GOAL PROGRAMMING APPLICATIONs IN AGRICULTURE

A DISSERTATION
submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF ENGINEERING
in
ELECTRICAL ENGINEERING
(System Engineering and Operations Research)

By

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CERTIFICATE

Certified that the dissertation entitled 'GOAL PROGRAMMING APPLICATIONS IN AGRICULTURE' being submitted by Shri Anil Kumar in partial fulfilment of the requirements for the award of the degree of MASTER OF ENGINEERING in ELECTRICAL ENGINEERING with specialization in SYSTEM ENGINEERING AND OPERATIONS RESEARCH of the University of Roorkee, Roorkee [India], is an authentic record of his own work carried out by him under our supervision and guidance. The matter embodied in this dissertation has not been submitted for award of any other Degree or Diploma.

This is to further certify that he has worked for a period of about nine months from Jan. 1987 to June 1987 and then again from Dec. 1987 to Mar. 1988 for preparing this dissertation.

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SYNOPSIS

Goal programming, which is a special extension of Linear programming, is capable of solving decision problems with single or multiple goals (might be conflicting goals). In goal programming we establish a hierarchy of priorities among the conflicting goals so that lower order goals are considered only after the higher order goals are satisfied or have reached a point beyond which no further improvements are possible. Goal programming is having wide ranging applications in Energy/Water resources, diet planning, Hospital administration, Manpur planning, crop planning etc. etc.

In the present study, goal programming is used to find out a policy for the optimal use of land and water resources resulting in maximizing net profit satisfying production requirement of the projected population for the year 1988 in the study area. The planning is done to meet the food and nutritional requirement of the local population. The optimal allocation of land and water for the sixteen major crops have been determined. The constraints include water and land, ammount of cereals and pulses, minimum and maximum area under each crop etc.

Results have been interpreted, suitable conclusions have also been drawn and some suggestions for further work have also been given.

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CHAPTER 1

INTRODUCTION

1.1 General

The modern agricultural practices involves the use of costly inputs, like irrigation, fertilizers, seeds, pesticides, labour etc. Water is a very scarce and precious resource so its use should be optimized. Along with water, the use of other inputs should be optimal for better returns to the farmers. To achieve all this crop planning is a must. The optimal cropping pattern will increase agricultural production, profits, employment etc. with bare minimum inputs which will go a long way to bring prosperity to a command area or to a nation in a broader sense.

In the cropping pattern, the choice and combination of crops grown by individual farmer depends on soil, climate, irrigation facilities available, farmer's requirements of food and fodder, market facilities and prevailing prices etc. Avialability of labour and capital also influence the cropping pattern. From national point of view, the optimum cropping pattern is one that gives the maximum profits subject to local conditions and fullfil the following consideration -

- Optimal use of available resources
- Increase in employment opportunities
- Attainment of the national objectives of self sufficiency in food grains.

In India only about one fourth of the cultivated land is irrigated and agriculture on the remaining land is rain fed. As in the irrigated area we have more flexibility in deciding the crops to be grown so efforts have to be made to obtain maximum yield from the irrigated area by judicious use of water. The survey of all water resources of India indicate that even after fullest exploitation of all surface and water resources, it would not be possible to irrigate more than half the cultivated area. Therefore, utmost need is to use the available irrigation water in such a way, that maximum production per unit of water is obtained by proper selection of crops and allocation of water.

For the efficient management of water resources, proper policies for optimal use of land and water resources in the catchment area are needed. According to the statement of Irrigation Commission (1979), the objectives of managing the majority of our public owned irrigation schemes can be stated as " Derivation of maximum agricultural production per unit of water supplied by the system and spreading the irrigation facilities to as large section of cultivators as possible in the command area". To assess the real situation in any irrigation project, it is essential to study selected areas and make systematic assessment of their water use both from technological and economic point of view. The present study is an attempt in this direction.

1.2 Objectives of the study

The primary objective of the study is to allocate optimally the land and water resources optimally, using goal programming technique.

More specifically the objectives of the study are

1) To study the existing cropping pattern, agricultural practices, crop and water utilization pattern and water management practices for developing a goal programming model.

2) To formulate a goal programming model for optimal allocation of land and water to different crops for maximization of net profits and employment generation.

3) To determine trade off between different objectives by changing the Goal priorities.

4) To propose a plan for optimal utilization of land and water under prevailing socio-economic constraints.

1.3 Methodology

Salawa command area is near Daurala in Meerut district of U.P. Water Resources Development and Training Centre (WRDTC) of Roorkee have done extensive surveys for this area to estimate surface water availability, ground water availability, existing cropping pattern, evapotranspiration, socio economic conditions etc. To develop the model the required data was collected from the various technical reports of WRDTC specially devoted to this area. The references of these reports are mentioned in the chapter 'The References'.

For the optimal allocation of land and water to different crops goal programming technique has been used. For crop planning both Rabi and Kharif crops are considered.

1.4 Limitations of the study

The basic assumptions of the study are conservative. No radical changes in the land tanure or water distribution efficiency are assumed.

The land allocations are ascertained for sixteen crops of two cropping sessons only [namely Rabi and Kharif]. The vegitable crops are not considered. Again third cropping session of Jaid is not considered due to lack of data.

The study assumes that water is supplied to saturation depth for each crop. The alternative possibility of using deficient water for some crops and putting the resulting saving in water to better economic

considered.

The study also assumes that the application and availability of nitrogen and labour are at optimum level whenever it is required.

1.5 Composition of thesis

In chapter two 'Review of the Literature' of some of the important techniques for optimal allocation of land and water to various crops are mentioned briefly. Again some of the important optimization technique applications in this area are also mentioned in this chapter.

In chapter three system state model is described in detail.

A brief discussion on goal programming and model formulation for the current work has been undertaken in chapter four.

The results are suitably interpreted in chapter five. The last chapter brings out the conclusions arrived at and possible avenues for further investigation have also been indicated.

CHAPTER 2

REVIEW OF THE LITERATURE

Many models for optimal use of land and water for crop planning have been developed in the past with varying objectives in mind.

The aim of the present study is to use and apply multiobjective techniques for crop planning for Salawa Command area in Meerut district. Irrigation planning is an essential component of water management in irrigated agriculture. At the start of each irrigation session, one must develope irrigation programmes for a combination of crops which will maximize the economic returns along-with efficient water use in limited land to achieve the self sufficiency in food production in nutritional requirements.

Optimal use of land and water are essential for optimal crop planning, giving maximum return under given limitations. The literature survery has been carried out to focus attention on the optimal allocation of land and water resources to various crops.

2.1 Optimal allocation of land and water to various crops

The age old cropping pattern, which have been sustained by various situation of rainfall and soil types has undergone change because of the introduction of high yielding varities of seeds and improved irrigation facilities. The optimization techniques generally used for optimal allocation of land to various crops are (I) benifit cost approach (II) functional approach (III) programming approach. Dorfman (1965) considered these approaches as complementary to each other and not mutually exclusive. However, the benifit cost approach serves only as a screening device for identifying the potential alternatives for a desired plan. The other analytical approaches help to further delimit the areas.

The benifit cost approach has been used to test the economic feasibility of watershed project and to allocate scarce resources among different alternatives. But often they are limited to a very few alternatives due to time and funds constraints. It becomes a tedious job to select the best alternative with the help of benifit cost approach if number of alternatives are large. In case of multipurpose project, the computation of benifit cost ratio becomes extremly complex due to inter-relations and feedback between different alternatives. The benifit cost ratio can be used as a screnning device which is very helpful companion to linear programming for finding out the potential alternatives. The inadequacy of benifit cost approach has been pointed out by Tolly and Riggs (1961), Mass (1962), Hall and Dracup (1970) etc.

The functional analysis approach aims to solve a set of mathematical equations generally related to obtaining benifit as a function of ammount and timing of water use in presence of various technical and other inputs in the production processes. The main difficulty in this approach is the need to have knowledge of numerous production functions for each of many varieties of crops, seasons, regions and resources. However the inequality of resource restrictions can not be handled by conventional formulations of this approach. All the available resources must be consumed fully. For these restrictions Hall and Dracup (1970) found this appreach unsuitable as the principal approach to choose the best alternative.

Tuttan (1964) and Headly (1965) for-casted water use with the help of analysis approach and used marginal values productivity models to estimate demand for irrigated land. Yaron (1967) combined production function analysis approach with the linear programming model to estimate water demand of crops. Thus the functional analysis approach has a limited but quite significant role in water resources system analysis estimating product response to a number of inputs.

Programming is one of the most widely used techniques of management science. This approach consists of solving a mathematical programming model using digital computer by considering large number of alternatives to get an optimal solution. Programming formulations have the distinct advantage of solving optimization problems of complex nature precisely and quickly. The programming approach can be classified as linear programming and Non-linear programming models.

Linear programming is a mathematical method of allocating scarce resources to achieve an objective with in the bounds of environmental constraints. Linear programming involves formulation and solutions of a certain type of managerial problem by optimizing a linear objective function subject to linear constraints.

The development of methamatical models to generate irrigation programmes has received the attention of many investigators. Moore (1961) identified the optimal allocation of irrigation water for economic productivity, since then many mathematical models have been developed for the purpose of irrigation programmes, for example Jenson (1970) Stewart and Hagan (1973), Stewart (1970).

Case studies of linear programming in Indian sub-continent have been carried out by Rogers and Smith (1970), Hiremath (1973), Singh (1974), Maji (1975), Duggal (1975), Lakhaminarayana (1977), Ranvir Singh (1981) etc.

The linear programming models are also formulated to select some future course of action, some investigators tried to use the predicted value likely to be experienced in the future. This led to the formulation of stochastic linear programming models. The objective of a stochastic linear programming approach is to check the implications of the decision role in the future.

Nonlinear programming problem differ from linear programming model in that the objective function and/or one or more constraint equation involved in nonlinear terms. General solution procedures for this catagory does not exists, however special purpose solution techniques are available that are applicable to limited subjects of general programme. Amongest non-linear programming model dynamic programming have been extensivaly used for example Bwet (1964), Hall and Butcher (1968) etc.

Goal programming is another approach of allocating scare resources. Goal programming is a modification and extension of linear programming which can be used for the solution of problems with multiple objectives. A recent trend in system analysis has been the consideration of problems which have more than one objective function. This is specially important in the study of large scale systems, where there tend to be several conflicting and non-commensurable objectives that the system modeller can identify. For example, in water resources planning, one wants to maximize both economic efficiency, which is measured in economic terms, and environmental quality, which is measured in units of pollutant concentration. Traditionally only one objective was considered, with the other objectives being included as constraints, or somehow made commensurate with the primary objective. However society is placing an increasing importance on non-picuniary objectives which are difficult to quantify monitarily. Multiple analysis has been applied to a wide variety of problems including transportation, project selection for research activities, economic production, the quality of life, managing an academic department, agricultural activities and many others.

The methodologies used for the solution of problems with multiple objectives are utility function, in difference function, parametric approach, ϵ constraint approach, goal programming, goal attainment method, adaptive search approach etc.

For solving decision problems involving multiple conflicting objectives using linear programming techniques, require to be introduced other objectives (other than the objective function) as model constraints. The linear programming model, however requires that the optimum solution must satisfy all constraint.

Furthermore, it is to be assumed that all the constraints have equal importance in solving the problems. However in reality, such assumptions are absurd. First of all it is possible that all constraint of the problem can not be satisfied. Such a problem is called infeasible. Next all the constraints does not have equal importance. Goal programming has been developed to solve decision problems which involves multiple conflicting objectives and taking into account above said considerations.

The concept of goal programming was first introduced by A. Charmes and W.W. Copper as a tool to resolve infeasible linear programming problems. This technique has been further refined by Y. Izri, S.M. Lee and others. Goal programming which is a special extension of linear programming, is capable of solving decision problems with a single goal or multiple goals. aA.M. nderson and M.D. Earle applied goal programming technique to select diets to meet specific nuitritional requirements. Nuitritional balance is difficult to achieve in diets selected by linear programming owing to the complex inter-relationships of the constraints. Goal programming achieves the nuitritional balance of the selected mix food through replacement of cost minimization in the objective function by total deviation of nuitriants from pre-specified levels required for optimum balance. Cost can be accounted for in this approach by obtaining solutions at different cost levels and hence defining a cost mutritional balance relationship.

In India not much work has been done on goal programming techniques. However, B. Soni (1985) in his work 'Goal programming approach for water resources management' formulated a goal programming model with the objectives to maximize (1) the net return (2) agricultural production (3) nutritional value of the product expressed in terms of Calorie and Protein. Again A.K. Changkakoti (1985) in his work 'Multiobjective crop planning for Garufella watershed (Assam) have used goal programming technique to optimize cropping pattern of Garufella water shed area.

CHAPTER 3

THE SYSTEM STATE MODEL

3.1 Description of the study area

(I) Physical feature of the study area -

The left Salawa distributory is one of the major distributories of Upper Ganga Canal, irrigating area in Meerut district of U.P. This distributory takes off from Upper Ganga Canal at 107.20 Km near village Salawa in Sardhana Tehsil of Meerut district. Total culturable command area of the Left Salawa system is 16250 hectare.

The command area lies between longitude east 77°37' to 77°45' and lattitude north 28°55' to 29°15' as shown in the figure 3.1. This area forms the part of the Indo-Gangetic alluvial plains. The alluviam consists of sand, silt, Kankar and clay. The deposites of sand layers are the main source of ground water.

There are three subdistributories which emerge from the Salawa distributory viz., Dabathua Distributory, Lower Daurala distributory and Meerut distributory. The total length of the left Salawa distributory is 33 Kms and its discharging capacity at the head is 6.30 cumecs or 223 cusecs.

The canal water supply is not sufficient to irrigate the area and the additional water is being utilized from ground water resources, through state tubewells, private tubewells and other minor irrigation works.

(II) Climate and rainfall

The area experiences moderate type of subtropical and monsoon climate. The temperature rises upto 40°C in the summer and goes down to 2°C in the winter. Monsoon generally sets towards the end of June and lasts till the end of september. Most of the precipitation occurs during the month of July, August and September, the winter rains are scanty.

The annual rainfall of the Meerut and Sardhana observatory are about 810.9 mm and 731.0 mm respectively. The monthly rainfall observed at the above-mentioned observatories are given in table 3.1.

In this area, two main irrigation seasons are there, namely

1) Kharif Season - starts in the month of April and lasting till September .

2) Rabi Season - starts in the month of October and lasting till March.

The main rabi crops are wheat, gram, mustard, potato, berseem etc. The main Kharif crops are sugar cane, rice, pulses, Jowar, Bajra etc. Although sugar cane is called a Kharif crop, but it lasts for ten months and actually overlaps with rabi and kharif crop seasons.

(III) Transport and communication

The command area of the Salawa distributory is well linked with the network of roads. The area is also well linked with rail lines, which provides additional source of transport. The Delhi-Hardwar metalled road facilitates easy movement of the people of this area and the head of Salawa distributory is 8 Kms from this highway. As such the area is having good metalled link roads also and people of this area have an adequate transport facility. Besides these facilities, postal services, transistor, telephones and televisions provides modern means of communication.

(IV) Miscellaneous

According to the agricultural statistics of U.P. 1978-79, the total geographical area of Meerut district is 393, 453 hectares and cultivated area is 313, 817 hectares i.e. about 75.8 percent of total area. According to the census 1981, the density of the population is about 719 persons per square kilometer and growth of population is 2.5 percent anually. The agriculture occupies the most vital place in the Meerut district economy.

The development of agriculture in the area has been carried out for the last few decades. The water, one of the important inputs has been employed by conjunctive use of surface and ground water. The other inputs which also plays an important role such as seeds, fertilizers and pesticides are supplies through co-operative societies, agro-services centres, private dealers, department of agriculture etc. Credit, specially for small and marginal farmers becomes very important and is made available through co-operative societies and nationalized commertial banks.

To avoid spolage and wastage of huge quantity of food grains due to increased marketable surplus, storage problem is most important. For this purpose, state government have supplied, the fabricates bims on subsidized rates under the 'Sane food grain scheme'.

However, the improvement of all these sectors are still needed, the increasing population and resulting increased food requirement reveals that more effective utilization of resources, capital and services becomes a must, for now and future.

3.2 Existing cropping pattern and Net returns

The existing acropping pattern of Salawa command area is given in table 3.2. It is clear from the table that the cash crops of the area are sugar cane and wheat. The other favoured crops are rice, maize and Berseem. The cropping

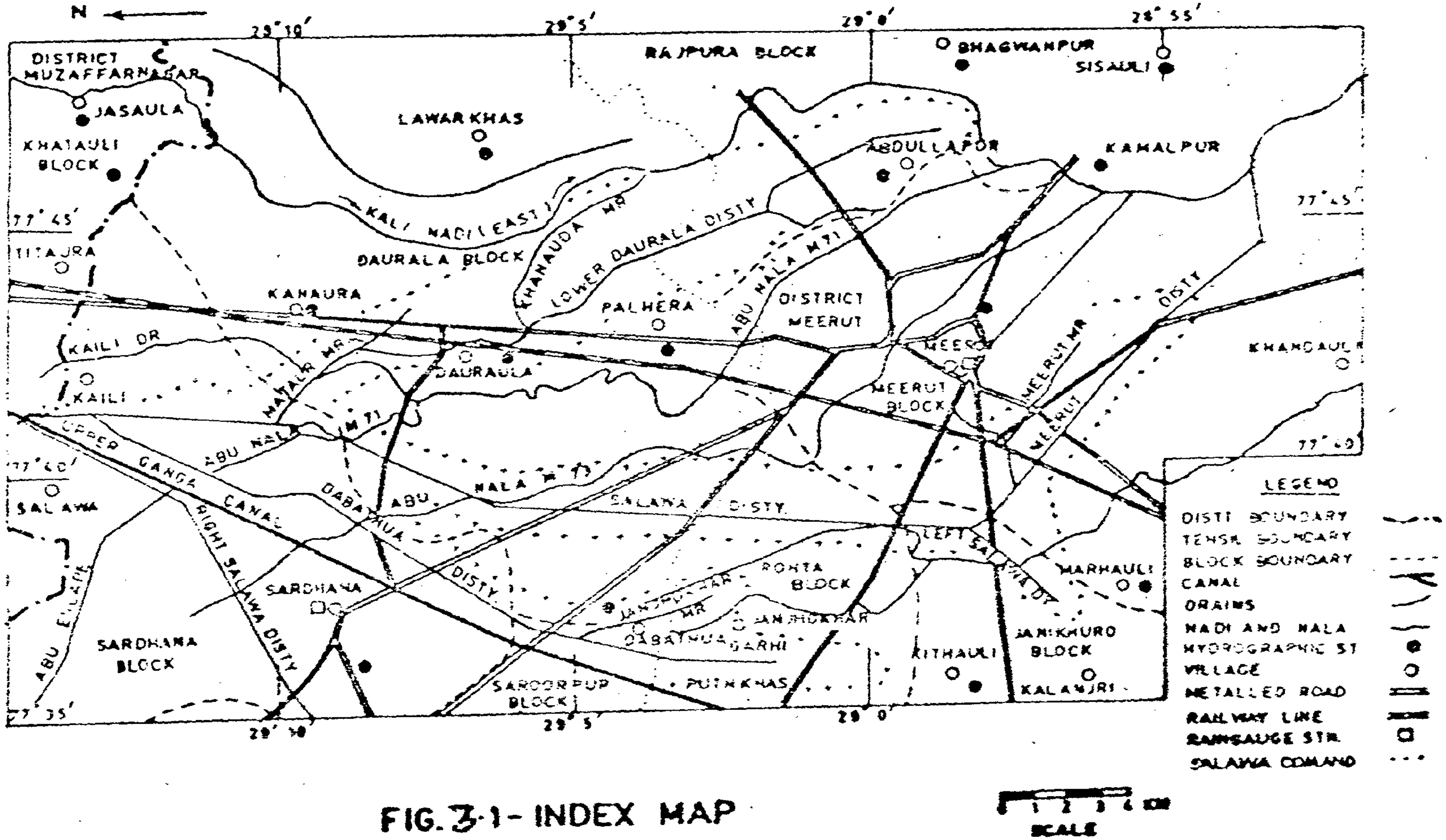

FIG. 3.1 - INDEX MAP

intensity comes out to be 74.93 percent.

This area is water scarce area. The crops like jowar, bajra, arhar, urd, moong, ground nut and gram are little irrigated or not irrigated crops. Again for other crops also water is applied at wrong times and sometimes inadequately. The other inputs are also applied inadequately. The consequence of above practices are low productivity.

The net returns associated with its yield at present, is shown in table 3.2.

Considering the net returns presented in table 3.2, the total annual net returns, for the exciting pattern is Rs. 1.80 crores.

3.3 Crop water requirement

(I) General

The assessment of water requirement for various crops is an important factor in choice of crops and it is one of the basic necessity for crop planning on a farm and for the planning of any irrigation project.

The water requirement is the quantity of water necessary in building plant tissue during the normal growth of the plant under the prevailing field conditions. This intensity comes out to be 74.93 percent.

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The water requirement is the quantity of water necessary in building plant tissue during the normal growth of the plant under the prevailing field conditions. This quantity of the water is mainly to meet the needs of evapotraspiration (ET) and it's metabolic activities. As the quantity of water required for metabolic activities of the plant is negligible when compared to evapotranspiration (ET), then the quantity of water required for evapotranspiration is practically treated as consumptive use (CU). Generally evapotranspiration is expressed in depth in cm or meter. The water requirement (WR) can be written as

WR = ET or CU + Losses during the application of water + water needed for special operations like land preparation, transplanting etc.

The crop water requirement calculation is made in the following way.

(II) Estimation of reference crop evapotranspiration(ETo)

The world bank have suggested that Penman equation should be used to calculate evapotranspiration in Indian subcontinent.

In 1948 Penman (16) has derived an equation of a short, well watered crop (generally assumed to be grass) based on the combination of energy balance at the crop surface and the heat mass transfer due to air movement.

This method requires data describing solar radiation, temperature, wind speed and relative humadity. Adopting these data from New Delhi (which is very near to Salawa command area), the average daily and monthly evapotranspiration is estimated and given in table 3.3.

(III) Crop co-efficient (K_c) and evapotranspiration of a specific crop (ET_{crop})

Crop co-efficient is the ratio of evapotranspiration occuring with specific crop to reference crop evapotranspiration

$$K_c = \frac{E\,T_{crop}}{E\,T_o}$$

The value of K_c varies with the crop, its stage or growth and the prevailing weather conditions. The values of K_c for different crops at different stage of development are mentioned in FAO Irrigation and Drinage paper No.24. The values of crop co-efficient are given in table 3.4, knowing the crop co-efficient K_c, the evapotranspiration of a specific crop (ET_{crop}) can be calculated as

$$ET_{crop} = K_c \times ET_o$$

(IV) Effective Rainfall (R)

From the point of view of the water requirement of the crops, the FAO of the United nations has defined the effective rainfall as part of the total annual or seasonal rainfall which is used directly or indirectly for crop production at the site where it falls, but without pumping.

Not all the rainfall is effective and part of it may be lost by surface runoff, deep percolation or evaporation. Only a portion of heavy and high intensity rains can enter and be stored in the root zone and effectivness is consequently low. Frequent light rains intercepted by plant foliage with full ground cover are close to 100 precent effective. With a dry surface and little or no vegetation cover rainfall upto 8 mm/day may be lost by evaporation, rain of 25 mm/day to 50 mm/day may be only 60 percent effective with a low percentage of vegitation cover.

The effective rainfall is calculated by the evapotranspiration/precipitation ratio method, table 34 of FAO Irrigation and Drinage paper No.24. Both Table 34 of FAO. Irrigation and Drinage paper No.24 and effective monthly rainfall is given in Appendix 1. The mean monthly rainfall is calculated from the average of Sardhana and Meerut monthly rainfall and is given in table 5.1.

(V) Percolation losses (P)

It is the downward movement of water through saturated or nearly saturated soil in response to the force of gravity. Percolation losses occur, in the standing water or when water is under pressure. The percolation loss in this area is about 6.1 mm/day.

Percolation losses take place in the case of rice only, because this is the only crop which needs standing water among the sixteen main crops being cultivated in this area.

(VI) Net Irrigation Requirement (NIR)

The net Irrigation requirement is the depth of Irrigation water exclusive of precipitation, carry over soil moiture or ground water contribution or other gains of soil moiture that is required consumptively for crop production.

Taking into account percolation losses (P) also, the net irrigation requirement work out to be

$$NIR = ET_{crop} + P - R$$

And $NIR = 0$ If $R > ET_{crop} + P$

It means no irrigation is required if the effective rainfall is more than the evapotranspiration and percolation losses for any crop in any period. This is quite obvious.

The designed capacity of the left Salawa distributory system is 6.3 cumecs or 223 cusecs. At the full flow, the monthly water made available by the distributory for irrigation comes out to be 1690.0 ha-m. As the flow of river Ganga is not constant and varies from season to season and hence the flow of the distributory also varies. Based on 75% dependability, the water flow in the distributory for different months is estimated. The water flow in the distributory in cusecs and water supplied by the distributory in one month in Ha-m is tabulated in table 3.6.

(II) Ground Water

For Salawa command area, Annual total recharge (15) to the ground water is 2466.7 ha-m. So the quantity of ground water which can be pumped and used for irrigation annually is 2466.7 ha-m.

3.5 Crop Calander

This calander specifies the dates of planting through it's harvesting for all the sixteen crops. In fact this calander indicates the land occupancy for different crops. The crop calander is developed for the sixteen crops cultivated in this command area, the name of the crops are sugarcane, rice, maize, jowar, bajra, arhar, urd, moong, ground nut, wheat, mustard, berseem,

(VII) Field irrigation requirement (FIR) and gross irrigation requirement (GIR)

The field irrigation requirement and the gross irrigation requirement are calculated by dividing the net irrigation requirement by field efficiency and the field irrigation requirement by conveyance efficiency respectively. The above statement can be written as

$$FIR = \frac{NIR}{\text{Field efficiency}}$$

$$GIR = \frac{FIR}{\text{Conveyance efficiency}}$$

The field efficiency is taken as 0.6 and conveyance éfficiency as 0.7.

By the abovementioned procedure, monthly gross irrigation requirement for different crops are calculated and is presented in table 3.5.

3.4 Assessment of availability of irrigation water

(I) Surface water

The area is served by a network of subcanal distributories namely left Salawa, Meerut, lower Daurala and Dabathua, which as a whole forms 'Left Salawa Distributory' system. This canal system is a part of Upper Ganga Canal System, which gets water from river ganga. The barley, gram, peas and potato. This calander is developed according to the existing practices. The land use co-efficients in the calander are mentioned monthwise. A land use co-efficient of 1.0 against a crop in month indicates that this crop occupies the field in this month if it is grown. The crop calander is given in table 3.7.

3.6 Returns per hectare

The net returns for different crops are calculated on per hectare basis as hectare is taken the unit of crop activity here in this study. The net returns for a crop per hectare is defined as the difference of total incomes (By the sale of products and by-products) and production cost for one ha. The production cost includes the cost of material, labour, draft animals and machinery services if any. In this analysis it is assumed that standard doses of irrigation, fertilizers, pesticides, labour etc. are given to the crops and hence yield per ha. will be standard. Based on above assumptions net returns per hectare is estimated. The yield / ha and net returns/ha is given in the table 3.8.

3.7 Employment generation per hectare

The number of mandays required as input by a cropping activity in one hectare is estimated here. For a particular crop human labour is required for operations like land preparations, sowing, manuring, interculture, irrigation, weeding, harvesting, theshing etc. The labour required for above mentioned operations for a crop is estimated in mandays for one hectare of cropping activity. To calculate the labour input for a crop for one hectare, the labour requirement for abovementioned operations are added. This calculation have been done for all the sixteen crops, and given in the table 3.9.

Monthly Rainfall of Sardhana (S) and Meerut (M) observatory (In mm)

S.No	Month	St.	1971	1972	1973	1974	1975	1976	1980	1981	1982	Average	Mean Monthly rainfall of salawa commans (mm)
1.	JAN	S	—	—	—	—	37	—	15	18	11	9.0	11.0
		M	—	—	15	—	46	—	6	29	22	13.1	
2.	FEB	S	13	62	5	—	—	30	—	13	8	14.6	14.2
		M	20	55	6	—	1	27	—	10	5	13.8	
3.	MAR	S	—	25	—	—	6	—	—	24	150	22.7	23.0
		M	—	25	3	—	16	7	—	24	135	23.3	
4.	APR	S	—	20	—	—	—	—	—	—	39	6.5	6.3
		M	—	3	—	—	—	—	—	—	51	6.0	
5.	MAY	S	33	—	—	—	—	23	—	17	—	8.1	14.2
		M	79	—	6	—	—	15	—	41	42	20.3	
6.	JUN	S	78	30	48	14	58	—	99	118	40	54.0	64.0
		M	136	51	93	20	155	30	74	36	72	74.1	
7.	JLY	S	—	255	148	214	530	147	260	294	192	226.6	233.0
		M	161	212	167	411	233	185	239	316	232	239.5	
8.	AUG	S	205	311	295	112	231	313	163	152	204	220.6	229.7
		M	317	295	217	114	219	332	188	158	309	238.1	
9.	SEPT	S	—	112	65	19	196	38	34	48	—	56.8	61.2
		M	—	78	94	14	235	18	74	77	2	65.7	
10.	OCT	S	—	—	36	—	28	—	15	—	5	9.33	14.9
		M	43	—	35	9	63	—	20	—	15	20.5	
11.	NOV	S	25	—	—	—	—	—	—	4.7	—	8.0	9.4
		M	30	20	—	—	—	—	—	47	—	10.7	
12.	DEC	S	—	—	—	—	—	—	48	—	22	7.8	10.0
		M	—	—	—	36	—	6	60	4	5	12.3	

TABLE 3.2

The existing cropping pattern, yield/ha and net returns/ha.

Sl. No.	Name of the crop.	Area under the crop. (ha)	Yield/ha Qtls.	Net returns/ha (Rs)	Total net returns (Rs)
1.	Sugar Cane	3417.0	450.0	2637.0	9010629.0
2.	Rice	1217.0	10.7	685.0	833945.0
3.	Mize	1173.0	6.6	435.0	510255.0
4.	Jowar	469.0	150.0	558.0	261702.0
5.	Bajra	211.0	125.0	575.0	121325.0
6.	Arhar	33.0	8.0	1072.0	35376.0
7.	Urd	225.0	6.0	1253.0	281925.0
8.	Moong	302.0	6.0	455.0	137410.0
9.	Ground nut	11.0	10.0	675.0	7425.0
10.	Wheat	3192.0	23.0	1475.0	4708200.0
11.	Mustard	16.0	9.0	588.0	9408.0
12.	Berseem	1318.0	140.0	1075.0	1416850.0
13.	Barley	66.0	18.0	750.0	49500.0
14.	Gram	297.0	8 .5	400.0	118800.0
15.	Peas	248.0	8.0	1025.0	254200.0
16.	Potato	183.0	150.0	1400.0	256200.0
	Grand Total	12378.0			18012850.0
					Rs. 1.8 crore

Cropping intensity = 74.9 %

Table 3.3

Reference Evapotranspiration (ETO) in Salawa Command Area

S.No	Month	ET_o (mm)	
		Daily	Monthly
1.	JAN	2.7	81.0
2.	FEB	4.5	135.0
3.	MAR	6.0	180.0
4.	APR	7.6	228.0
5.	MAY	8.4	252.0
6.	JUN	8.1	243.0
7.	JLY	6.5	195.0
8.	AUG	5.5	165.0
9.	SEP	5.6	168.0
10.	OCT	5.3	159.0
11.	NOV	3.8	114.0
12.	DEC	2.7	81.0

Table 3.4

The crop coefficient (Kc) for different crops in different months.

S.No	Name of the Crop	Month											
		JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEPT	OCT	NOV	DEC
1.	Sugar cane	0.0	0.42	0.76	0.95	1.1	1.21	1.1	1.1	1.1	1.2	0.92	0.66
2.	Rice	-	-	-	-	-	1.1	1.1	1.05	1.0	0.95	-	-
3.	Maize	-	-	-	-	-	-	0.24	0.75	1.05	0.77	-	-
4.	Jawar	-	-	-	-	-	0.19	0.38	0.97	0.96	0.67	-	-
5.	Bajra	-	-	-	-	-	-	-	0.24	0.93	0.99	0.52	-
6.	Arhar	-	-	-	-	-	-	0.18	0.25	0.60	0.98	1.10	-
7.	Urd	-	-	-	-	-	-	0.23	0.92	0.85	-	-	-
8.	Moong	-	-	-	-	-	-	0.24	0.85	1.07	0.72	-	-
9.	Ground nut	-	-	-	-	-	-	0.2	0.43	0.95	0.90	0.7	-
10.	Wheat	1.12	1.10	0.60	-	-	-	-	-	-	-	0.27	0.65
11.	Musturd	1.05	1.05	0.75	-	-	-	-	-	-	-	0.24	0.36
12.	Berseem	0.8	0.8	0.8	-	-	-	-	-	-	0.8	0.8	0.8
13.	Barley	1.12	0.8	0.3	-	-	-	-	-	-	-	0.3	0.8
14.	Gram	1.08	1.08	0.65	-	-	-	-	-	-	0.23	0.3	0.82
15.	Peas	1.1	1.05	-	-	-	-	-	-	-	0.24	0.42	1.06
16.	Potato	1.1	0.94	-	-	-	-	-	-	-	-	0.24	0.65

TABLE 3.7

Crop Clander

S. No.	Name of the Crop.	MONTH											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1.	Sugar cane	-	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2.	Rice	-	-	-	-	-	0.5	1.0	1.0	1.0	0.42	-	-
3.	Maize	-	-	-	-	-	-	0.81	1.0	1.0	0.45	-	-
4.	Jawar	-	-	-	-	-	0.5	1.0	1.0	1.0	0.58	-	-
5.	Bajra	-	-	-	-	-	-	-	0.81	1.0	1.0	0.47	-
6.	Arhar	-	-	-	-	-	0.5	1.0	1.0	1.0	1.0	0.4	-
7.	Urd	-	-	-	-	-	-	0.8	1.0	0.5	-	-	-
8.	Moong	-	-	-	0.8	1.0	1.0	0.48	-	-	-	-	-
9.	Ground nut	-	-	-	-	-	-	0.52	1.0	1.0	1.0	0.4	-
10.	Wheat	1.0	1.0	1.0	-	-	-	-	-	-	-	0.5	1.0
11.	Mustard	1.0	1.0	0.48	-	-	-	-	-	-	-	0.5	1.0
12.	Berseem	1.0	1.0	0.77	-	-	-	-	-	-	0.52	1.0	1.0
13.	Barley	1.0	1.0	0.22	-	-	-	-	-	-	-	0.8	1.0
14.	Gram	1.0	1.0	1.0	-	-	-	-	-	-	0.32	1.0	1.0
15.	Peas	1.0	0.4	-	-	-	-	-	-	-	0.52	1.0	1.0
16.	Potato	1.0	1.0	-	-	-	-	-	-	-	-	0.8	1.0

TABLE 3.5

Monthly Gross Irrigation requirement for different crops.

(Meters)

S. No.	Name of the Crop.	MONTH											
		JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEPT	OCT	NOV	DEC
1.	Sugar cane	-	0.03	0.292	0.516	0.648	0.541	0.104	0.067	0.318	0.433	0.250	0.131
2.	Rice	-	-	-	-	-	0.083	0.79	0.505	0.714	0.332	-	-
3.	Maize	-	-	-	-	-	-	-	-	0.298	0.123	-	-
4.	Jowar	-	-	-	-	-	0.149	-	0.037	0.267	0.136	-	-
5.	Bajra	-	-	-	-	-	-	-	0.119	0.256	0.357	0.066	-
6.	Arhar	-	-	-	-	-	0.194	-	-	0.311	0.353	0.074	-
7.	Urd	-	-	-	-	-	-	-	0.026	0.159	-	-	-
8.	Moong	-	-	-	0.325	0.537	0.478	0.014	-	-	-	-	-
9.	Ground nut	-	-	-	-	-	-	-	-	0.263	0.346	0.076	-
10.	Wheat	0.223	0.303	0.233	-	-	-	-	-	-	-	0.156	0.130
11.	Mustard	0.209	0.288	0.139	-	-	-	-	-	-	-	0.152	0.072
12.	Berseem	0.159	0.216	0.239	-	-	-	-	-	-	0.147	0.217	0.159
13.	Barley	0.223	0.216	0.021	-	-	-	-	-	-	-	0.208	0.159
14.	Gram	0.215	0.297	0.245	-	-	-	-	-	-	0.165	0.081	0.163
15.	Peas	0.219	0.123	-	-	-	-	-	-	-	0.180	0.114	0.211
16.	Potato	0.219	0.256	-	-	-	-	-	-	-	-	0.195	0.130

Table 3.6

Monthly Surface Water Avialability
(75% dependable)

S.No	Month	Designed canal capacity cusecs	Canal flow cusecs	Monthly avialabl surface water Ha - m
1.	JAN	223.0	114.6	868.6
2.	FEB	223.0	99.8	683.8
3.	MAR	223.0	104.8	788.3
4.	APR	223.0	148.5	1089.3
5.	MAY	223.0	195.2	1479.6
6.	JUN	223.0	195.2	1479.6
7.	JLY	223.0	195.2	1479.6
8.	AUG	223.0	195.2	1479.6
9.	SEPT	223.0	195.2	1479.6
10.	OCT	223.0	193.1	1463.7
11.	NOV	223.0	155.8	1142.8
12.	DEC	223.0	126.0	955.1

TABLE 3.7

Crop Clander

S. No.	Name of the Crop.	MONTH											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1.	Sugar cane	-	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2.	Rice	-	-	-	-	-	0.5	1.0	1.0	1.0	0.42	-	-
3.	Maize	-	-	-	-	-	-	0.81	1.0	1.0	0.45	-	-
4.	Jawar	-	-	-	-	-	0.5	1.0	1.0	1.0	0.58	-	-
5.	Bajra	-	-	-	-	-	-	-	0.81	1.0	1.0	0.47	-
6.	Arhar	-	-	-	-	-	0.5	1.0	1.0	1.0	1.0	0.4	-
7.	Urd	-	-	-	-	-	-	0.8	1.0	0.5	-	-	-
8.	Moong	-	-	-	0.8	1.0	1.0	0.48	-	-	-	-	-
9.	Ground nut	-	-	-	-	-	-	0.52	1.0	1.0	1.0	0.4	-
10.	Wheat	1.0	1.0	1.0	-	-	-	-	-	-	-	0.5	1.0
11.	Mustard	1.0	1.0	0.48	-	-	-	-	-	-	-	0.5	1.0
12.	Berseem	1.0	1.0	0.77	-	-	-	-	-	-	0.52	1.0	1.0
13.	Barley	1.0	1.0	0.22	-	-	-	-	-	-	-	0.8	1.0
14.	Gram	1.0	1.0	1.0	-	-	-	-	-	-	0.32	1.0	1.0
15.	Peas	1.0	0.4	-	-	-	-	-	-	-	0.52	1.0	1.0
16.	Potato	1.0	1.0	-	-	-	-	-	-	-	-	0.8	1.0

Table 3.8

Net Returns and Yield per hectare

S.No.	Name of the crop	Yield/ha (Qtls)	Net returns/ha [Rupees]
1.	Sugar Cane	500.0	3238
2.	Rice	30.0	1087
3.	Maize	30.0	850
4.	Jowar	Fodder crop (250)	881
5.	Bajra	Fodder crop (200)	890
6.	Arhar	10.0	1340
7.	Urd	10.0	1607
8.	Moong	9.0	632
9.	Ground nut	12.0	770
10.	Wheat	35.0	1670
11.	Mustard	10.0	1009
12.	Berseem	Fodder crop (270)	1642
13.	Barley	20.0	823
14.	Gram	20.0	779
15.	Peas	20.0	2291
16.	Potato	300.0	2500

Table 3.9

Employment generated per hectare by various cropping activities

(Mandays)

S.No.	Name of the crop	Employment generated/h (Mandays).
1.	Sugar cane	330
2.	Rice	76
3.	Maize	120
4.	Jowar	140
5.	Bajra	120
6.	Arhar	110
7.	Urd	92
8.	Moong	92
9.	Ground nut	120
10.	Wheat	76
11.	Mustard	105
12.	Berseem	62
13.	Barley	135
14.	Gram	115
15.	Pras	110
16.	Potato	205

CHAPTER 4

GOAL PROGRAMMING MODEL FORMULATION

4.1 Goal Programming

A recent trend in system analysis has been the consideration of problems which have more than one objective function. This is especially important in the study of large scale systems, where there tend to be several conflicting and noncommensurable objectives, that the system moduller can identify. Multiobjective analysis technique has been applied to such problems. Goal programming is a multiobjective analysis technique.

If it is decided to use linear programming to solve decision problems with multiple objectives, it is required to introduce other objectives (other than the objective function) as model constraints. The linear programming, however, requires that the optimum solution must satisfy all the constraints. Further more it is assumed that all constraints have equal importance in solving the problems. However, in reality such assumptions are not always valid. It is quite possible that all constraints of the problem can not be satisfied. Such a problem is called infeasible. But the very important management problem which can not be solved by linear programming technique can not be abandoned. Thus goal programming technique has been developed to solve decision problems that involve multiple conflicting objectives and infeasible problems can also be optimised in the best possible way by this technique.

The concept of goal programming was first introduced by A. Charnes and W.W. Copper (1961) as a tool to resolve infeasible linear programming problems. This technique has been further refined by Y. Iziri (1965), S.M. Lee (1972) and others. Goal programming which is a special extension of linear programming, is capable of solving decision problems with a single goal or multiple goals. The objective function of goal programming is not unidimensional, as in linear programming. The unidimensional objective function models can handle only the problems which are composed of a single goal with a single or multiple subgoals. The multidimensional objective function models of goal programming can handle decision making problems consisting of either a single goal with multiple subgoals or multiple goals with multiple subgoals.

The basic assumption in goal programming is whether goals are attainable or not, an objective may be stated in which optimization gives a result which comes as close as possible to the indicated goal.

The heart of goal programming is the objective function which consists of at least two of the three vectors.

1. deviational variables
2. ordinary priority factors
3. weighted factors.

Objective Function:

The objective function is composed of either a pair of or asingle deviational variable for each goal constraint. If overachievement is acceptable, the positive deviation (di^+) can be eliminated from the objective function. On the other hand if underachievement means a satisfactory solution, the negative deviation (d_i^-) should not be included in the objective function. Exact achievement of a goal requires both negative and positive deviations be represented in the objective function to achieve the ordinal solution.

Deviational Variables:

The matrix used in the goal programming is composed of two types of constraints. They are goal and non-goal constraints. Each goal constraint may be assigned a positive or negative deviational variable or both. An optimal solution is obtained when the sum of non-atainment of goals is minimized according to the priority structure established by the decision maker.

Priority Ranking:

To achieve the goals according to their importance, goal programming provides a means by which the negative and positive deviations about the goal may be ranked according to an ordinal priority ranking scale in order of preference of each goal level.

Weighted Factors:

These values are assigned to priority factors for minimizing the deviational variables. They are only assigned to the deviational variables which have been assigned the same priority levels.

The deviational variables and the ordinal priority factors are always present in each objective function. The weights need not to be assigned but are useful when needed.

This technique has been found very suitable for this work and is used to allocate land and water for multicrop planning in Salawa Command, Meerut (U.P.).

4.2 Goal Programming Model

The steps in the formulation process is given below -

1) Develop the base line model
2) Specify aspiration levels for each and every objective.
3) Include negative and positive deviation variables for each and every goal and constraint.
4) Rank the goal in terms of importance.
5) Establish the achievement function.

The general form of liner goal programming model is

find $X = (x_1, x_2, \dots x_m)$ so as to

minimize $Z = d^+ + d^-$

Subject to $BX + d^- - d^+ = h$

$AX \leq b$

$X, d^-, d^+ \geq 0$

where,

B	=	(1xm)	row vector of objective function co-efficients.
X	=	(nx1)	coloumn vectors of real variables.
b	=	(mx1)	coloumn vector of right hand side constraint.
A	=	(mxm)	matrix of technological co-efficients.
d^+	=		deviational variable in positive direction.
d^-	=		deviational variables in the negative direction.
h	=		Goal level set by the decision maker.

The expression $A x \leq b$ is the environmental constraints and the expression $BX + d^- - d^+ = h$ is the goal constraint of the problem. The objective function (Z) is to minimize the deviation values of d^- and d^+ to as near the desired goal as possible. When d_i^+ and d_i^- are minimized, the optimal attainment of goal hi will be achieved for a certain value of X. The deviational variables are complementary to each other. If d_i^- takes a nonzero value, d_i^+ will be zero and vice versa. Since at least one of the variables will be zero, their product will always be zero (i.e. $d_i^+ . d_i^- = 0$).

4.3 Goal Programming Model Formulation

The matrix used in the goal programming is composed of two types of constraints. They are goal and nongoal constraints. Each goal constraint may be assigned a positive or negative deviational variable or both. Three possibilities exists for each goal or constraint equation. The left hand side can be less than or equal to, greater than or equal to or exactly equal to the right hand side. These three possibilities and how they are handled in goal programming formulation are given in the following table ?

Table 4.1

Type	Goal or constraint type	Processed goal or constraint	Deviational variable to be minimized in the objective function
1.	$f_i(X) \leq b_i$	$f_i(X)+d_i^- - d_i^+ = b_i$	d_i^+
2.	$f_i(X) \geq b_i$	$f_i(X)+ d_i^- - d_i^+ = b_i$	d_i^-
3.	$f_i(X) = b_i$	$f_i(X) + d_i^- - d_i^+ = b_i$	$d_i^+ + d_i^-$

4.3.1 Goal constraints

The objective of the study is, to allocate irrigated area to alternate crops (j) and quantity of water released in a unit time (i) through canals (C_i) and pumped ground water (G_i) to meet the necessary water requirements for all the crop j ($j = 1,2,\ldots m$) during ith period in the year of operation ($i = 1,2,\ldots n$) so that the system gives max benifit, employment and at the same time local nutrition requirements should be fulfilled. Hence the goal constraint will be

(I) <u>The net return constraint</u>

The net return for all the crops, has been estimated. The equation for this goal constraint with both side deviation variables can be written as

$$\sum_{j=1}^{m} A_j B_j + d_1^- - d_1^+ = B \qquad \ldots (1)$$

or in expanded form

$$b_1 a_1 + b_2 a_2 + \ldots + b_{16} a_{16} + d_1^- - d_1^+ = B$$

where

B = Net return per year aspired from the command area in Rupees. In our case this is 9 crore rupees.

B_j = Net benifit per hactare from jth crop activity in Rupees.

A_j = Area allocated to jth crop in hactares.

d_1^+ = Overachievement of Net return.

d_1^- = Underachievement of Net return.

j stands for different cropping activity.

Here

$j = 1$ for Sugar cane
$j = 2$ for Rice
$j = 3$ for Maize
$j = 4$ for Jowar
$j = 5$ for Bajra
$j = 6$ for Arhar
$j = 7$ for Urd
$j = 8$ for Moong
$j = 9$ for Ground nut
$j = 10$ for Wheat
$j = 11$ for Mustard
$j = 12$ for Berseem
$j = 13$ for Barley
$j = 14$ for Gram
$j = 15$ for Peas
$j = 16$ for Potato

(II) <u>Employment generation constraint</u>

Labour requirement for different crops per hectare has been estimated. Our goal is to provide jobs to the 25% of the population for 200 days in a year. This goal constraint can be written as.

$$\sum_{j=1}^{m} L_j A_j + d_2^- - d_2^+ = TL \qquad \text{.. (2)}$$

or $$l_1 a_1 + l_2 a_2 + l_3 a_3 + \cdots + l_{16} a_{16} + d_2^- - d_2^+ = TL$$

where

L_j = Labour requirement per hectare for jth crop in mandays.

TL = Total mandays aspired. We aspired 8250000 mandays.

4.3.2 Non-goal constraints

(I) Nutritional requirement constraint

We aspire to allocate the cropping area in such a way that local nutritional requirements are fulfilled. The projected population of Salawa command area for the year 1988 will be 177680. For food requirement purpose 75% of this or 133260 persons is taken as equivalent adult population. Now as per 'Social and preventive medicine' books the balanced diet/day for an Indian adult must contain 450 grams of careals and 80 grams of pulses. Hence to meet annual, local cereals and pulses requirements we must produce 23104000 and 3900000 Kgs of careals and pulses respectively.

In our crop list we have only Four careals namely Barley Rice, Maize and Wheat. Hence cereal requirement constraint can be written as

$$a_2y_2+a_3y_3+a_{10}y_{10}+a_{13}y_{13}+d_3^- - d_3^+ = CR \qquad .. (3)$$

where

y_2, y_3, y_{10}, y_{13} are yield per ha. for rice, maize, wheat and barley respectively, in kg/hectare.

a_2, a_3, a_{10}, a_{13} are area allocated to rice, maize wheat and barley respectively in hectares. CR = total cereal requirement in kg and should be equal to 23104000 Kgs. d_3^- and d_3^+ are underachievement and overachievement variables.

Again pulses which are cropped in the area are arhar, moong urd and gram. Hence the pulses requirements constraint can be written as.

$$a_6y_6 + a_7y_7 + a_8y_8 + a_{14}y_{14} + d_4^- - d_4^+ = PR \quad .. (4)$$

where

y_6, y_7, y_8, y_{14} are the yield for arhar, urd, moong and gram respectively in Kg/hectare. a_6, a_7, a_8, a_{14} are the area allocated to the arhar, urd, moong and gram respectively in hectares.

PR = total pulse requirement in kg. This should be equal to 3900000 kg.

d_4^- and d_4^+ are underachievement and overachievement variables.

(II) <u>Production constraints</u>

In the sight of self sufficiency in food, local practices and practical limitations, it is necessary to impose a maximum and minimum limit to the area devoted to all the crops. The consideration may be local requirement, marketability, land capability, topography etc. These constraints in general can be expressed as

$$X_{1j} < A_j < X_{2j} \quad .. (5)$$

where

X_{1j} = minimum area allocated to the jth crop.

X_{2j} = maximum area allocated to the jth crop.

The minimum and maximum, limits are given in table 4.2 given below.

TABLE 4.2

Sl. No.	Name of Crop.	Minimum area (ha)	Maximum area (ha)
1.	Sugarcane	1000.0	4000.0
2.	Rice	500.00	4000.0
3.	Maize	400.0	1500.0
4.	Jawar	200.0	1000.0
5.	Bajra	100.0	1000.0
6.	Arhar	20.0	2000.0
7.	Urd	150.0	4000.0
8.	Moong	50.0	1500.0
9.	Ground nut	20.0	1000.0
10.	Wheat	1000.0	4000.0
11.	Mustard	300.0	2500.0
12.	Berseem	600.0	1500.0
13.	Barley	20.0	1500.0
14.	Gram	50.0	2000.0
15.	Peas	150.0	1000.0
16.	Potato	600.0	4000.0

(III) Land constraints

These constraints specify that the total cropped area in any month or season should not exceed the total land of the command area i.e. 16520 hectares. Crop calander given in table 3.7 is of great help here. In general land constraints can be written as

$$\sum_{i=1}^{12} \sum_{j=1}^{16} L_{i,j} A_j \leq TA \qquad \text{.. (6)}$$

where

$L_{i,j}$ = Land use co-efficient for jth crop. in the ith month.

i = No, of months i.e. 12

j = No. of crops i.e. 16.

TA = Total culturable command area i.e. 16520 ha.

In matrix form the above constraint can be written as

$$l_{1,1}a_1 + l_{1,2}a_2 + \cdots + l_{1,16}\,a_{16} \leq TA.$$

$$l_{2,1}a_1 + l_{2,2}a_2 + \cdots + l_{2,16}\,a_{16} \leq TA.$$

$$\vdots$$

$$l_{12,1}a_1 + l_{12,2}a_2 + \cdots + l_{12,16}a_{16} \leq TA.$$

(IV) Water availability constraints

As water required for all the crops in a month must be less than or equal to the sum of canal discharge plus ground water mined in the same month. These constraints put the above-said argument in the Logic of the mathematical model.

The availability of ground water is specified over a year. To optimize the achievement or objective function, no ground water constraint is put in any month. However, it is necessary to impose an additional ground water constraint specifying that the sum of the utilization of ground water in one year should be less than or equal to total estimated safe with-drawal of ground water in one year. The safe with drawal of ground water in one year is to be taken as 2466.7 ha-m. The ammount of surface water available in any month is given in table 3.6. In general water availability constraint can be written as

$$\sum_{i=1}^{12} \sum_{j=1}^{16} W_{i,j} A_j - G_i \leq C_i \qquad \text{.. (7)}$$

where

$W_{i,j}$ = Water requirement of jth crop in ith month in m.

The values of $W_{i,j}$ is given in table 3.5

G_i = Total ground water pumped in ith month in ha-m.

C_i = Surface or canal water available in ith month in ha-m.

The matrix for the above constraint can be expanded as -

$$w_{1,1}a_1 + w_{1,2}a_2 + \cdots\cdots + w_{1,16}a_{16} - g_1 \leq C_1$$

$$w_{2,1}a_1 + w_{2,2}a_2 + \cdots\cdots + w_{2,16}a_{16} - g_2 \leq C_2$$

$$\vdots$$

$$w_{12,1}a_1 + w_{12,2}a_2 + \cdots\cdots + w_{12,16}a_{16} - g_{12} \leq C_{12}$$

The constraint for annual ground water use can be written as

$$g_1 + g_2 \cdots\cdots + g_{12} \leq G$$

Where

G = total annual ground water with drawal limit in ha-m.

4.3.3 The model objective function

In goal programming we have to assign priority to different goals. Here two major goals are considered. Based on subjective judgement, priority to the goal are assigned. The assigned priorities are P_1, P_2,... etc. from highest to the lowest priority in the rank is as follows -

P_1 The highest priority is assigned to the maximization of the net return. Here a very high value of net return is taken, which can not be achieved, from the available resources and management practices. So the negative deviational variable of the net return constraint is included in the objective function.

P_2 The second highest priority is assigned to the maximization of the employment generated by the cropping activity. In this study we aspired to generate employment for one fourth of the total population, (which is app. equal to the working male and female adults) for 200 days in a year. Again this can not be achieved and hence negative deviational variable of the employment generation constraint will appear in the objective function.

Based on the above priority structure the objective function of the model is formulated as follows:

$$\text{Min } Z = P_1 d_1^- + P_2 d_2^-$$

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 General

Goal programming used in the study for solving multiobjective goals for allocation of limited water to different crops. Based on the priority structure of model, the analysis has been done under a set of constraints. When the priority of the goals are changed, the solution and trade-off between the goals have been determined.

The formulated problem has been solved for three water availability constraints. These are -

(1) Actual water availability in different months

(2) The maximum monthly discharge of the canal at present is made uniform throughout the year. This way monthly water availability will be 1480.0 Ha-m.

(3) The canal is made to run at its designed capacity throughout the year. This way monthly water availability will be 1690.0 Ha-m.

Each of this plan contains two different sets. In the one case, first priority is assigned to the net returns and second to the employment generation. In the other case first priority is assigned to the employment generation and the second to the net returns. The goal programming model for all these cases have been formulated and solved. Based on the subjective judgement, the optimal plan for the Salawa command area have been proposed.

5.2 First Plan

In the first plan water available in different months from all the sources have been estimated and used for allocation to different and crops. The area allocated to 16 crops and total net returns are shown in table 5.1. Due to the limited water available, only 13366 ha. of land has been allocated. The availability and allocation of water in different months are shown in table 5.2. It is observed that the water available in the Rabi season has been fully utilized, whereas in Kharif season some surplus water is available. The production of cereals and pulses are shown in table 5.3 and table 5.4 respectively. The employment generation is shown in table 5.5.

As clear from table 5.2 the water constraint in certain period is getting tight. The cropping intensity comes out to be 81% (Table 5.1) which is very low and is an indicator of surplus land. The satisfactory level of cropping intensity would have been about 150% as we are considering two crops i.e. rabi and kharif. The net returns, with the proposed cropping pattern is 1.93 crore rupees (table 5.1) which is 7.2% higher than the net returns with existing cropping pattern which is 1.83 crore rupees. The total employment generated by the proposed cropping intensity is 1397345.0 mandays (Table 5.5) which is 17% of the aspired value (8250000.0 mandays) for employment generation.

To satisfy the Cereals and pulses requirements of the local population, more allocations have been made for wheat, urd, maize and rice crops (4000.0, 2178.0, 1500.0 and 1337.2 hectare respectively). These crops have used a bigger share of available water. So in a water scarcity situation(which is the case now) less water is left for other crops. This is the reason why only 534.6 hectare has been allocated for to sugar cane (water consumption 3.33 m) crop, which is less than the minimum limit of 1000.0 ha specified for sugar cane.

The interesting point of the analysis is that with the existing availability of the water, for higher net returns and more employment generation, we should decrease area under sugar cane to a minimum and ideally to zero. This point is highlighted by the fact that for sugar cane crop only allocation is below the prespecified minimum limit. In the existing cropping pattern (Table no. 3.2) around 20% area of total CCA is under sugar cane, and this area is increasing year after year. Taking into account the population affinity and the exciting agricultural practices a higher minimum limit of 1000.0 ha.was specified for sugar cane.

Wheat and maize is allocated 4000.0 ha and 1500 ha of land respectively, (Table 5.3) which is quite high and happens to be maximum specified limit for these crops. Although wheat needs a high doze of water (1.045 meters), but it is prefered as its yield per hectare (3500 kg) and return/hectare (Rs 1670.0) is very high and labour requirement of 76 mandays is moderately high.

For maize crop yield per ha is 3000.0 kg and labour requirement per ha. is 120 mandays which is quite high and return per hectare is Rs 850.0 which is moderately high. Again water requirement for maize is 0.421 meters which is very low and that is why maize is a prefered crop in water scarce situation.

These are the reasons why maximum possible allocation is made for wheat and maize. In cereals third preference goes to rice and 1337.2 ha. is allocated for this crop, as for rice crop yield, labour requirement and net return per hectare is 3000.0 kg, 76.0 mandays and 1087.0 rupees respectively. Each of them is at higher side but water requirement of rice is 2.425 meter which is very high and hence a lower allocation has been made for this. In case of Barley only labour input (135 mandays) is high. Yield and net return per hectare is 2000.0 kg and 823.0 rupees which is at the lower side. For above said reasons barley is made a low allocation of 296.13 ha.

To meet the local needs of pulses a positive bias has been for Urd and Moong. The reason why a large allocation of 2178.0 ha (Table 5.4) is made for Urd is that its yield and net return per ha. is 1000.0 kg and 1607.0 rupees respectively. Net return for urd is highest among the pulses and yield is next to gram only. Again it requires min.water (0.184 meter) and can be harvested with in two and half months. For moong maximum specified 1500.0 ha is allocated. The reason for this preference is that it occupies the field from April to July which happens to be low cropping intensity months. The water requirement for moon is 1.354 meters which is not very high. For gram and arhar allocation is 50.0 and 20.0 ha respectively, this is the min.specified limit for these crops. The reason is that for gram net return per hectare is Rs 779.0 which is second lowest. For arhar the occupancy of field is in the intense rabi cropping season. Due to these reasons allocations for these crops are bare minimum.

With the present allocations, fodder position is also quite comfortable. A good hundred hectare is allocated to jowar and bajra each. Again 600.0 ha is allocated to Berseem which is very nutitious fodder. The less allocation to sugar cane 534.7 ha (compared to 3417.0 ha in existing cropping pattern) in terms of fodder is made good by more allocation to wheat 4000.0 ha (3192.0 ha in the existing cropping pattern).

For all the other crops the allocation is bare minimum as specified.

The estimation of utilization of available water is made by using table 5.2. The surface water utilization is 82.1% and ground water utilization is 100%.

In the months of January, February, March, September and November, the surface water utilization is 100% and in the months of January, February, March and September to meet the increased irrigation demands the ground water is needed. The reason being that in above said months cropping intensity is very high and except september monthly rainfall is very scanty. The maximum surplus water (693 ha-m) is in the month of August. Which is due to the heavy rains. Again 325.9, 328.06, 329.1, 347.0, 416.7 and 83.2 ha-m surplus surface water is there in the months of April, May, June, July, October and December.

The ground water mining is required when surface water is falling short. The total ground water used in this plan is 2466.6 ha-m which is the safe limit of ground water withdrawal. The maximum ground water is pumped out in the month of Feb (1011.3 ha-m). In the months of January, February and March ground water is pumped out to the tune of 428.1, 1011.3 and 503.7 ha-m respectively. The reason for withdrawal is lower canal flow and high irrigation needs of rabi crops.

5.3 Second Plan

In the previous analysis water is becoming short in certain months. Now a constant monthly surface water availability of 1480.0 ha-m is considered which is the maximum monthly discharge of the canal in a normal year. The formulated problem is solved in two sets.

5.3.1 First set

Here first priority is assigned to the net returns and second to the employment generation.

Table 5.6 shows area allocated to different crops with increased surface water availability. Table 5.7 shows water availability and water use in different months. Table 5.8 and 5.9 gives the cereals and pulses production, while table 5.10 gives total employment generation, and employment generated by different cropping activities as well.

As clear from the comparision of table 5.1 and table 5.6, when water availability is increased, the total area under cultivation is increased by 30.28%.

The phenomenal change here is that with more water available for irrigation, crops requiring heavy irrigation like suger cane (3.33 meter) and rice (2.425)meter) but with higher returns (sugercane 3238.0 Rupees/ha and rice 1087.0 rupees/ha) are given preference over crops requiring less irrigation like moong (1.354 meters) and barley (0.827 meter) with low net returns (moong 632.0 rupees/ha and barley 823.0 rupees/ha). The allocation for sugarcane and rice is increased from 534.6 and 1337.2 ha to 1044.6 and 1521.3 ha respectively(Table 5.6). The allocation for moong and barley is decreased from 1500.0 and 296.13 ha to 1495.0 and 20.0 ha. This is due to the first priority assinged to the netreturns. Again the allocation for sugar cane (1044.6 ha) is more than the min. specified limit of 1000.0 ha. Means that if water is more, it is economical to grow sugar cane.

For urd allocation is raised from 2178.0 ha to 4000.0 ha which is the specified max. limit for this crop. This is to increase net returns.

For maize and wheat crops, max. specified area of 1500.0 and 4000.0 ha is allocated. For arhar and gram min specified area of 20.0 and 50.0 ha is allocated which is the same as in the first plan.

In the second plan also local requirements of 23104000.0 kgs of cereals and 5465500.0 Kgs of pulses are fulfilled. In fact now 1817500.0 kgs of pulses is more than the local population requirement (table 5.9) which can be sold.

In the second plan allocation for peas and potato is raised from 150.0 and 600.0 ha to 1000.0 and 2542.0 ha respectively (Table 5.6). For peas 1000.0 ha is specified as upper limit. The reason for more allocation is that net return per ha for potato and peas is 2500.0 rupees and

2291.0 rupees respectively, which is second and third highest net return per ha in the list of sixteen crops. So this is done purely for economic reasons.

By the examination of table 5.7 it is quite clear, that water use is very uniform. About 92.3% of available surface water is used and 100% of ground water is utilized.

In this plan net returns works out to be 3.06 crore rupees (Table 5.6) and total employment generated is 2.199 million mandays (Table 5.10). Again due to scarcity of water 6978.8 ha of land remained uncultivated.

5.3.2 Second set

Here first priority is given to the employment generation and second to the net returns. The land and water allocations are tabulated and the results are compared and shown in Table 5.11.

Comparision of table 5.6 and table 5.11 gives an inkling how the land allocation is changing when the priorities are interchanged. In second set first priority is given to the employment generation.

It is observed from Table 5.11 that for crops jowar, bajra, barley and sugar cane more allocation have been made. For jowar, bajra, barley and sugar cane crops allocations have been raised from 200.0, 100.0, 20.0 and 1044.6 hac. to 1000.0, 1000.0, 1500.0 and 1092.9 ha. respectively. The reason is simple that for these crops labour input is higher. Although labour input for potato is higher (205 mandays/ha) compared to jowar, barley and bajra (140.0, 135.0 and 120 mandays respectively) but for potato water requirement is more than these crops (0.8 m) and hence allocation is reduced from 2452.0 ha to 1912.6 ha.

The other crops, for which land allocation is reduced are rice, peas and moong. The allocations are reduced from 1521.3, 1000.0 and 1495.0 ha to 534.7, 150.0 and 1437.0 ha respectively. In case of moong and rice the labour input is low (76.0 and 92.0 mandays per ha respectively) and so that allocation is reduced. In case of peas although labour input is 110 mandays per ha. but its water requirement is higher (.84 m) compared to other crops, and secondly it occupies the field in the intense cropping rabi season and hence the allocation is reduced.

When the first priority is assigned to employment generation, the labour input is 2.339 million mandays and net return is 2.89 crore rupees. So compared to first set labour input have increased by about 0.14 million mandays and net returns have decreased by 0.17 crore rupees.

In the second plan, when first priority is assigned to net returns, the net returns are 3.06 crore rupees and total employment generation is 2.199 million mandays. These are 58.590 and 57.4% higher than the first plan. As with more water the difference in net returns and employment generation is quite high so there is a strong case for increasing water availability. In the third plan monthly surface water availability is taken as 1690.0 ha-m, which is the designed capacity of the canal.

5.4 Third Plan

The monthly water availability is taken 1690.0 ha-m which is the designed capacity of the canal.

5.4.1 First Set

In this case the first priority is assigned to the net returns and second to the employment generation. The allocation of land and water to different crops, cereals and pulses production and employment generation, with this water availability are shown in tables 5.12 to 5.16.

With monthly water availability of 1690.0 ha-m the cropping intensity obtained is 118.019 (Table 5.12) which is 6.73% more than the plan 2 (table 5.6). The total net returns are 3.41 crores which is 11.4% more than the plan 2. The employment generation is 2.606 million mandays (Table 5.16) which is about 14% more than plan 2. The surface water used for plan 3 for one year is 18471.1 ha-m which is about 12.6% more than plan 2. These statistics shows that output per unit water input is not saturated at this point also.

The major changes (compared to second plan) in the allocation are made in the case of sugar cane and potato crops. For both the crops the allocation is increased from 1044.6 and 2542.0 ha to 1529.6 and 3357.0 ha respectively. This is due to the higher net returns for sugar cane (3238.0 rup./ha) and potato (2500.0 rup/ha) crops respectively.

The allocation for moong is reduced from 1495.0 ha to 1301.4 ha. This is due to the lower net returns/ha (632.0 rupees/ha) for moong. Inspite of lower allocation for moong, surplus or marketable pulses will be to the tune of 1643260.0 kgs (table 5.15).

No change is made in cereal allocations. The cereal availability will be 23163900.0 kgs (table 5.14) which will be just sufficient to fulfil the local cereal requirements.

In this plan also, the maize, urd, wheat and peas crops are allocated maximum specified areas that is 1500.0, 5000.0, 4000.0 and 1000.0 ha respectively.

The surface water utilization is shown in Table 5.13. The 91% of available surface water (20280.0 ha-m) is utilized. Again 100 % of the ground water is also used.

5.4.2 Second Set

In the second part priorities are interchanged. First priority is assigned to the employment generation and second to the net returns. The change in land allocation and employment generation due to changing the goals priority are shown in Table 5.17.

5.5 Comparision of the Three Plans

The comparision of various plans have been done and shown in Table 5.18 and 5.19.

When annual surface water availability of 14088.5 ha-m in plan 1 increased by 77% and employment generation by 80%. This shows that by increasing the per unit input of water, the increament in output is much higher. As water availability for irrigation is more (Plan 3), the cropping intensity has increased from 81% to 118.01%, which is an indication of better land utilization. But at the enhanced canal flow of 1690.0 ha-m per month as assumed in plan three, 5432.4 ha of land still remains incultivated, due to the shortage of water. In all the three plans, the needed quantity of cereals (23104000.0 kg) and pulses (3648000.0 kg) are produced. In plan two and three, the pulses production is more than local needs.

The water utilization is very efficient in all the plans. The surface water utilization ranges between 81% to 92%. The ground water utilization is 100%.

The area allocated to different crops in different plans is given in table 5.18. In land allocation, maximum area is allocated to wheat, maize and urd crops. The allocation for wheat and maize in all the plans are maximum specified i.e. 4000.0 ha and 1500.0 ha respectively. For urd in first plan allocation is 2178.0 ha and in the second and third plans, the allocation is 4000.0 ha which is the upper specified limit.

As the water availability is more in second and third plan the crops which get more area are peas, potato, sugar cane and Rice. The area allocated for peas is 150.0 ha in the first plan and 1000.0 ha in the second and third plan (1000.0 ha is the max. specified limit for peas). For potato (net returns 2500.0 rupees/ha) the area allocated in the first, second and third plans are 600.0 ha, 2542.0 and 3357.0 ha respectively. For sugar cane (net returns 3238.0 rupees/ha) the area allocated in the first, second and third plans are 534.6, 1044.6 and 1529.6 ha respectively. In case of rice allocation is raised from 1337.2 ha in the first plan to 1521 ha in the second and third plan. The increased allocation, will maximize the net returns.

In case of moong and Barley (net returns 632 rupees/ha) (net returns 823 rupees/ha), the allocations are reduced. For moong allocation is 1500.0, 1495.0 and 1301.4 ha in the first second and third plans respectively. Again allocation for barley is reduced from 296.13 ha in the first plan to 20.0ha in the second and third plan. The main reason for reduced allocation is their low net return/ha.

The crops which have not taken off, are jowar, bajra, arhar, ground nut, mustard, berseem and gram. Allocations for these crops are bare minimum.

When first priority is assigned to the employment generation, a positive bias is shown for crops which has higher labour requirement/ha. Hence more area have been allocated to sugar cane (327.0 mandays/ha), jowar (140.0 mandays/ha), bajra (120.0 mandays/ha) and barley (135 mandays/ha) For potato (205.0 mandays/ha) and peas (110 mandays/ha), the labour requirement is high, but in a water tight position, it generates more employment to grow other crops like jowar, bajra etc.

5.6 Sensitivity Analysis

The area allocation to the different crops for different surface water availability is shown in table 5.20.

At the initial stages when water available for irrigation is low, the prefered crops are maize, urd, moong and wheat. In the first plan when water availability is the real water availability, the area allocated for the above crops are 1500.0, 2178.0, 1500.0 and 4000.0 ha respectively. These crops are prefered as the net returns and yields for these crops are higher. Again these crops are cereal and pulse crops, so to fulfil local requirements of cereals and pulses, allocation to these crops has to be higher.

As water availability is increased the allocation for sugar cane increases gradually. The allocation for sugarcane have increased from 534.6 ha in the first trial to 4000.0 ha in the 8th trial (table no. 5.20).

In the case of potato, the allocation increases from 600.0 ha in the first trial to 4000.0 ha in the fourth trial.

In this study cereal crops are rice, maize, wheat and barley. The allocation to maize and wheat are 1500.0 and 4000.0 ha which is maximum possible allocation specified for these crops, right from the first trial. As local cereal requirements is just fulfilled and hence the allocation to the rice and barley are inter-related i.e. if allocation to the barley is increased, allocation to the rice is decreased. This is clear from table 5.20. This is the reason, why allocation to rice is increased in the second and third trial to 1521.3 ha from 1337.2 ha in the first trial and allocation to barley is decreased in second and third trial to 20.0 ha from 296.1 ha in the first trial. From third plan and onwards, allocation to the rice decreases and allocation to barley increases gradually. The reason for peculair variation of land allocation can be explained in the following words. Initially with increasing water availability allocation to the rice crop also increases as the constraint is due to Rabi scarcity. As water availability is increased further more allocation is being made to sugar cane (which occupies field

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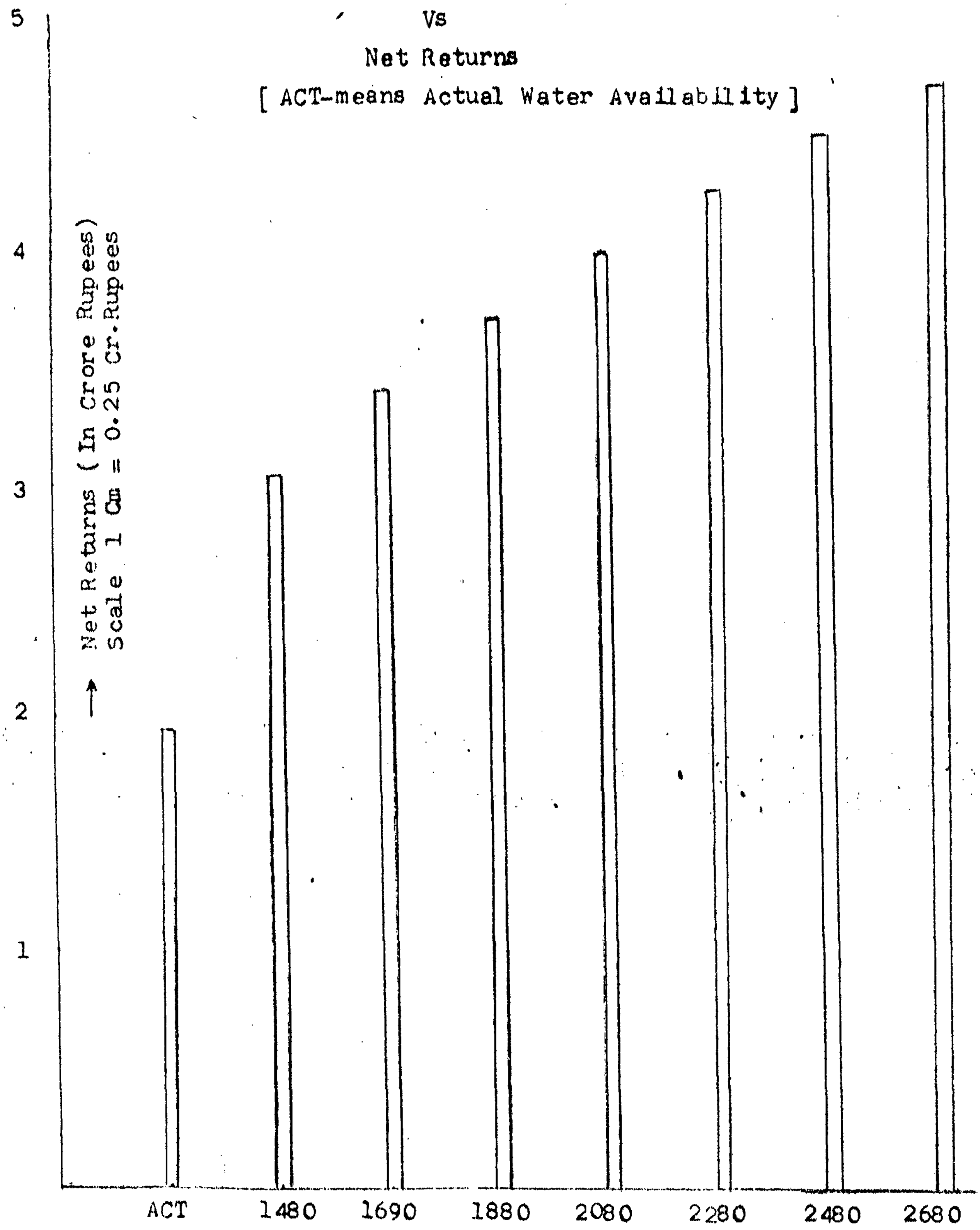
When surface water us is increased by 238% in ninth trial compared to the first trial, the net returns and employment generation is increased by 244.5% and 272% respectively. Again cropping intensity rises from 81% in the first trial to the 152% in the ninth trial. This level of cropping intensity is desirable.

FIG 5.1

Surface Water Availability
Vs
Net Returns
[ACT-means Actual Water Availability]

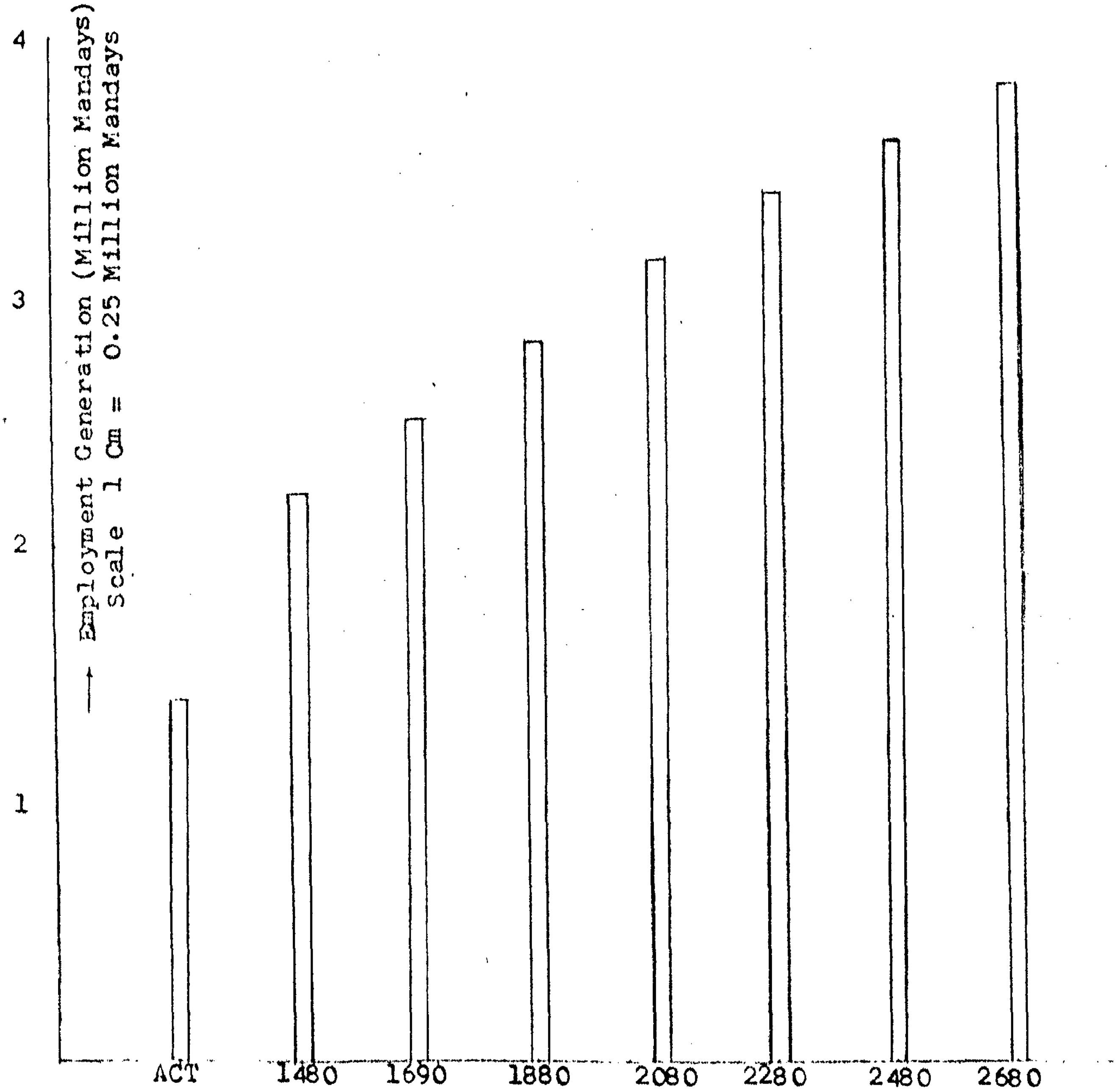


→ Monthly Surface Water Availability (Ha-m)
Scale 1 Cm = 100 Ha-m

FIG 5.2

Surface Water Availability
Vs
Employment Generation

[ACT - means Actual Water Availability]



→ Monthly Surface Availability (Ha-m)
Scale 1 Cm = 100 Ha-m

TABLE 5.1

Net returns and Area allocated to different crops.

Sl. No.	Name of the Crop.	Area allocated (ha)	% of CCA	Net Returns/ha (Rs.)	Total Net Returns (Rs.)
1.	Sugar cane	534.6	3.2	3238.0	1731034.8
2.	Rice	1337.2	8.1	1087.0	1453536.4
3.	Maize	1500.0	9.1	850.0	1275000.0
4.	Jawar	200.0	1.2	881.0	176200.0
5.	Bajra	100.0	0.6	890.0	89000.0
6.	Arhar	20.0	0.12	1340.0	26800.0
7.	Urd	2178.0	13.1	1607.0	3500046.0
8.	Moong	1500.0	9.1	632.0	948000.0
9.	Ground nut	20.0	0.12	770.0	15400.0
10.	Wheat	4000.0	24.2	1670.0	6680000.0
11.	Mustard	300.0	1.8	1009.0	302700.0
12.	Berseem	600.0	3.63	1642.0	985200.0
13.	Barley	296.13	1.8	823.0	243715.0
14.	Gram	50.0	0.3	779.0	38950.0
15.	Peas	150.0	0.9	2291.0	343650.0
16.	Potato	600.0	3.63	2500.0	1500000.0
Grand Total		13385.9	81.0		19309231.0

TABLE 5.2

Water Allocation

Sl. No.	Month	Surface Water Available (ha-m)	Water Used (ha-m)		Surplus Surface Water (ha-m)	% of Surface Water Used
			Surface	Ground		
1.	JAN	868.0	868.0	428.1	0.0	100.0
2.	FEB	683.6	683.6	1011.3	0.0	100.0
3.	MAR	788.0	788.0	503.7	0.0	100.0
4.	APR	1089.3	763.4	0.0	325.9	70.0
5.	MAY	1479.6	1151.5	0.0	328.06	77.8
6.	JUN	1479.6	1150.5	0.0	329.1	77.7
7.	JLY	1479.6	1132.6	0.0	347.0	76.5
8.	AUG	1479.6	786.6	0.0	693.0	53.1
9.	SEPT	1479.6	1479.6	528.6	0.0	100.0
10.	OCT	1163.7	747.0	0.0	416.7	64.2
11.	NOV	1142.8	1142.8	0.0	0.0	100.0
12.	DEC	955.1	871.9	0.0	83.2	91.3
	Total	14088.5	11565.5	2466.7	2525.9	82.1

TABLE 5.3

Cereal Production

Sl. No.	Name of Cereal	Yield/ha (Kg)	Area Allocated (ha)	Total Yield (Kg)
1.	Rice	3000.0	1337.2	4011600.0
2.	Maize	3000.0	1500.0	4500000.0
3.	Wheat	3500.0	4000.0	14000000.0
4.	Barley	2000.0	296.13	592260.0
	Grand Total			23103860.0

TABLE 5.4

Pulse Production

Sl. No.	Name of Pulse	Yield/ha (Kg)	Areal Allocated (ha)	Total Yield (Kg)
1.	Arhar	1000.0	20.0	20000.0
2.	Urd	1000.0	2178.0	2178000.0
3.	Moong	900.0	1500.0	1350000.0
4.	Gram	2000.0	50.0	100000.0
	Grand Total			3648000.0

TABLE 5.5

Employment Generation

Sl. No.	Name of the Crop.	Area allocated (ha)	Mandays requirement per hectare	Total Employment Generated (mandays)
1.	Sugar cane	534.6	327.0	174814.2
2.	Rice	1337.2	76.0	101627.2
3.	Maize	1500.0	120.0	180000.0
4.	Jowar	200.0	140.0	28000.0
5.	Bajra	100.0	120.0	12000.0
6.	Arhar	20.0	110.0	2200.0
7.	Urd	2178.0	92.0	200376.0
8.	Moong	1500.0	92.0	138000.0
9.	Ground nut	20.0	120.0	2400.0
10.	Wheat	4000.0	76.0	304000.0
11.	Mustard	300.0	105.0	31500.0
12.	Berseem	600.0	62.0	37200.0
13.	Barley	296.13	135.0	39977.6
14.	Gram	50.0	115.0	5750.0
15.	Peas	150.0	110.0	16500.0
16.	Potato	600.0	205.0	123000.0
	Grand Total			1397345.0

TABLE 5.6

Net Returns and Area Allocation to Different Crops.

Sl. No.	Name of Crop.	Area Allocated (ha)	% of CCA	Net Returns/ha (Rs.)	Total Net Return (Rs.)
1.	Sugar cane	1044.6	6.32	3238.0	3382414.8
2.	Rice	1521.3	9.2	1087.0	1653653.1
3.	Maize	1500.0	9.1	850.0	1275000.0
4.	Jowar	200.0	1.2	881.0	176200.0
5.	Bajra	100.0	0.6	890.0	89000.0
6.	Arhar	20.0	0.12	1340.0	26800 .0
7.	Urd	4000.0	24.2	1607.0	6428000.0
8.	Moong	1495.0	9.0	632.0	944840.0
9.	Ground nut	20.0	0.12	770.0	15400 .0
10.	Wheat	4000.0	24.2	1670 .0	6680000.0
11.	Mustard	300.0	1.8	1009.0	302700.0
12.	Berseem	600.0	3.6	1642.0	985200.0
13.	Barley	20.0	0.12	323 .0	16460 .0
14.	Gram	50.0	0.3	779.0	38950.0
15.	Peas	1000.0	6.1	2291.0	2291000.0
16.	Potato	2542.0	15.3	2500.0	6355000.0
	Grand Total	18412.9	111.28		30660617.0

Water Allocation

Sl. No.	Month	Surface Water Avialable (ha-mm)	Water Used (ha-m)		Surplus Surface Water (ha-m)	% of Surface Water Used
			Surface	Ground		
1.	JAN	1480.0	1480.0	361.1	0.0	100.0
2.	FEB	1480.0	1480.0	779.6	0.0	100.0
3.	MAR	1480.0	1434.8	0.0	45.21	96.9
4.	APR	1480.0	1025.8	0.0	454.21	69.3
5.	MAY	1480.0	1480.0	0.0	0.0	100.0
6.	JUNE	1480.0	1439.9	0.0	40.1	97.3
7.	JLY	1480.0	1331.4	0.0	148.6	90.0
8.	AUG	1480.0	961.9	0.0	518.1	65.0
9.	SEPT	1480.0	1480.0	111.9	0.0	100.0
10.	OCT	1480.0	1480.0	0.0	0.0	100.0
11.	NOV	1480.0	1480.0	221.5	0.0	100.0
12.	DEC	1480.0	1326.7	0.0	153.3	89.6
	Total	17760.0	16400.5	2474.6	1359.5	92.3

TABLE 5.8

Creal Production

Sl. No.	Name of cereal	Yield/ha (Kg)	Area Allocates (ha)	Total Yield
1.	Rice	3000.0	1521.3	4563900.0
2.	Maize	3000.0	1500.0	4500000.0
3.	Wheat	3500.0	4000.0	14000000.0
4.	Barley	2000.0	20.0	40000.0
	Total			23103900.0

TABLE 5.9
Pulse Production

Sl. No.	Name of Pulse	Yield/ha (Kg)	Area Allocated	Total Yield
1.	Arhar	1000.0	20.0	20000.0
2.	Urd	1000.0	4000.0	4000000.0
3.	Moong	900.0	1495.0	1345500.0
4.	Gram	2000.0	50.0	100000.0
	Total			5465500.0

Employment generation

Sl. No.	Name of Crop	Area Allocated (ha)	Labour requirement per ha (mandays)	Employment Generated (mandays)
1.	Sugar Cane	1044.6	327.0	341584.2
2.	Rice	1521.3	70.0	115618.8
3.	Maize	1500.0	120.0	180000.0
4.	Jowar	200.0	140.0	28000.0
5.	Bajra	100.0	120.0	12000.0
6.	Arhar	20.0	110.0	2200.0
7.	Urd	4000.0	92.0	368000.0
8.	Moong	1495.0	92.0	137540.0
9.	Ground nut	20.0	120.0	2400.0
10.	Wheat	4000.0	76.0	304000.0
11.	Mustard	300.0	105.0	31500.0
12.	Berseem	600.0	62.0	37200.0
13.	Barley	20.0	135.0	2700.0
14.	Bram	50.0	115.0	5750.0
15.	Peas	1000.0	110.0	110000.0
16.	Potato	2542.0	205.0	521110.0
	Total			2199603.0

TABLE 5.11

Net Returns, Land Allocation And Employment Generation

Sl. No.	Name of Crop	Area Allocated (ha)	Employment gen/ha (mandays)	Net Returns/ha (Rs.)	Net Returns (Rs.)	Employment Generated (Mandays)
1.	Sugar Cane	1092.9	327.0	3238.0	3538810.2	357378.3
2.	Rice	534.7	76.0	1087.0	581218.9	40637 .2
3.	Maize	1500.0	120.0	850.0	1275000.0	180000.0
4.	Jowar	1000.0	140.0	881.0	881000.0	140000.0
5.	Bajra	1000.0	120.0	890.0	890000.0	120000.0
6.	Arhar	20.0	110.0	1340.0	26800.0	2200.0
7.	Urd	4000.0	92.0	1607.0	6428000.0	368000.0
8.	Moong	1437.0	92.0	632.0	908184.0	132204.0
9.	Ground nut	76.0	120.0	770.0	58520.0	9120.0
10.	Wheat	4000.0	76.0	1670.0	6680000.0	304000.0
11.	Mustard	300.0	105.0	1009.0	302700.0	31500.0
12.	Berseem	600.0	62.0	1642.0	985200.0	37200.0
13.	Barley	1500.0	135.0	823.0	1234500.0	202500.0
14.	Gram	50.0	115.0	779.0	38950.0	5750.0
15.	Peas	150.0	110.0	2291.0	343650.0	16500.0
16.	Potato	1912.6	205.0	2500.0	4781500.0	392083.0
	Total				28954033.0	2339073.0

TABLE 5.12

Net Returns and Area Allocated to Different Crops

Sl. No.	Name of Crop.	Area Allocated (ha)	% of CCA	Total Net Returns/ha (Rs.)	Total Net Returns (Rs.)
1.	Sugar cane	1529.6	9.3	3238.0	4952844.8
2.	Rice	1521.3	9.2	1087.0	1653653.1
3.	Maize	1500.0	9.1	850.0	1275000.0
4.	Jewar	200.0	1.2	881.0	176200 .0
5.	Bajra	100.0	0.6	890.0	89000.0
6.	Arhar	20.0	0.12	1340.0	26800.0
7.	Urd	4000.0	24.2	1607.0	6428000.0
8.	Moong	1301.4	7.8	632.0	822484.0
9.	Ground nut	20.0	0.12	770.0	15400.0
10.	Wheat	4000.0	24.2	1670.0	66840000.0
11.	Mustard	300.0	1.8	1009.0	302700.0
12.	Berseem	600.0	3.6	1642.0	985200.0
13.	Barley	20.0	0.12	823.0	16460.0
14.	Gram	50.0	0.3	779.0	38950.0
15.	Peas	1000.0	6.05	2291.0	2291000.0
16.	Potato	3357.0	20.3	2500.0	8392500.0
	Grand Total	19519.3	118.01		34146192.0

TABLE 5.13

Water Allocation

Sl. No.	Month	Surface Water Available (ha-m)	Water used (ha-m)		Surplus surface water (ha-m)	Percentage of surface water used
			Surface	Ground		
1.	JAN	1690.0	1690.0	329.4	-	100.0
2.	FEB	1690.0	1690.0	791.8	-	100.0
3.	MAR	1690.0	1576.4	-	113.6	93.2
4.	APR	1690.0	1212.2	-	477.8	71.7
55	MAY	1690.0	1690.0	-	-	100.0
6.	JUN	1690.0	1609.0	-	80.5	95.2
7.	JLY	1690.0	1401.0	-	289.0	82.9
8.	AUG	1690.0	1008.0	-	681.7	59.6
9.	SEPT	1690.0	1690.0	1067.6	-	100.0
10.	OCT	1690.0	1690.0	-	-	100.0
11.	NOV	1690.0	1690.0	278.61	-	100.0
12.	DEC	1690.0	1528.7	-	166.81	90.1
	Grand Total	20280.0	18471.1	2467.4	1807.2	91.0

TABLE 5.14

Cereal Production

Sl. No.	Name of Cereal	Yield/ha (Kg)	Area Allocated (ha)	Yield (Kg)
1.	Rice	3000.0	1521.3	4563900.0
2.	Maize	3000.0	1500.0	4500000.0
3.	Wheat	3500.0	4000.0	14000000.0
4.	Barley	2000.0	20.0	40000.0
	Total			23103900.0

TABLE 5.15

Pulse Production

Sl. No.	Name of Pulse	Yield / ha (Kg)	Area Allocated	Yield (Kg)
1.	Arhar	1000.0	20.0	20000.0
2.	Urd	1000.0	4000.0	4000000.0
3.	Moong	900.0	1301.4	1171260.0
4.	Gram	2000.0	50.0	100000.0
	Total			5291260.0

TABLE 5.16

Employment Generation

Sl. No.	Name of Crop	Area Allocated	Mandays Generated per ha	Total Employment Generation (mandays)
1.	Sugar Cane	1529.6	327.0	500179.2
2.	Rice	1521.3	76.0	115618.8
3.	Maize	1500.0	120.0	180000.0
4.	Jowar	200.0	140.0	28000.0
5.	Bajra	100.0	120.0	12000.0
6.	Arhar	20.0	110.0	2200.0
7.	Urd	4000.0	92.0	368000.0
8.	Moong	1301.4	92.0	119728.8
9.	Ground nut	20.0	120.0	2400.0
10.	Wheat	4000.0	76.0	304000.0
11.	Mustard	300.0	105.0	31500.0
12.	Berseem	600.0	62.0	37200.0
13.	Barley	20.0	135.0	2700.0
14.	Gram	50.0	115.0	5750.0
15.	Peas	1000.0	110.0	110000.0
16.	Potato	3357.0	205.0	688185.0
	Total			2506236.0

TABLE 5.17

Net returns, land allocation and employment generation

Sl. No.	Name of Crop.	Area allocation (ha)	Employment generation per ha. (mandays)	Ner returns per hectar (Rs.)	Net returns (Rs.)	Employment Generationn (man days)
1.	Sugar cane	1812.2	327.0	3238.0	5867903.6	542589.4
2.	Rice	534.7	76.0	1087.0	581218.9	40637.2
3.	Maize	1500.0	120.0	850.0	1275000.0	180000.0
4.	Jowar	1000.0	140.0	881.0	881000 .0	140000.0
5.	Bajra	770.9	120.0	890.0	686101.0	92508.0
6.	Arhar	20.0	110.0	1340.0	26800.0	2200.0
7.	Urd	4000.0	92.0	1607.0	6428000.0	368000.0
8.	Moong	960.0	92.0	632.0	607162.4	88384.0
9.	Ground nut	20.0	120.0	770.0	15400.0	2400.0
10.	Wheat	4000.0	76.0	1670.0	6680000.0	304000.0
11.	Mustard	300.0	105.0	1009.0	302700 .0	31500.0
12.	Barseem	600.0	62.0	1642.0	985200.0	37200.0
13.	Berley	1500.0	135.0	823.0	1234500.0	202500.0
14.	Gram	50.0	115.0	779.0	38950.0	5750.0
15.	Peas	150.0	110.0	2291.0	343650 .0	16500.0
16.	Potato	2675.0	205.0	2500.0	668500 .0	648457.0
	Grand Total				32642085.0	2652626.0

TABLE 5.18

Comparision of Area Allocation

Area allocation in different plans (ha)

Sl. No.	Name of the Crop.	Ist Plan	IInd Plan		Third Plan	
			First Set	IInd Set	First Set	IInd Set
1.	Sugar Cane	534.6	1044.6	1092.9	1529.6	1812.2
2.	Rice	1337.2	1521.3	534.7	1521.3	534.7
3.	Maize	1500.0	1500.0	1500.0	1500.0	1500.0
4.	Jowar	200.0	200.0	1000.0	200.0	100.0
5.	Bajra	100.0	100.0	1000.0	100.0	770.9
6.	Arhar	20.0	20.0	20.0	20.0	20.0
7.	Urd	2178.0	4000.0	4000.0	4000.0	4000.0
8.	Moong	1500.0	1495.0	1437.0	1301.4	960.7
9.	Ground nut	20.0	20.0	76.0	20.0	20.0
10.	Wheat	4000.0	4000.0	4000.0	4000.0	4000.0
11.	Mustard	300.0	300.0	300.0	300.0	300.0
12.	Berseem	600.0	600.0	600.0	600.0	600.0
13.	Barley	296.13	20.0	1500.0	20.0	1500.0
14.	Gram	50.0	50.0	50.0	50.0	50.0
15.	Peas	150.0	1000.0	150.0	1000.0	150.0
16.	Potato	600.0	2542.0	1912.6	3357.0	2675.4

TABLE 5.19

Comparision of Other Indices

Sl. No.	Item Name	First Plan	Second Plan		Third Plan	
			First Set	Second Set	First Set	IInd Set
1.	Net return (Rs.)	19309231.0	30660617.0	28954033.0	34146192.0	32642085.0
2.	Employment generated (man-days)	1397345.0	2199603.0	2339073.0	2506236.0	2652626.4
3.	Total areaunder crop (ha)	13385.9	18412.9	19174.2	19519.3	19893.7
4.	Cropping Intensity	81.0%	111.28%	116.01%	118.01%	120.4%
5.	Surplus land (ha)	9989.3	6979.8	6930.6	5663.4	5432.4
6.	Annual surface Water available (ha-m)	14088.5	17760.0	17760.0	20280.0	20280.0
7.	% utilization surface water	62.1%	92.3%	86.36%	91.0%	86.08%
8.	Annually available ground water (ha-m)	2466.6	2466.6	2466.0	2466.0	2466.0
9.	% of utilization of gr.water.	100%	100.0%	100.0%	100.0%	100.0%
10.	Total Cereals Production (kg).	23103860.0	23103900.0	23104100.0	23103900.0	23104100.0
11.	Total Pulses production (kg).	3648000.0	5465500.0	5413390.0	5291260.0	4984333.0

TABLE 5.20

Area Allocation to Different crops (ha) for Different Surface Water Availability (Ha-m).

Sl. No.	Name of the crop.	ACT	1480.0 (Ha-m)	1690.0 (Ha-m)	1880.0 (Ha-m)	2080.0 (Ha-m)	2280.0 (Ha-m)	2480.0 (Ha-m)	2580.0 (Ha-m)	2680.0 (Ha-m)
1.	Sugar Cane	534.6	1044.6	1529.6	2029.4	3071.5	3477.0	3785.0	4000.0	4000.0
2.	Rice	1337.2	1521.3	1521.3	1409.7	659.0	534.7	534.7	534.7	534.7
3.	Maize	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	150000	1500.0	1500.0
4.	Jowar	200.0	200.0	200.0	200.0	200.0	863.5	1000.0	1000.0	1000.0
5.	Bajra	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
6.	Arhar	20.0	20.0	20.0	20.0	20.0	20.0	418.2	722.9	1268.7
7.	Urd	2178.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0
8.	Moong	1500.0	1495.7	1301.4	1051.9	167.0	50.0	50.0	50.0	160.0
9.	Ground nut	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
10.	Wheat	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0
11.	Mustard	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	470.0
12.	Berseem	600.0	600.0	600.0	600.0	600.0	1034.5	1494.2	1500.0	1500.0
13.	Barley	296.1	20.0	20.0	187.5	1313.4	1500.0	1500.0	1500.0	1500.0
14.	Gram	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
15.	Peas	150.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
16.	Potato	600.0	2542.2	3357.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0

ACT means actual water availability.

TABLE 5.21

Comparision of Different Indices for Different Surface Water Availability

Sl. No.	Name of Index	ACT	MONTHLY (Surface water availability (Ha-m) 14800	1690.0	1880.0	2080.0	2280.0	2480.0	2680.0
1.	Net Returns (Rs.)	19309338.0	30660617.0	34146192.0	37247210.0	40156622.0	42716598.0	45120376.0	4720441.0
2.	Employment Generation (Mandays)	1397345.0	2199603.0	2506236.0	2795541.0	3148192.0	3405838.0	3597958.0	3789914.0
3.	Total Land under Cropp-ing (Ha)	13386.9	18412.9	19519.3	20468.5	21000.4	22449.7	23752.8	25103.4
4.	Cropping intensity (%)	81.2	111.28	118.01	123.9	127.12	135.8	143.7	152.0
5.	Ground water use (Ha-m)	2466.7	2466.7	2466.7	2466.7	2466.7	2466.7	2466.7	2466.7
6.	Surface water use (Ha-m)	11565.5	16400.0	18471.1	20129.5	21485.0	23427.1	25439.1	27257.3

ACT means actual water availability.

CHAPTER 6

CONCLUSIONS

In the present study an attempt has been made to develop an optimal cropping pattern for Salawa command area by optimizing land and water resources from the point of view of net return and employment generation maximization and with constraints like available land water, local cereals and pulses requirement fulfilment and upper and lower land limits to a particular crop. A goal programming model has been formulated taking above mentioned considerations into account in chapter four, and optimum allocation of land to different crops has been calculated and tabulated (in table 5.19).

The trade offs between different objectives by changing the goal priorities have been ascertained and are given in the chapter on 'Results and Discussions'.

As is clear from table 5.20 the cropping intensity with the present water availability is 81% only, which is very low. Again 9989.3 Hectares of land are still uncropped. Hence there is a strong case for increasing water for irrigation. As ground water already being mined to the safe limit of 2466.7 Ha-m. We can increase water availability of by increasing surface water utilizarion.

Accordingly the availability of surface water has been increased in steps, the reallocation of land, net returns and employment generation for the new conditions are calculated and tabulated in tables 5.19 and 5.20. The increase in net returns and employment generation with increase in water availability are also shown in figures 5.1 and 5.2, respectively.

As is clear from figures 5.1 and 5.2, the most spectacular gains in net returns and employment generation is in going from first plan to second plan. From second plan and onwards the gains are increasing at a slower pace. When the surface water use is increased by 142% in the second plan compared to first plan, the increase in net returns and employment generation are 158 % and 157 % respectively. When monthly surface water availability of 1480.0 Ha-m in the second plan is increased to 2680 Ha-m in the last plan (increment of 181%) the increase in the net returns and employment generation is 154 % and 172 %. This shows signs of saturation. As net returns and employment generation is having maximum forward linkage, so surface water availability should be increased to a level where social returns are maximized for a reasonable capital investment.

Suggestions for Implementation

1. As the net returns and employment generation is increasing with increasing water, so more surface water should be made available for irrigation. This

should be economically viable and should give maximum economic and social returns to the society.

2. The surface water is not being made available as the crop requirement. In the rabi season when water requirement is more, available water is less. This loophole should be plugged.

3. The areas under pulses and oil seeds is very low. While they gives better profit and needs less water. The problem is that these crops are prone to pests and diseases. So appropriate seeds and technology should be developed and supplied to the farmers. This way we can put more area under these crops.

Suggestions for further Investigations

1. The monthly effective rainfall is calculated deterministically by considering average monthly rainfall. To get a more realistic value of effective rainfall, one can use stochastic methods.

2. It is being assumed that standard dozes irrigation, fertilizers, pesticides and labour is made available at the appropriate time, hence standard yield per hectare is considered. Practically it is not true. The availability of all the inputs at appropriate times can not be assured. This way the yield will be less than the standard yield taken in the analysis. This can also be included in the model formulation.

3. To maintain the fertility and nitrogen level of the soil, cropping pattern should be such that leguminous crops should be followed by other crops. This is very useful in long run strategies. In future this can also be incorporated in the model formulation.

REFERENCES

1. Lee, Sang, M. (1976), 'Linear optimization for management', Petro Celli/Character, New York.

2. Ignizio, James, P., 'Linear programming in single and multiple objective systems', Prentice-Hall, Inc., Englewood Cliffs.

3. Ijiri, Y., 'Manament goals and accounting for controls'.

4. Seal, S.C., 'A Text book of social and preventive medicine'.

5. Ministry of Agriculture, 'A guide for estimating irrigation water requirement', Dept. of Agriculture, Water Management Division, New Delhi, 1971.

6. Indian Agriculture Research Institute, 'Water requirement and Irrigation management of crops in India', IARI Monograph No. 4, New Delhi, 1977.

7. Pathak, A.K. (1984), 'Optimal water use for Nutrient Maximization', M.E. (Hydrology) thesis, UOR, Roorkee, India.

8. Changkakoti, A.K. (1985), 'Multi-objective crop planning for Garufella watershed (ASSAM)', M.E. (Hydrology) thesis, UOR, Roorkee, India.

9. Soni, B., Sahay, S.S., and Singh, J. (1984), 'Allocation of land and water using goal programming - A case study', Fourth Congress Asian and Pacific Division, International Association for Hydraulic Research, Chiang Mai - Thailand.

10. Soni, B. (1985), 'A goal programming approach for water resources management - A case study', National Institute of Hydrology, UOR, Roorkee Campus, India.

11. Anderson, A.M., Earle, M.D., 'Diet planning in the third world by linear and goal programming', Food and Technology Department, Massey University, Palmerston North, New Zealand.

12. Samal, Y., 'Socio-economic study in a selected area of Salawa Distributory', Technical Report (1982), WRDTC, Roorkee, India.

13. Suryaranshi, A.R., 'Evaluation of existing water distribution methods and their modernization', Technical Report (1982), WRDTC, Roorkee, India.

14. Sharma, S.B., 'Evaluation of Irrigation Efficiency and Water Course losses in Salawa command area', Technical Report (1982), WRDTC, Roorkee, India.

15. Gandhi, K.B., 'Water Budgeting for Salawa Command', Technical Report (1982), WRDTC, Roorkee, India.

16. Doorenbos, J., and Prisitt, W.O., 'Crop water requirement', FAO Irrigation and Drainage Paper No. 24, Rome, 1977.

17. Sharma, A., 'Shifting trends in cropping pattern of Salawa Distributory', Technical Report,(1982), WRDTC, Roorkee, India.

18. Charyulu, P.G., 'Crop planning for Gomti Kalyani Doab', Technical Report (1981), WRDTC, Roorkee, India.

19. WRDTC Report, 'Cropping pattern studies, system studies of Gomti Kalyani Doab', UOR, Roorkee (1981), India.

20. Olson, D.L., 'Comparison of four goal programming algorithms', A and M University, Texas.

APPENDIX - 1

A.1 Food and Agriculture Organization Rome, Paper No.24, Table No. 34.

TABLE A-1

Average Monthly ET Crop (mm) ↓ \ Monthly Mean Rainfall (mm) →	12.5	25.0	37.5	50.0	62.5	75.0	87.5	100.0	112.5	125.0	137.5	150.0	175.0	200.0
25	8	16	24											
50	8	17	25	32	39	46								
75	9	18	27	34	41	48	56	62	69					
100	9	19	28	35	43	52	59	66	73	80	87	94		
125	10	20	30	36	46	54	62	70	76	85	92	98	116	
150	10	21	31	39	49	57	66	74	81	89	97	104	119	133
175	11	23	32	42	52	61	69	78	86	95	103	111	126	141
200	11	24	33	44	54	64	73	82	91	100	109	117	134	150
225	12	25	35	47	57	68	78	87	96	106	115	124	141	159
250	13	25	38	56	61	72	84	92	102	112	121	132	150	167

Where net depth of water that can be stored in soil at the time of irrigation is taken 75mm. If effective storage is greater or smaller than 75mm the correction factor to be used is

Effective Storage	20	25	37.5	50	62.5	75	100	125	150	175	200
Correction Factor	0.73	0.77	.86	.93	.97	1.0	1.02	1.04	1.06	1.07	1.08

A.2 EFFECTIVE RAINFALL

If monthly ET crop for any crop in a month, and mean monthly rainfall in the same month is known, than from table A-1 we can calculate effective rainfall. Mean monthly rainfall for different months in Salawa command is given in table 3.1. ET crop is calculated and tabulated in the table 3.4. With the help of table A-1 effective rainfall is estimated and given in table A-2.

TABLE A-2

Effective Rainfall in Salawa Command Area (in mm)

Sl. No.	Name of the Crop.	MONTH											
		JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEPT	OCT	NOV	DEC
1.	Sugar cane	-	2.6	18.9	-	14.2	66.7	179.8	159.4	51.4	19.6	-	-
2.	Rice	-	-	-	-	-	68.0	175.9	155.9	51.0	12.0	-	-
3.	Maize	-	-	-	-	-	-	78 .8	135.0	51.2	10.8	-	-
4.	Jowar	-	-	-	-	-	41.4	126.3	150.0	49.0	10.0	-	-
5.	Bajra	-	-	-	-	-	-	-	132.0	48.6	12.8	-	-
6.	Arhar	-	-	-	-	-	40.8	92.0	166.3	50.9	12.7	-	-
7.	Urd	-	-	-	-	-	-	76.2	145.2	51.2	-	-	-
8.	Moong	-	-	-	-	14.2	67.7	100.2	-	-	-	-	-
9.	Ground nut	-	-	-	-	-	-	68.0	121.2	40.2	12.7	-	-
10.	Wheat	-	11.3	17.9	-	-	-	-	-	-	-	-	-
11.	Mustard	-	11.3	18.2	-	-	-	-	-	-	-	-	-
12.	Berseem	-	10.3	22.3	-	-	-	-	-	-	12.4	-	-
13.	Barley	-	10.3	14.4	-	-	-	-	-	-	-	-	-
14.	Gram	-	10.2	14.4	-	-	-	-	-	-	12.4	-	-
15.	Peas	-	12.7	-	-	-	-	-	-	-	10.0	-	-
16.	Potato	-	11.0	-	-	-	-	-	-	-	-	-	-