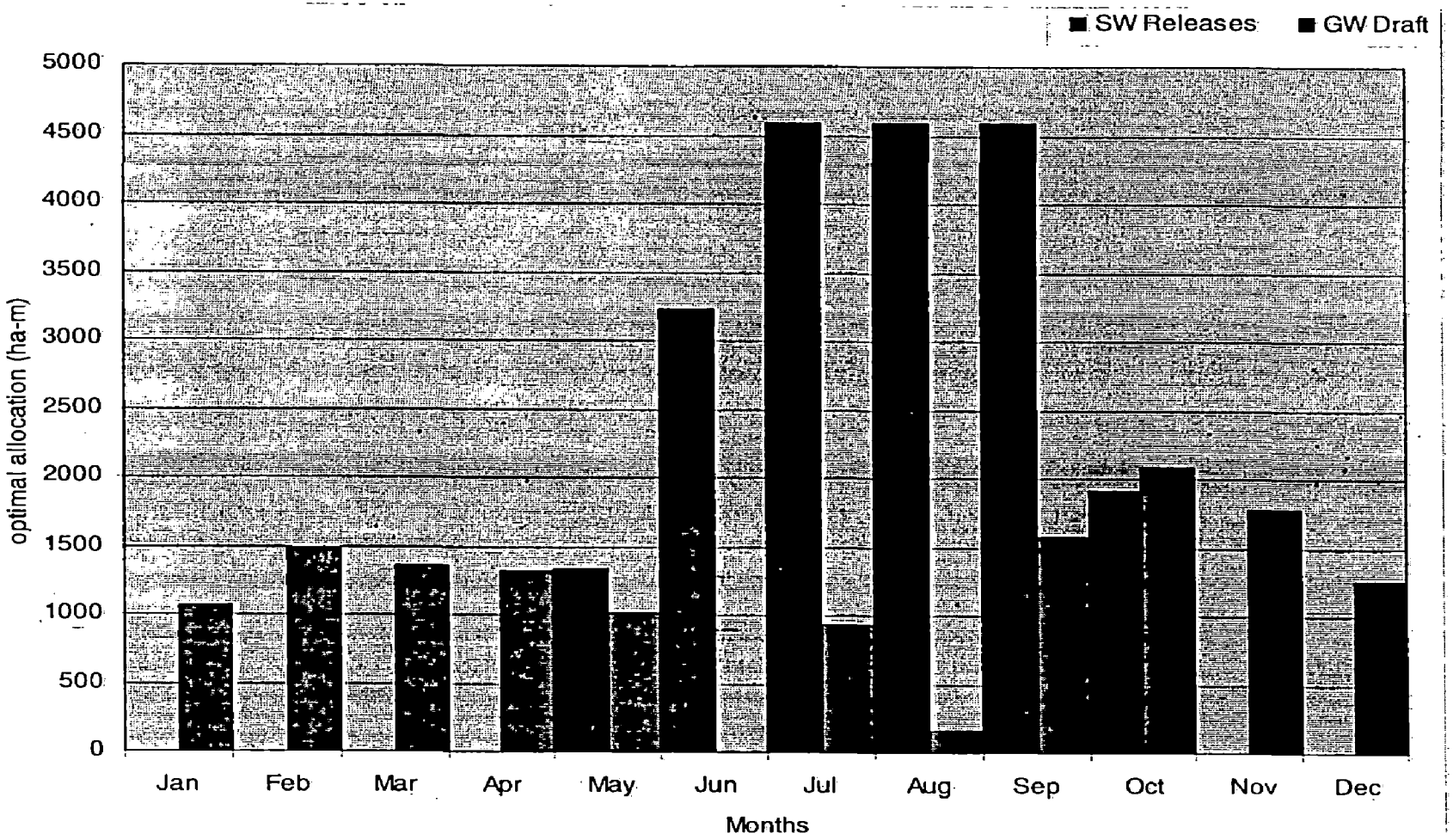


Table 5.14 Alternate cropping pattern with availability of surface water with 10% mining (Run -14)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1071.04
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1495.48
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1404.08
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	1361.02
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	1095.18
6	Gram	11.44	2000.00	4.57	800.00	Jun	3336.690	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	992.51
8	Groundnut	11.44	2000.00	2.86	500.00	Aug	4590.000	157.11
9	Potato	5.15	900.00	2.86	500.00	Sep	4590.000	1457.04
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	1933.28
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1773.33
12	Sugarcane	8.58	1500.00	39.76	6954.00	Dec	0.000	1260.88
		100.00	17490.00	111.17	19444.00		20358.600	14000.95

Maximum value of net benefits from Irrigation works = Rs. 7517.44 lakhs

Annual canal water diversions < 24867.64 H.M. (water available at outlet)

Annual ground water draft < 14001.00H.M.

Utilization of ground water =99.99%

Fig 5.14 Optimal releases of surface and ground water: (Run – 14)

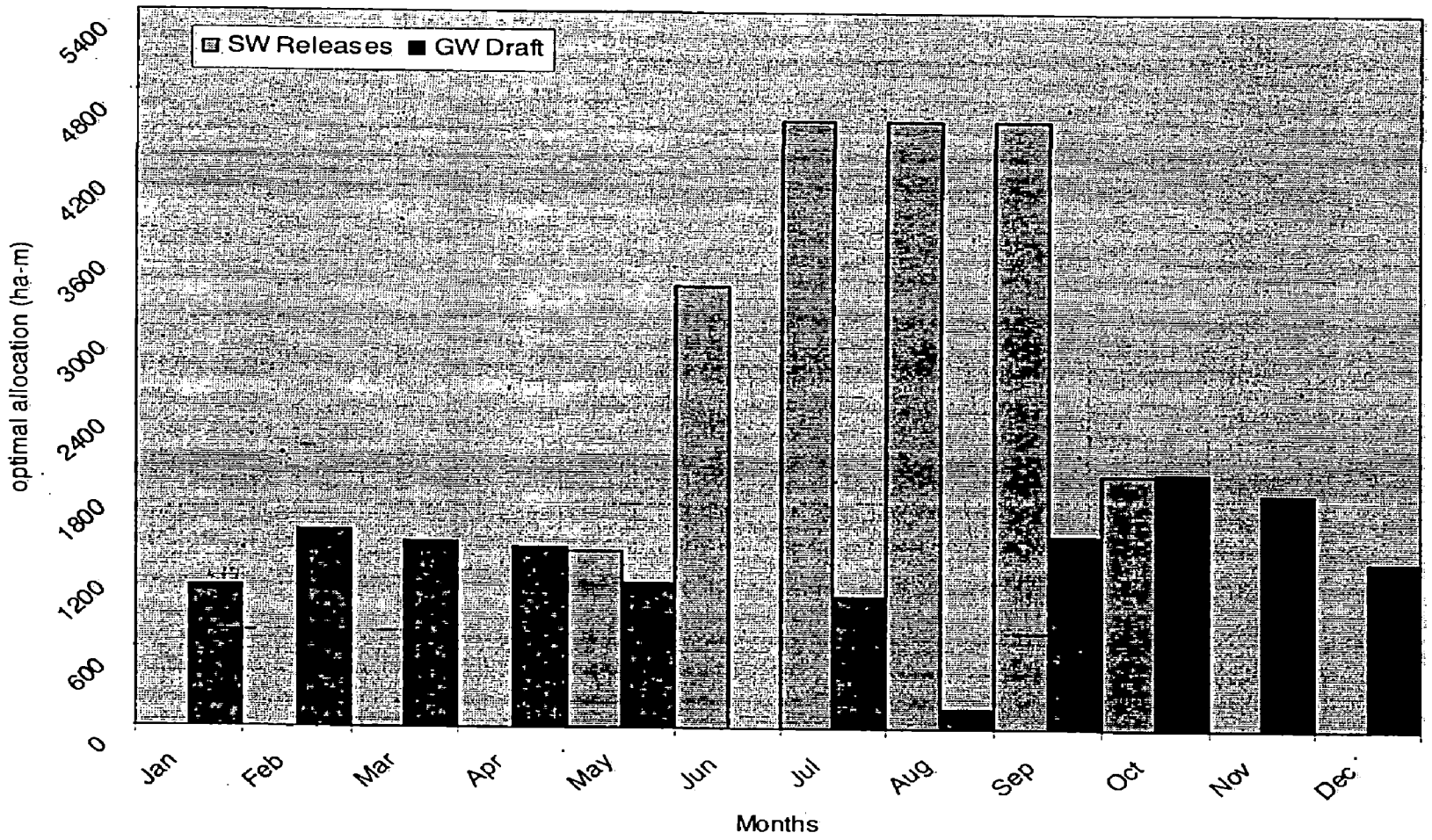


Table 5.15 Alternate cropping pattern with availability of surface water with 10% mining (Run -15)

S.No.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1087.86
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1492.09
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1360.24
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	1308.97
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	999.29
6	Gram	11.44	2000.00	4.57	800.00	Jun	3213.410	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	919.58
8	Groundnut	11.44	2000.00	8.58	1500.00	Aug	4590.000	152.70
9	Potato	5.15	900.00	4.57	800.00	Sep	4590.000	1551.98
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	2067.52
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1782.23
12	Sugarcane	8.58	1500.00	38.19	6680.00	Dec	0.000	1278.29
		100.00	17490.00	117.04	20470.00		20235.320	14000.75

Maximum value of net benefits from Irrigation works = Rs. 7522.35 lakhs

Annual canal water diversions < 24867.64 H.M. (water available at outlet)

Annual ground water draft < 14001.00H.M.

Fig 5.15Optimal releases of surface and ground water: (Run – 15)

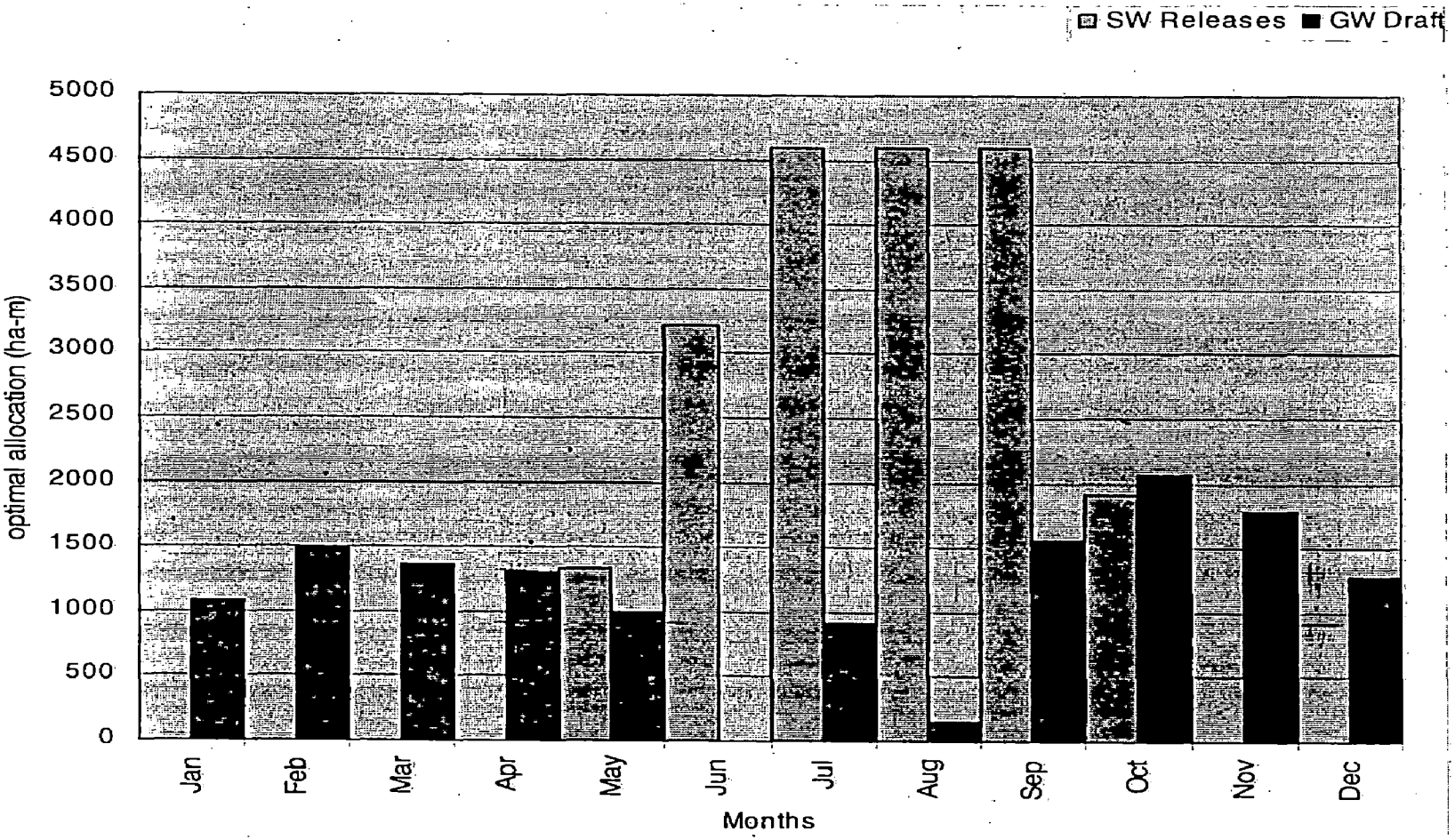


Table 5.16 Alternate cropping pattern with availability of surface water with 10% mining (Run -16)

S.N.	Name of the crops	Crop area constraints		Optimal crop Area allocation		Months	optimal release of water	
		%	Area (Ha)	%	Area (Ha)		canal Water (H-M)	Ground water (H-M)
1	Rice	25.73	4500.00	25.73	4500.00	Jan	0.000	1323.22
2	Wheat	11.44	2000.00	11.44	2000.00	Feb	0.000	1627.18
3	Maize	2.86	500.00	2.86	500.00	Mar	0.000	1294.79
4	Barley	2.86	500.00	4.57	800.00	Apr	0.000	1231.24
5	Jwar	8.58	1500.00	8.58	1500.00	May	1339.020	856.11
6	Gram	11.44	2000.00	4.57	800.00	Jun	3029.320	0.00
7	Pea	10.86	1900.00	6.86	1200.00	Jul	4590.000	792.76
8	Groundnut	11.44	2000.00	8.58	1500.00	Aug	4590.000	17.70
9	Potato	5.15	900.00	17.15	3000.00	Sep	4590.000	1380.16
10	Berseem	0.51	90.00	0.51	90.00	Oct	1912.890	1969.34
11	Bajra	0.57	100.00	0.57	100.00	Nov	0.000	1940.87
12	Sugarcane	8.58	1500.00	35.86	6271.82	Dec	0.000	1567.58
		100.00	17490.00	127.28	22261.82		20051.230	14000.95

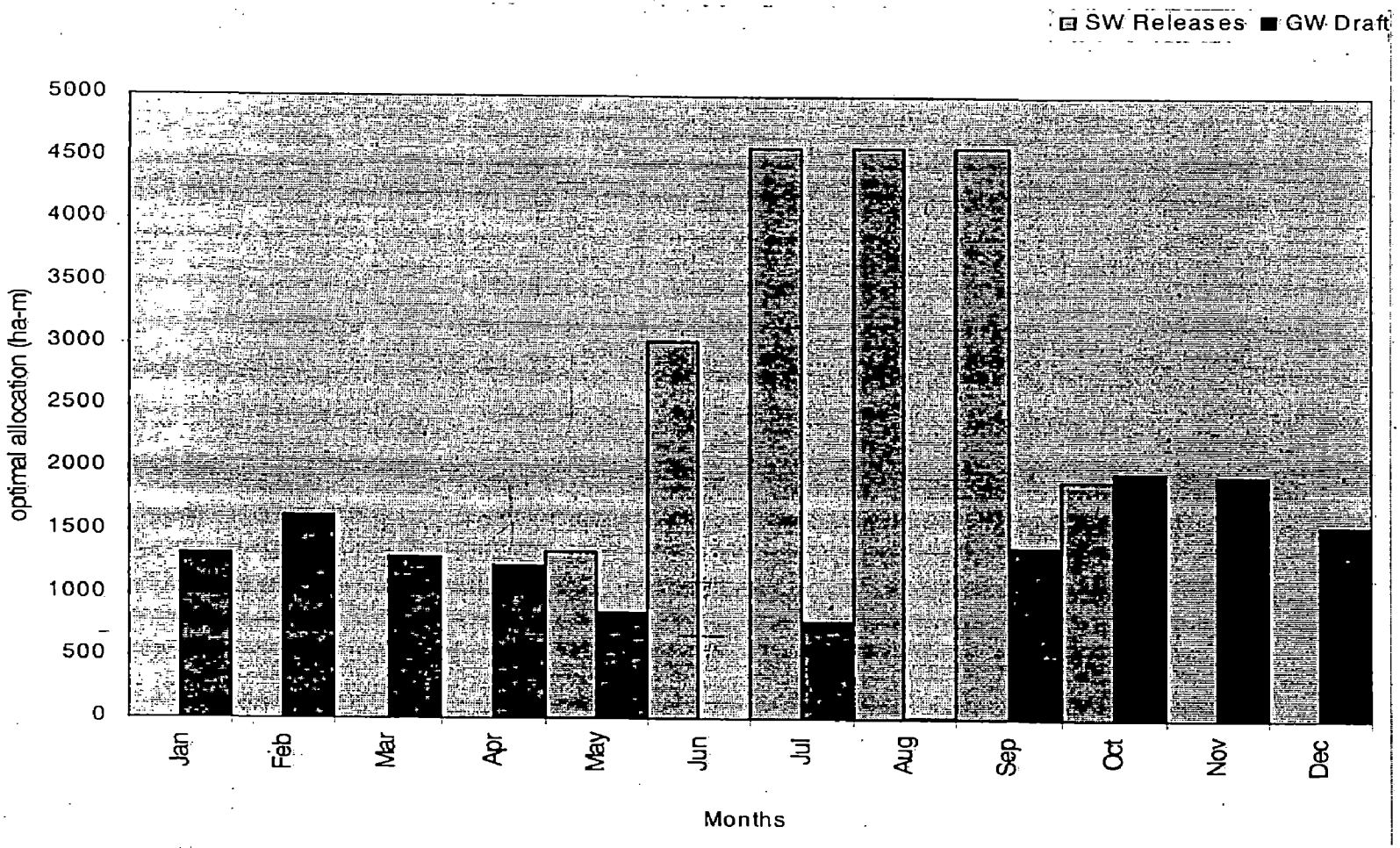
Maximum value of net benefits from Irrigation works = Rs. 8013.30 lakhs

Annual canal water diversions < 24867.64 H.M. (water available at outlet)

Annual ground water draft < 14001.00H.M.

Utilization of ground water =99.99%

Fig 5.16Optimal releases of surface and ground water: (Run – 16)



Conclusion and Scope for Further Study

6.1 General

This chapter deals mainly with conclusion derived and scope for further study for the study area.

6.2 Conclusions and suggestions

In this study present cropping pattern of chandok branch canal command has been studied in comparison to the cropping pattern in the area before introduced of canal water. Optimal cropping pattern to maximize the net benefit from the area is suggested on the basis of water requirement, crop area, and socio-economic constraints.

The optional conjunctive use of surface and ground water has been made. The maximum value of net annual benefit from the surface and ground water irrigation resources along with the monthly optional releases of surface and ground water and the optimal area allocation to the crops has been evolved on the basis of existing cropping pattern with surface water and ground water draft. From the present study following conclusions may be drawn.

(i) Present cropping intensity in the command is 113.33% constituting rice (24.87 %), wheat (34.82 %), Jwar (17.9 %), & sugarcane (16.3 %) as main crops.

(ii) 13.33 % of increase in cropping intensity is achieved after introduction of canal water in the area & this has (or increased production by 1.3 Tonnes to 2.1 Tonnes).

(iii) Area under rice crop in the command is limited to 24.87 % due to the introduction of sugarcane as a cash crop, & poor agricultural Extension service.

(iv) The optimal cropping pattern gives the net annual benefit of Rs 4317.35 may increased to Rs. 7097.84 lakhs considering Socio-economic constraint i.e. by 64.48%

(v) When 10% ground water mining is allowed it is observed that net annual benefit increases to Rs. 7517.44 lakhs.

(vi) When surface water i.e. canal system is not exist the net annual benefit is Rs. 1325.92 lakhs.

Conclusions based on observation in the study area

(vii) The farmer does not distinguish between irrigated and unirrigated areas i.e. crop cutting experiment, Yield data are not available.

(viii) Farmers should know about proper irrigation adequate input supplies, fertilizer seed, pesticides current cultural practices.

(ix) Agricultural extension service should be effective.

(x) Cropping pattern in head/ middle/tail reach should be according to the availability of water.

(xi) Need training for farmers as well as lower level staff of project.

(xii) Hybrid seed should be supplied to the farmers.

(xiii) Marketing, storage and processing facilities should be improved.

6.3 Scope For Further Study

(i) The present analysis has been carried out on a small area of chandok branch canal system which can be extended to cover EGC command.

(ii) The present study has been carried out using linear programming Algorithms. But in nature no event behaves linearly so to incorporates the non linearly of the problem some other operation research technique may be used e.g. etc.

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APPENDIX – 1

Variables Name	Description of Item	Variables Name	Description of Item
Crops (A_i,i = 1,2----12)		Canal Diversion Month (Ci,i=1,2,-----12)	
x1	Rice	X13	January
x2	Wheat	X14	February
x3	Maize	X15	March
x4	Barley	X16	April
x5	Jwar	X17	May
x6	Gram	X18	June
x7	Pea	X19	July
x8	Groundnut	X20	August
x9	Potato	X21	September
x10	Berseem	X22	October
x11	Bajra	X23	November
x12	Sugarcane	X24	December
Groundwater pumping in the month (G_i, I =1,2 ---------- 12)			
X25	January		
X26	February		
X27	March		
X28	April		
X29	May		
X30	June		
X31	July		
X32	August		
X33	September		
X34	October		
X35	November		
X36	December		

OBJECTIVE FUNCTION

Max. (Net Benefit)

$$\sum_{j=1}^{J}(P_j Y_j - E_j)A_j - [C_P^C C_C + C_P^G C_G + G_{OM} C_i + G_{OM} G_{ti})]$$

Max. [(16653 X1 + 16385 X2 + 10957 X3 + 12750 X4 + 10880 X5 + 13519 X6 + 12095 X7 + 15921 X8 + 41173 X9 + 15043 X10 + 14361 X11 + 104142 X12)

– (6074 X13 + 6074 X14 + 6074 X15 + 6074 X16 + 6074 X17 + 6074 X18 + 6074 X19 + 6074 X20 + 6074 X21 + 6074 X22 + 6074 X23 + 6074X24)

- (3233 X25 + 3233 X26 + 3233 X27 + 3233 X28 + 3233 X29 + 3233 X30 + 3233
-
- X31 + 3233 X32 +3233 X33 + 3233 X34 + 3233 X35 + 3233 X36)

CONSTRAINTS EQUATION'S

(A) CROP AREA CONSTRAINTS 3(A)

Sum of are under various crops is a month cannot exceed the total irrigated area available for cultivation.

$$\sum_{j=1}^{n} \beta_{ij} A_j \leq T_A \quad \text{For each month}$$

1. 1.0 X2 + 1.0 X4 + 1.0 X6 + 1.0X7 + 1.0 X9 + 1.0 X10 + 1.0 X12 ≤ 17415
2. 1.0 X2 + 0.33 X4 + 1.0 X6 + 0.42 X7 + 1.0 X9 + 1.0 X10 + 1.0 X12 ≤ 17415
3. 1.0 X2 + 0.22 X6 + 1.0 X10 + 1.0 X12 ≤ 17415
4. 1.0 X2 + 0.50 X10 + 1.0 X12 ≤ 17415
5. 1.0 X12 ≤ 17415
6. 0.50X1 + X12 ≤ 17415
7. 1.0 X1 + 0.13 X3 + 0.50 X5 + 0.48 X8 + 1.0 X12 ≤ 17415
8. 1.0 X1 + 1.0 X3 + 1.0 X5 + 1.0 X8 + 0.80 X11 + 1.0X12 ≤ 17415
9. 1.0 X1 + 1.0 X3 + 1.0 X5 + 1.0 X8 + 1.0 X11 + 1.0 X12 ≤ 17415
10. 0.40 X1 + 0.35 X3 + 0.50 X4 + 1.0 X5 + 0.26 X6 + 0.51 X7 + 1.0X8 + X11 + X12 ≤ 17415
11. 0.35 X2 + 1.0 X4 + 0.50 X5 + 1.0 X6 + 1.0 X7 + 0.39 X8 + 0.70X9 + X10 + 0.46 X11 + X12 ≤ 17415
12. 1.0 X2 + 1.0 X4 + 1.0 X6 + 1.0 X7 + 1.0 X9 + 1.0 X10 + 1.0 X12 ≤ 17415

3(B) App. 3 – 6/2

(B) CROP WATER REQUIREMENT CONSTRAINTS

13. 0.131 X2 + 0.067 X4 + 0.14 X6 + 0.07 X7 + 0.12 X9 + 0.14 X10 + 0.07 X12 – 1.0 X13 -1.0 X25 ≤ 0
14. 0.167 X2 + 0.16 X4 + 0.14 X6 + 0.14 X7 + 0.08 X9 + 0.2 X10 + 0.1 X12 – 1.0 X14 – 1.0 X26 ≤ 0

15. $0.117\ X2 + 0.03\ X6 + 0.37\ X10 + 0.16\ X12 - 1.0\ X15 - 1.0\ X27 \leq 0$

16. $0.009\ X2 + 0.24\ X10 + 0.19\ X12 - 1.0\ X16 - 1.0\ X28 \leq 0$

17. $0.35\ X12 - 1.0\ X17 - 1.0\ X29 \leq 0$

18. $0.046\ X1 + 0.45\ X12 - 1.0\ X18 - 1.0\ X30 \leq 0$

19. $0.76\ X1 + 0.001\ X3 + 0.012\ X8 + 0.31\ X12 - 1.0\ X19 - 1.0X\ 31 \leq 0$

20. $0.44\ X1 + 0.14\ X3 + 0.23\ X5 + 0.086\ X8 + 0.14\ X11 + 0.33\ X12 - 1.0\ X20 - 1.0\ X32 \leq 0$

21. $0.52\ X1 + 0.15\ X3 + 0.39\ X5 + 0.21\ X8 + 0.21\ X11 + 0.42\ X12 - 1.0\ X21 - 1.0\ X33 \leq 0$

22. $0.31\ X1 + 0.05\ X3 + 0.03\ X4 + 0.26\ X5 + 0.01\ X6 + 0.17\ X7 + 0.2\ X8 + 0.31\ X11 + 0.24\ X12 - 1.0\ X22 - 1.0\ X34 \leq 0$

23. $0.15\ X2 + 0.07\ X4 + 0.05\ X5 + 0.06\ X6 + 0.14\ X7 + 0.02\ X8 + 0.1X9 + 0.19\ X10 + 0.06\ X11 + 0.15\ X12 - 1.0\ X23 - 1.0\ X35 \leq 0$

24. $0.08\ X2 + 0.16\ X4 + 0.1\ X6 + 0.09\ X7 + 0.15\ X9 + 0.16\ X10 + 0.1\ X12 - 1.0\ X24 - 1.0\ X36 \leq 0$

App. 3-6/3

(C) GROUND WATER PUMPING CONSTRAINTS 3(C)

The total ground water pumped in each month in a year should not exceed the ground water recharge.

25. $1.0\ x25 + 1.0\ x26 + 1.0x27 + 1.0\ x28 + 1.0\ x29 + 1.0\ x30 + 1.0\ x31 + 1.0\ x32 + 1.0\ x33 + 1.0\ x34 + 1.0\ x35 + 1.0\ x36 \leq 6146$ ---------- Case I

$\leq$ 12729.00 H.M. ----------Case II

Recharge calculation App – 3 6/4

Case I – when surface water is not available (i.e. canal system is not existing)

(A) Recharge due to rainfall

-	Recharge factor for study area	=	0.2
-	Area under study	=	37490 Ha.
-	Average Annual rainfall	=	0.465
∴	Recharge due to rainfall	=	0.2*37490*0.465
		=	3486.57 ha-m

(B) Recharge due to irrigation

-	Total draft	=	2440.40 ha-m.
-	Water Recharging 30%	=	732.12 ha-m
∴	Recharge due to irrigation water (80% water Recharging)	=	585.89 ha-m.

Total Recharging = 3486.57+585+2440.40*.85
= 6146.53 ha-m

Case II – When canal system is existing App 3-6/5

(a) Recharge due to rainfall = 3486.57 ha-m.

(b) Recharge due to Irrigation

-	Total withdrawal from ground	=	2440.40*0.85
-	Water Available at outlet (70% water available at head of outlet)	=	17407.35 ha-m
-	Total water available for irrigation	=	3486.57 + 2074.34 + 17407.35 =22968.26 ha-m
-	Water Recharging (30 % of available water)	=	6890.478 ha-m.
-	Recharge due to irrigation (80% of water recharging)	=	5512.38 ha-m.