OPTIMAL RESOURCES ALLOCATION FOR CROP PLAN IN SELECTED DISTRICTS OF VIDARBHA REGION

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfilment of the requirements
for the Degree of

MASTER OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING
(SOIL AND WATER CONSERVATION ENGINEERING)

By

Ku. PREETAM GAUTAM KAMBLE

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING,
POST GRADUATE INSTITUTE, AKOLA
Dr. PANJABRAO DESHMUKH KRISHI VIDYAPEETH,
KRISHINAGAR PO, AKOLA (MS) 444104

Enrolment Number - X/49 **2009**

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled **"OPTIMAL RESOURCES ALLOCATION FOR CROP PLAN IN SELECTED DISTRICTS OF VIDARBHA REGION"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or Scientific Organisation. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Kamble

Place : Akola. (Miss. Preetam Gautam Kamble)

Date : 12 / 06 /2009 Enrolment No. X/49

CERTIFICATE

This is to certify that the thesis entitled **"OPTIMAL RESOURCES ALLOCATION FOR CROP PLAN IN SELECTED DISTRICTS OF VIDARBHA REGION"** submitted in partial fulfilment of the requirement for the degree of **MASTER OF TECHNOLOGY** in **AGRICULTURAL ENGINEERING** in Soil Water Conservation Engineering of the Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Miss. Preetam Gautam Kamble** under my guidance and supervision.

The subject of thesis has been approved by the Student's Advisory Committee.

Place : Akola
Date : 12/06/09

30/05

(Shri. S. B. Jajoo)
Chairman,
Advisory Committee

Countersigned

Associate Dean,
Post Graduate Institute, Akola
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA–VOCE)

1.	Chairman	Prof. S. B. Jajoo	
2.	Member	Dr. G. U. Satpute	
3.	Member	Dr. S. B. Wadatkar	
4.	Member	Dr. R. G. Deshmukh	
5.	Member	Prof. K. J. Shinde	
6.	External Member	(Prof G R Atal)	

Acknowledgements

It is with this profound sense of it's pride that, I herald the successful completion of my research. I express my deepest indebtedness and thanks to the 'God' for tolerance, patience and power he gave me to complete this task. My enterprise had plethora of troubles and hurdles which are eventually surmounted not only by my spirit and hard work, but the pursuant and immutable interest and efforts of my Honorable Chairman Prof. S. B. Jajoo, Associate Professor, Department of Soil and Water Conservation Engineering, Dr. PDKV, Akola. I have immense pleasure to express my sense of gratitude towards him. He provided the conceptual and theoretical background of this study as well as suggested me the rational approach. Without the due attention and interest of him this study could not have attended the last stage.

I also express my grateful thanks to the member of my advisory committee, Dr. G. U. Satpute, Assistant Professor, Department of Soil and Water Conservation Engineering, Dr. PDKV, Akola, Dr. S. B. Wadatkar, Head, Department of Irrigation and Drainage Engineering, Dr. PDKV, Akola, Prof. K. J. Shinde, Assistant Professor, Department of Mathematics, Dr. PDKV, Akola and Dr. R. G. Deshmukh, Associate Professor and Head, Section of Agricultural Economics and Statistics, Dr. PDKV, Akola for their ever willing generous help and valuable suggestion during my project work.

I am deeply thankful to Prof. R. C. Bhuyar, Head, Department of Soil and Water Conservation Engineering, for their sympathetic nature, constant encouragement for completing the project work.

I am thankful to Dr. D. L. Sale, Associate Dean, Post Graduate Institute, Dr. PDKV, Akola for providing opportunity for this project work.

My sincere thanks to Shri. M. S. Shaikh, Head, Agricultural Economics and Statistics Section, District Agriculture Department, Akola, Shri. Gavai, Project Incharge, Taluka Level Agriculture Department, Akola, Er. Ram Patil, Project Engineer, Irrigation Department, Akola and Dhore Madam, Lecturer, R.D.G. College Akola for providing necessary information required throughout the project.

Special thanks to Prof. Kud, Head, Agricultural Price Cell, Dr. PDKV, Akola, Prof. Wanjari, Head, Department of Meteorology, Dr. PDKV, Akola and Prof. Ganvir, Department of Economics, Dr. PDKV, Akola for providing necessary data.

I express my heartiest thanks to Mr. R. K. Khandhare, Mr. Dhande, Mr. Rathod, Mr. Tikar and Raju for their timely help.

I am overwhelmed with rejoice and indebted to avail this rare opportunity to thanks adorable Er. Zubeir for his care and conscious guideline and painstaking efforts throughout my M.Tech. degree and research work.

Words cannot utter my profound sense as for gifts and devoted thanks to my friend Vrushali for her constant help wherever necessary. It is my worth mention names of my Pals, Niraja, Bhagyashri, Namrata, Pranita, Kirti, Harshada, Karuna, Bhavita, Dhammadina, Samodini, Anita, Sukeshnitai, Pradnya, Priti and Pallavi for their suggestions and timely help.

Words are less to express my sense of gratitude towards my beloved parents Mr. Gautam R. Kamble and Sunanda Gautam Kamble, my uncle and aunty Mr. Madhukar and Sandhya, Mr. Ramesh and Suhasini and my loving Grandmother Mrs. Anjanabai R. Kamble for their showers of blessings and providing mental support in completion of my degree and research work. I also thank to my sister Poonam and brother Prashant for their love and care for me.

At last but not least I would like to thank the persons who directly or indirectly helped me and if am not mentioned.

Thanks one and all.

Kamble

Place : Akola. (Miss. Preetam Gautam Kamble)

Date : 12 / 06 /2009. Enrolment No. X/49

Table of Contents

(A) List of Tables

(B) List of Figure

(D) Abbreviations

%	-	Percentage
°C	-	Degree Celsius
/	-	Per
@	-	At the rate
mm	-	Millimeter
cm	-	Centimeter
Dr. PDKV	-	Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
e.g.	-	Exampli gratia (For example)
et al.	-	And others
etc.	-	Et cetra
Fig.	-	Figure
ha	-	Hectare
hrs	-	Hours
i.e.	-	That is
Kg.	-	Kilogram
M.S.	-	Maharashtra State
^{0}E	-	Degree East longitude
^{0}N	-	Degree North latitude
T	-	Ton
No.	-	Number (s)
LP	-	Linear programming
LPP	-	Linear programming problem
Mm^3	-	Million meter cube
q/ha	-	Quintals per hectare
qtl.	-	Quintal
gm	-	Gram
Rs.	-	Rupees
Sr. No.	-	Serial number
m^3	-	Meter cube

Viz.,	-	Videlicet (namely)
SCS	-	Soil conservation services
d1	-	Shallow
d2	-	Moderately shallow
d3	-	Moderate
d4	-	Deep
d5	-	Very deep
AMC	-	Antecedent moisture condition
CRS	-	Central research station
ET_o	-	Reference crop evapotranspiration
ET_c	-	Crop evapotranspiration
ET	-	Evapotranspiration
E_p	-	Pan evaporation
Fig.	-	Figure
FAO	-	Food and Agriculture Organisation
K_c	-	Crop coefficient
mm/day	-	Millimeter per day
SWCE	-	Soil and Water Conservation Engineering
a.a.r	-	Average annual rainfall
CNT	-	Curve Number Technique

(F) **Thesis Abstract**

a)	**Title of the thesis**	:	**OPTIMAL RESOURCES ALLOCATION FOR CROP PLAN IN SELECTED DISTRICTS OF VIDARBHA REGION**
b)	**Full name of student**	:	**Miss. Preetam Gautam Kamble**
c)	**Name and address of Major Advisor**	:	**Shri. S. B. Jajoo** Associate Professor, Department of Soil and Water Conservation Engineering, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.
d)	**Degree to be awarded**	:	M.Tech. (Agril. Engg.)
e)	**Year of award of degree**	:	2009
f)	**Major subject**	:	Soil and Water Conservation Engg.
g)	**Total number of pages in the thesis**	:	84
h)	**Number of words in the abstract**	:	148
i)	**Signature of the student**	:	Kamble
j)	**Signature, name and address of forwarding authority**	:	

Head,
Department of Soil and Water
Conservation Engineering,
Post Graduate Institute,
Dr. Panjabrao Deshmukh Krishi
Vidyapeeth, Akola (MS).

HEAD
Deptt. of Soil and water
Cons. Engineering
Dr. P. D. K. V., Akola

ABSTRACT

This study has been undertaken for Akola, Amravati and Buldhana districts using linear programming model to allocate the area under various crops with objective of maximize net benefits and compare it

with existing. The model is subjected to the constraints i.e. land, water, capital and food requirement.

Socio-economic study was carried out to know present status of people, use of existing land and water resources. In the selected districts runoff, effective rainfall were estimated and farm ponds and nala bunds were designed. Calculated crop water requirement gross and net retrun. Considering availability of water in different seasons and other constraints optimal solution were found out. In existing and proposed crop plan for Akola, Amravati and Buldhana cropping intensity is 103.94, 91.51, 91.41% and 156.17, 165.20, 156.00%, respectively. The net benefit increases by Rs 3630, Rs 4736 and Rs 4614 per ha in Akola, Amravati and Buldhana district by investing Rs 4526, Rs 6789 and Rs 6539 per ha more over existing respectively.

CHAPTER I

INTRODUCTION

1.1 Background information

Agriculture has been considered major factor in transforming human societies from small primitive bands into huge technologically advanced nations. The advance of human being is largely due to awareness of progress and need of cultivation for food production.

Food is the basic need of mankind, which is fully dependent on agriculture. Land and water are two major natural resources essential for crop production and are scarce, so it is necessary to use them in best possible way to get maximum production. Judicious management of land, water, labour and other inputs in the area has a good potential and may yield better result. To irrigate more area and to achieve maximum benefits from unit area, it is necessary to use land and water efficiently and optimally. Therefore, it is essential to develop optimal strategies through application of mathematical programming approach to suggest the best possible combination of all constraints to maximize the net profit by considering the stochastic nature of hydrological events.

In order to allocate resources to their optimum the process of optimization which is technique of linear programming can be used. Linear programming is mathematical modeling technique designed to optimize the usage of limited resources. It consists of an objective function of decision variable which is to be optimized (Maximized or minimized) and certain conditions, which should be satisfied. All relations among the decision variables are linear both in objective function and in the function forming constraints.

1.2 Importance of study

The economic fulfillment of a developing country depends largely on a sound and stable agriculture base. In India, agriculture is the main occupation of the people and about 70 per cent of its population is engaged in agriculture. It contributes about 25 per cent of national income and remains a major sector that employees 60 per cent of labour force in rural India (Suresh Chandra Babu, 2005).

Water is major input for crop production. Restricted supply of water affects the crop yield and hinders the other nutrients to the crop so it is necessary to manage the water and land for efficient crop production. If the availability of water is limited then it is necessary that farmer should choose a cropping pattern such that the peak water demand is met satisfactory and to increase productivity per unit out of existing availability of irrigation water.

Land being definite and complex system with its topography dimension and special nature and it is basic requirement to meet all human needs. The ever increasing population growth has resulted correspondingly tremendous demands on food, fodder, fuel, etc. and per capita availability of land is declining day by day.

Limited availability of land and water to rising population and declining yields forced farmers to search for alternate ways for raising farm income. With passage of time farmers become increasingly commercialized and started farming for maximizing their output. At most of times, the farmers have limited resources at his disposal and how best to utilize the scare farm resources, with a view to maximize net returns of farm income is persistent problem of Indian farmers. The ability to achieve rapid economic growth in crop productivity and production output depends to a large extent on its ability to choose the best among the alternative paths available for maximization of agricultural produce and economics scarce resources.

Optimization techniques are applicable in cases where limited resources are to be allocated in an optimum manner with a view to maximize the net returns.

1.3 Objectives of study

This study is undertaken to maximize net benefit by allocating the optimal area to various crops considering the resources constraints such as land, water, food requirement etc. with following objectives.

1) To collect basic information of agricultural resources like land, water, and existing crop plan of the Akola, Amravati and Buldhana districts.
2) To formulate linear programming model
3) To suggest optimal crop plan
4) To compare existing and suggested optimal crop plan

1.4 Hypothesis and assumptions

Proper allocation of agricultural resources increases productivity and net return per hectare.

Adoption of water harvesting techniques helps to increase availability of water potential, cropping intensity and area under rabi and summer crops.

1.5 Scope and limitation of the study

Scope

Optimization techniques give optimal output by proper allocation of scarce available resources.

Using proper water harvesting structures the irrigation potential and cropping intensity can be increased.

Limitation

The constraints and objective functions in LPP are linear.

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with the silent features of the work done at different places relevant to the present study. The important results obtained, methodology followed, various tools and practices adopted by different research workers as related to the objectives of the present study has been summarized and the literature for the study has been reviewed below.

2.1 Socio economic study

Socio economic study was carried out to study different social aspects as food, occupation, labour, employment, village, town, cities etc. Surveys are carried out for finding facts regarding people and their problems, these are helpful in further planning and development of the community to improve the welfare of the rural peoples and helping them to solve their problems.

Bharara et al. (1984) carried out socio economic survey in upper Luni Basin in Rajasthan desert. The study showed predominance of agricultural caste groups of Rajput, Seervi, Jat, Mali, Bishnoi, Rawat with 71 persons/sq km in 1971. The traditional households had disintegrated into nuclear households. Literacy rate was very low. Cultivation followed by agricultural labours and animal husbandry followed by casual labour was the main and subsidary occupations of population. Over 28% of total area, was cultivable waste land. On an average a household owned 1.05 ha of irrigated and 2.51 ha unirrigated land. Subsidence crops had low yield.

Solanki (1997) surveyed the socio economic status in command area of Jakham Irrigation Project. He studied and analysed the impact of Jakham Irrigation Project on farm economy of the tribal belt of Rajasthan and found that gross income was to be highest from sesasum in kharif and gram in rabi season, respectively.

Khatik and Singh (1998) carried out the socio economics study during 1993 in Navamota watershed in Khedbrahmma taluka of Sabarkantha district of Gujrat to access adoption behaviour of farmers towards SWC practices. The study showed that majority of farmers were tribals (86%) with small fragmented land holdings. The adoption level of soil and water conservation practices by tribals was medium, education and communication behaviour were found significant parameters with adoption behaviour of tribal farmers in Navamota watershed.

Machiwal (2001) carried out socio economic study of Jakham irrigation project. The outcomes of interviews conducted with sample farmers and the analysis of the questionaires shows that the per cent of literate and illiterate people were found to be 28.81 and 71.19 per cent, respectively. Family composition of sample farmers had female/male sex ratio lower (832/1000) than the national average of female/male (927/1000) as per 1991 census. Cropping pattern in kharif was maize, soyabean, grass and sugarcane. Whereas, in rabi, wheat, barley, gram, mustard was observed.

Singh et al. (2005) carried out socio economic survey of command area under Badliya distributory on right main canal of Mahi Bajaj Sagar Project. He observed that most of the farmers of the project area are small or marginal with little or no financial stability. On the basis of interviews, he concluded that farmers have no definite knowledge of quantity of water that should be applied to different crops at different stages of growth. As a result, the farmers have a tendency to utilize water much above the requirement.

Mahadadalkar (2007) carried socio economic study in Belura watershed of Akola district in Maharashtra for knowing the present status of the people in Belura watershed. The total population in watershed is 3677. Out of which 60.70% are illiterate people Out of 788 families in Belura watershed,small land holding farmers (upto 2ha)were 353 and they occupy the land 507.45 ha(21.32%).Total cultivable area is 87.08% of geographic area.Cultivable area under kharif,rabi and summer including perenial crops are 100%, 0.93% and 0.02% respectively.The study was carried out for optimal resources utilization in watershed.

2.2 Study on water balance

Michael (1978) reported that the water balance method is nothing but an inflow-outflow method, is suitable for large areas (watersheds) over long periods. It may be represented by the following hydrological equation.

Precipitation = Evapotranspiration + Surface runoff + subsurface drainage + change in soil water contents

This method necessities adequate measurement of all factors, except evapotranspiration. The value of evapotranspiration is computed from the measured data.

Pawade and Michael (1988) studied water balance in 1980-81 at Central Research Station, PKV, Akola. Following equation was used to obtain water balance.

$$P = R + E_T + V \pm S_s \pm S_g$$

Where,

P = Precipitation
R = Runoff, mm
E_T = Evaporation, mm
V = Subsurface flow, mm
S_s = Change in soil moisture, mm
S_g = Change in ground water storage, mm

The subsurface flow was assumed to be negligible. It was concluded that 70% of rainfall was utilized by vegetation through evapotranspiration and 12% rainfall resulted into surface flow. The estimated average gravity yield was approximately 8.8% and 2.2% of rainfall excluding and including soil profile moisture changes respectively.

Taley and Kohale (1990) studied hydrological budgetting of watershed at Central Research Station, PKV, Akola during the high rainfall year 1988-89 with 1399.47 mm rainfall. The groundwater fluctuations in 23 observation wells were recorded over 400 ha watershed. It was observed that availability of total water balance was 994.84 mm (73% of total rainfall) of this, about 48% comprised soil moisture, 14% surface runoff and about 11% ground water recharge. The evapotranspiration over the season was observed to be 493.71 mm (about 36% of rainfall).

Reddy et al. (1991) estimated ground water recharge of Dulapally basin situated towards north of Hydrabad city in semi arid tropics. The average annual rainfall, estimated surface runoff and groundwater recharge from water balance model during study period 1977 to 1990 were 867 mm, 181 mm and 124 mm respectively. The average percent of surface runoff and groundwater recharge with respect to rainfall worked out to be 20.9% and 14.4%, respectively.

Jat et al. (2004) carried out weekly water balance computation for Udaipur region (1981-1995). The variability in the mean length of growing season was analysed. The date of commencement of kharif season rains was found to influence considerably, the period of water availability for crop growth (appropriate crop plan) based on analysis cultural operation schedule is suggested.

Gray and Katz (1982) suggested that for runoff determination and prediction or design calculations using the soil conservation service curve number method of the urban drainage area simulator programme, it is necessary to select an appropriate antecedent moisture condition class for the growing season for the particular situation under study. Study provides estimates of the probability of occurrence of a particular antecedent moisture condition which will assists to decide the wetness index and further crop planning, etc.

2.3 Resources allocation study

Singh and Wolkewitz (1983) carried out study to optimize use of land and water resources for crop production and planning in irrigated agriculture. The objective function was maximized subject to different restrictions of land, water fertilizer, labour and other resources required for crop production. The land and water assumed to be limiting resources. Large area can be brought under cultivation and net profit may be increased by average canal water supply. The land area was increased from 18544 ha to 17785 ha.

Senapati et al. (1985) developed a resource management plant to maximize the production through land and water allocation to different crop activities for Simlapal block of Bankura district of West Bengal. They considered the constraints related to available area, water, fertilizers, labour and calorific values. The study revealed that the average production in existing cropping system increased from 30.56 to 39.76 quintals per hectares.

Raman and Vasudevan (1991) formed a general optimization programme which deals with the determination of optimal allocation of limited resources to meet given objectives. More specifically they refer to a situation where a number of available resources such as man power, materials, machines, water, land and capital are to be combined to yield one or more products.

Panda et al. (1996) developed three nonstructural management models for the management of soil and water resources in semi arid regions and linked together to aid in planning the optimum allocation of land and water resources to achieve the objectives of maximizing return in command area of a canal distributary. The ground water simulation model uses the mass balance approach to simulate water table depths. The seasonal crop water response models were developed to compute crop yields. Inter seasonal irrigation system planning model maximize net annual return through conjunctive use of surface water and gypsum treated sodic groundwater to achieve on operate at five water mixing indexes on operated at five water mining indexes and seven probability of excedence levels where rainfall, crop water requirements and canal water supply were assumed as random variables. These random variables were filled well to the gamma probability density function.

Singh et al. (2005) tried a linear programming model in Badliya command area of Mahi canal system in Banswara district of Rajasthan state to maximize the net return through optimal utilization of resources. The study indicated that efficiently managing resources of command area, net return could be increased from 71.57 lacs under existing cropping pattern to 90.22 lacs under optimal cropping pattern.

Thakur et al. (2006) developed the optimal land use planning model to minimize soil loss in Chorgaliya watershed, based on resource constraints such as land, water labour opportunities and net return. The model was developed by using the linear programming technique considering only monsoon season. The plan of existing cropping pattern with restriction on food grains was found to generate minimum soil loss.

Jajoo et al. (2008) planned optimal resource utilization using linear programming model for Belura watershed (567.19 ha cultivable area) in Akola district under limited land, water and capital resources. While formulating the linear programming model, preparation of crop plan constraints like land texture, depth, slope, availability of water in different seasons, investment capacity, affinity towards the crops and food requirements of the people in the watershed were considered to optimize the net returns. In the optimal crop plan the investment and net return is 14721 and 9101 Rs/ha respectively as against in existing pattern 11,184 and 6,469 Rs/ha respectively.

Roy (2008) carried out study for optimal land and water use plan to bring waste land and fallow land under remunerative production activity, KVK farm Jashpur (20.0 ha) constitute such waste and fallow land where the study took place. As per guidelines received from Dy. Director General (Agril Ext.) ICAR, detailed land use plan adopting water harvesting and recycling was prepared, to increase the production, productivity of crops. The main objective of study was to work out the development plan, to design water harvesting and drainage system, to work out optimal crop plan and its economics for sustainable use and development of land and water resources.

2.4 Use of linear programming models

The LP problem essentially consists of three parts i) Linear objective function ii) Set of linear constraints, embedding the technical specifications and iii) A set of non negativity constraints to avoid negative solution. Various authors have used linear programming technique to optimize the various criteria in command area projects the available literature is cited below.

Singh and Sirohi (1976) suggested the use of linear proprammіng technique to optimize timing and quantity of irrigation water so as to maximize the total harvestable crop production.

Lakshminarayan and Rajagopalan (1977) used linear programming model to determine the extent of allocation of irrigated area to alternative crops and the amount of seasonal water releases necessary for seasonal crop water requirements during one year period of operation such that the benefits from the system were maximized. The model was applied to Bori-Doab basin in Punjab and the optimal solutions were reported under the constraints of seasonal river discharge, canal capacity available land and seasonal crop water requirements Besides, the sensitivity analysis of the parameters was also done.

Vedula and Roger (1981) used a linear programming formulation to model a four reserviour system on a monthly basis to find the optimum cropping pattern subject land, water and downstream constraints for irrigation planning if a river basin that is extensively developed in the downstream reach and that has high potential for development in the upper reaches. The model was applied to Cavery river basin in India. Two objectives, maximize net economic benefits and maximize irrigated cropped area were analysed in context of multi objective planning and the trade were discussed.

Singh and Wolkewitz (1983) used linear programming technique for crop planning for the winter season in the canal command area of Hissar major distributory of western Jamuna Canal System. In the study, it has been assumed that for a particular crop irrigated with different seasonal irrigation depths, the production cost changes only because the cost of irrigation changes. The objective was to maximize net profit subject to different restrictions of land, water, fertilizer, labour and other resources required for crop production.

Salokhe and Rahaman (1989) studied linear programming technique to maximize the profit from the area by optimum utilization of land and water and compared increase in amount of net returns by their management over existing management. Objective functions was

$$\text{Maximize } (z) = \sum_{j=1}^{i} (CjYi - Pj)\,Aj - Cs \sum_{i=1}^{n} Si - Cg \sum_{i=1}^{n} Gi$$

Where,

Z	=	Net annual return (Rs)
i	=	Index for month
j	=	Index for crop
Cj	=	Unit cost of crop j (Rs/ton)
Yj	=	Yield per unit area of crop (t/ha)
Pj	=	Unit cost of production of crop j (exclusive of water) Rs/ha
Aj	=	Area under crop j
Cs	=	Unit cost of canal water Rs/ha m
Si	=	Volume of canal water used from canal for irrigation
Cg	=	Unit cost of ground water Rs/ha m
Gi	=	Value of ground water allocated in month (i for irrigation), ha-m

Under the following constraints,

Irrigation water requirement, Land use restrictions, Area constraint based on food demand, Labour constraint, and Ground water availability constraint.

Raman and Vasudevan (1991) planned an experiment to maximize the net benefit from irrigation with the available water resources through the application of linear programming technique. Benefits from the region are maximum only when the entire area is covered with crops based on optimal cropping pattern. It was seen that the linear programming technique was highly flexible to accommodate any number of variable and constraints.

Singh (1996) developed a LP model to obtain optimum crop combination for maximum net benefit with available land and water in Bijnor district of Rajasthan. In this study, the crop water requirement was calculated by pan evaporation methods. Crop coefficient were adopted for different crops and different stages of maturity to determine monthly consumptive use. She indicated that by optimum utilization of land and water resources it would be possible to increase the agricultural income of the district by almost 80%.

Radheyshyam et al. (1997) derived cropping pattern, depending upon crop suitability to different soil types of Nainital, Bhabar region under varying availability of irrigation water. The optimal cropping pattern, obtained through use of LP model results in increase of return from 20.60 per cent to 35.88 per cent against different supply levels of water in Bhabar region.

Bankar and Atre (1998) applied linear programming technique for planning rabi crops in watershed. The crops grown in Aagadgaon watershed of 226.01 ha in kharif season were considered. The optimization model for maximization of income from cropped area was determined.

Linear programming irrigation planning model was developed by Srinivasa and Nagesh (2001) in Andra Pradesh, for the evaluation of irrigation development strategy and applied to a case study with the objective of maximization of net benefits. It is observed that net benefits at 75% dependability level are 68.8% more than those at 90% dependability level.

Mahadadalkar (2007) formulated linear programming model to optimally allocate land to various crops with the objective of maximization of net benefits. The net benefit was increased by Rs 3214/ha over existing.

2.5 Optimal crop planning

Maji and Heady (1978) developed an optimal cropping pattern and reservoir management policy for Mayurakshi irrigation project (India). Two chance constrained linear programming models were formulated to account for the stochastic nature of the monthly inflows. The results indicated that a change in the existing cropping pattern and reservoir management policy is desirable and resulted into maximization of net return to the project area.

Chhikara and Singh (1986) studied scientific determination of optimum cropping pattern and main objective was to determine optimum crop plan based on existing production technique and improved production techniques by formulating linear programming model.

Kanade (1989) collected data such as canal flow, availability of water, yield and decided optimal cropping pattern for one minor in Mula command on the basis of water availability were considered. To achieve these objectives, two probabilities i.e. 30% and 50% of canal water availability were considered. Two irrigation conditions were also considered i.e. irrigation condition I (20% ETo and 60% Re) and Irrigation condition II (40% ETo & 70% Re). Two objective functions were considered such as production maximization and net profit maximization. Net profit was calculated for minium, maximum and average prices. The land allocations to various crop activities were worked out by linear programming model.

Raman and Paul (1992) studied the cropping pattern in command area using linear programming technique for obtaining an optimal cropping pattern from among the various alternatives viz., conjunctive use of surface and groundwater. The optimal cropping pattern was selected for two purpose, viz., maximize the net profit from the command area for a year and to maximize the net area put to cultivation in a year appropriate constraints were also included while formulating the problem on cropping area of each month, cropping area of each crop, surface and ground water availability and monthly crop water requirement. He further stated that the model is very flexible to alter the constraints or add any more constraints according to the policy makers decision from time to time based on socio economic consideration. The area allocation model had several components viz., i) benefit maximization ii) area maximization iii) Sensitivity analysis iv) availability of water v) saving of water.

Gorantiwar et al. (1996) developed an optimization model based on LP technique to obtain area to be irrigated under different crops (area allocation plan) for four different conditions for the known supply of water. The area allocation plan obtained for different conditions were compared with the existing cropping pattern. The results revealed the need for computing the demand of water on scientific basis and optimum allocation of area to different crops for obtaining maximum crop production.

Meena and Arya (1999) presented a system approach to derive an optimal cropping pattern for the command area to use the water efficiently for each and every crop under the limitation of various resources inputs. The efforts were aimed in developing optimal water management strategies through application of linear programing approach.

Singh et al. (1999) carried out study with production maximization as a prime objective developing an linear programming model for optimizing resource utilization, their study indicated that crop planning at command area level has potential to enhance crop production by 60% to 96% and net return by 23 to 26%. Establishment of co-operative societies in command area is recommended to achieve better crop planning and higher production.

Pawar and Suryakant (2001) assessed precisely available water resources and decided optimal cropping pattern of Udaisagar reservoir using a linear programing software TORA (version 2.0 Oct 1996) using Weibulls plotting position methods, probability analysis of yield available due to surface runoff, annual evaporation and seepage losses and average industrial water requirement. For these available water resources, optimal cropping pattern was found out.

Sethi et al. (2002) developed linear programing model for optimal crop planning and ground water management for maximization of economic returns. The model was applied to portion of costal river basin in Orissa and optimal crop plan was obtained for various scenario of river flow and ground water availability.

Hassan et al. (2005) applied linear programming model for obtaining optimal cropping pattern under various price options. Model was applied to calculate optimal crop acerage, production and income of irrigated Punjab in Pakistan. The result showed that irrigated agriculture in Punjab is more or less operating at optimal level. As a result of optimal cropping pattern income increased by 1.57%.

Madadalkar et al. (2008) applied the linear programming technique for conjunctive use of surface water and groundwater and obtained the cropping plan. The study was undertaken to optimally allocate the area to various crop activities with objective of maximizing net benefits subjected to number of constraints such as land, water, capital, food requirement etc. Total net return in existing and proposed pattern in Bellura watershed of Akola district comprises of 2380.11 ha is Rs 142.8 and Rs 219.64 lakhs with increase over existing by 76.84 lakh.

2.6 Other models

Tyagi and Narayana (1984) applied deterministic linear programming model for allocation of surface and ground water for irrigation of crops within the project area and for water export, development of a technique to estimate the system parameters which are of a transient nature and generation of system response at different stage of soil reclamation. The dynamic nature of agricultural system and the nonlinearity of the crop water production function are incorporated by using separate input data for each time increment in the model and by introducing multiple activities for each crop respectively. The model is applied to a representative alkali area in Indo-Gangetic plains of India. Optimal cropping pattern over a period of 20 yr at five discrete stages of reclamation are determined. Parametric analysis is used to determine optimal water resources management policies with regard to canal water diversion, ground water mining and export water.

Pandit and Senapati (1991) applied a multi objective optimization procedure using the goal programming technique to assist planners so as to sustain the productivity of land at derived level to decision making model for planning period of 12 months is formulated and applied to a canal command area in Orisa in order to demonstrate the economic utilization of irrigation water under controlled conditions. Alternate solutions by changing goal priorities have been developed and an optimal model has been selected. Out of 12 crop area allocation models developed by making 16 runs in the computer, the best model is obtained in run when the canal systems is operated at its 80% design flow with the project efficiency being maintained at 60% by adopting optimal cropping pattern the cropping intensity has been found to be 56.62% and net return per mm of irrigation water as Rs. 14.95 which shows a considerable improvement in both economic returns as well as utilization of land and water resources.

Carrello et al. (1998) developed nonlinear management model to obtain an optimal cropping pattern for conditions existing in Chile. The objective function was based on crop water production relations taking into account different conditions of climate, soils and parameters such as maximum evapotranspiration, labour needs, production costs, irrigation efficiencies and price of the obtained products. The model furnishes the optimal distribution of areas and crops, water requirements and total profit.

Paul et al. (2000) optimal resources allocation strategies for canal commanding the semiarid region of Indian Punjab are developed under stochastic regime, proposed strategies are divided into two modules using multilevel approach. The proposed strategies are divided into two stages first module determines seasonal allocation of water as well as optimal cropping pattern and second stage is deterministic dynamic programming model which takes into account the multi crop situation. The second model takes output of first and gives optimal weekly irrigation allocations for each crop by considering the stress sensitivity factors of crops.

Srinivasa and Nagesh (2004) applied Genetic algorithms (GA) for irrigation planning. The GA technique is used to evolve efficient cropping pattern for maximizing benefits for an irrigation project in India. Constraints include continuity equation, land and water requirements, crop diversification and restriction on storage. Penalty function approach is used to convert constrained problem into a unconstrained one. Results obtained by GA are compared with linear programming solution and found to be reasonably close. GA is found to be an effective tool for irrigation planning and results obtained can be utilized for efficient planning of any irrigation system.

Khare et al. (2006) analyzed the feasibility of conjunctive use management using mathematical model in Sapon irrigation command area of Kulon Progo Regency, Indonesia. The water demand and available water resources in the study area are evaluated considering surface, water and groundwater. A simple economic engineering optimization model is presented to explore the possibilities of conjunctive use of surface and groundwater using linear programming with various hydrological and management constraints, and to arrive at an optimal cropping pattern for optimal use of water resources for maximization of net benefits. The LINDO 6.1 optimization package has been used to arrive at optimal allocation plan of surface water and ground water.

CHAPTER III

THEORETICAL CONSIDERATIONS

This chapter deals with the theoretical concepts, which were used for the development of linear programming as allocation model.

3.1 Formulation of general linear programming model in scalar form

Linear Programming is a technique of allocation of scarce resources to competing activities under the assumption of linearity. This technique is used either to maximize or minimize a given objective function. In general linear programming problem can be stated in the following form:

Maximize (or minimize) :

$$Z = C_1 X_1 + C_2 X_2 + \dots\dots\dots\dots + C_n X_n. \qquad \dots(3.1)$$

Subject to the constraints

$$\begin{array}{l} a_{11} X_1 + a_{12} X_2 + \dots\dots\dots + a_{1n} X_n \ (\leq = \text{or} \geq)\ b_1 \\ a_{21} X_1 + a_{22} X_2 + \dots\dots\dots + a_{2n} X_n \ (\leq = \text{or} \geq)\ b_2 \\ \dots\dots \quad \dots\dots \quad \dots\dots \quad \dots\dots \quad \dots\dots \quad \dots\dots \\ \dots\dots \quad \dots\dots \quad \dots\dots \quad \dots\dots \quad \dots\dots \quad \dots\dots \\ a_{m1} X_1 + a_{m2} X_2 + \dots\dots\dots + a_{mn} X_n \ (\leq, = \text{or} \ \geq)\ b_m \end{array} \qquad \dots.(3.2)$$

and

$$X_1 \geq 0, \ X_2 \ \geq 0, \ \dots\dots\dots, \ X_n \geq 0 \qquad \dots.(3.3)$$

3.2 Assumptions

The following assumptions were considered in developing the model.

1) The relationship between the variables in the objective function and the constraints are linear.

2) All parts of the land under consideration are put to the same management practices.

3) All inputs other than water, viz. seeds, fertilizers, weedicides, labours and pesticides of desired quality are available in adequate quantities.

4) Time and period of crop sown is same in every year.

5) Crop yield considered is same throughout the district.

6). Ground water is used only during winter and summer season.

7) Gross irrigation efficiency is taken as 75 per cent for surface water.

3.3 Development of linear programming model

Linear programming deals with the problem of allocation of limited resources among competing activities in an optimal manner. Basically it is an optimizing technique with an objective function consisting of variables subject to number of constraints. It incorporates stochastic nature of variables like rainfall and inflows. A linear programming model is developed for the selected district (Akola, Amravati and Buldhana) of Vidarbha region.

3.3.1 Defination of variable used in LP model

For the development of LP model, the subscripts used are 'i' representing crop activity. Particulars of the subscripts are given in the Table 3.1.

3.3.2 Objective function

In order to maximize the objective of net benefit, a mathematical model is developed for optimal allocation of land for the selected area. The objective function is subjected to the following various constraints.

Table 3.1 Subscripts for crops in different season used in the model with notations

Sub-script 'i'	Crop for kharif season	Sub-script 'i'	Crop for rabi season	Sub-script 'i'	Crop for summer season	Sub-script 'i'	Annual Crops
1	Cotton (CK)	11	Wheat (WR)	16	Green vegetables (VGS)	18	Fruits (FA)
2	Jowar (JK)	12	Gram (GR)	17	Other vegetables (VOS)	19	Silvipasture (AA)
3	Cotton + Tur (C_TK)	13	Safflower (SR)			20	Dryland horticulture (DA)
4	Soybean + Tur (S_TK)	14	Green vegetables (VGR)				
5	Mung/ Udid (MK)	15	Other vegetables (VOR)				
6	Groundnut (GK)						
7	Soybean (SK)						
8	Sunflower (SuK)						
9	Green vegetables (VGK)						
10	Other vegetables (VOK)						

(Note : RK = Rice used for Amravati district only)

Objective : Net benefit maximization

Net benefit per hectare is to be maximized in order to consider the economic upliftment of the farming community in the project area.

$$\text{Max. NB} = \sum_{i=1}^{n} NbiXi$$

Where,

Nbi = Net benefit from i^{th} crop, Rs/ ha

Xi = Area under i^{th} crop, ha

3.3.3 Constraints

1. Area constraint

The area under each crop during the growing season should not exceed total area available for cultivation in the watershed.

$$\Sigma X_i \leq A_i$$

Where,

A_i = Total area available for cultivation, ha

2. Water constraint

The water requirement of all crops in the area is fulfilled by the existing water resources in the watershed.

$$\Sigma W_i X_i \leq W$$

Where,

W_i = Depth of water required for i^{th} crop in particular season, cm

W = Total water availability in the watershed, ha-cm

3. Food requirement constraint

Food available from the crops grown in the district should fulfill the actual food requirement of people in the district.

$$\Sigma N_i X_i \leq N$$

Where,

N_i = Production of i^{th} crop, q /ha

N = Quantity of crop to be produced to fulfill food requirement of population, q

4. Capital constraint

In a developing country like India, capital is the biggest constraint for any planning. The capital available from the entire source should not be less than the total expenditure involved in planning.

$$\Sigma\ C_i X_i \leq C$$

Where,

Ci	=	Working capital for i^{th} crop, Rs/ ha
C	=	Total capital available for cultivation of crops, Rs

5. Land capability constraint

On the basis of land capability classes, total area allocated for different crops should be less than or equal to the area suitable for growing the particular crop.

$$\Sigma\ X_i \leq L$$

Where,

L	=	Total area of land which is suitable for i^{th} crop, ha

6. Non-negativity constraint

$$X_i \geq 0$$

In addition, some other constraints are also considered based on local affinity, market risk and production risk such as :

1) Lower and upper limits of area are given for each crop.
2) Limits of area are also fixed for silvipasture and dryland horticulture plantation.

Fig. 1. Map of Akola, Amravati and Buldhana district

CHAPTER IV

MATERIAL AND METHODS

4.1 Material required

Linear Programming an Optimization Technique was used for deriving optimal resources allocation for Akola, Amravati and Buldhana districts of Vidarbha region Basic recent information of agricultural resources like land, water, existing cropping pattern, water requirement of different crops, investment, gross and net return of different commonly grown crops and water balance study were required. These were collected from District Agricultural Statistic Department, Akola. Irrigation and Water Management Department Akola, Agricultural Price Cell of Economics Dept. Dr. PDKV and Economics and Statistic Bulletin of respective districts . Linear Programming technique was solved using optimization tool of MATLAB software on HCL computer system.

4.2 Methods adopted

4.2.1 Land capability classes of study area

On the basis of land capability classification, the area having soil classes and depth of Akola, Amravati and Buldhana districts are given in table 4.1 and details for Akola district are given in Appendix A.

Table 4.1. Land capability classification, ha

S. N.	District	Geogro-phic area	Obser-ved area	Culitv-able area	Land capability classes Depth		Depth				
					I to IV	V toVIII	Shallow (d1)	Moder-ately shallow (d2)	Modera-te (d3)	Deep (d4)	Very deep (d5)
1.	Akola	543000	426282	477778	407610	18672	14881	66401	64581	55723	224696
2.	Amravati	1221000	746253	827524	725217	21036	21036	210478	116608	79579	318552
3.	Buldhana	966100	843747	770300	738215	105532	78640	277065	258626	148147	81269

4.2.2 Water balance study

Water balance study involves precipitation, infiltration and runoff. The relation between various parameters of water balance equation is given as below.

Precipitation = Infiltration + Runoff+ Evaporation .....(4.1)

The computation of each parameter of water balance study is given as under.

4.2.2.1 Rainfall

The daily rainfall data for last 25 yrs (1983-2007) for Akola district was obtained from the Department of Meteorology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and 10 yrs data from (1998-2007) for Amravati and Buldhana was available on website agri.mah.nic.in. This rainfall was analyzed for computing weekly rainfall during Kharif season i.e. from 23rd to 40th metrological weeks and average runoff is estimated by curve number technique.

4.2.2.2 Infiltration of water into soil

1) Available soil moisture for crop
2) Deep percolation
3) Groundwater recharge

1) Available soil moisture for crop

The soil moisture between field capacity and permanent wilting point is referred as available soil moisture. The Table 4.2 presents the range of available water holding capacities and available water of different soil textural groups.

Table 4.2. Range of available water holding capacity of soils

Soil	Per cent moisture, based on dry weight of soil		Depth of available water
	Field capacity	Permanent wilting point	cm per meter depth of soil
Fine sand	3-5	1-3	2-4
Sandy loam	5-15	3-8	4-11
Silt loam	12-18	6-10	6-13
Clay loam	15-30	7-16	10-18
Clay	25-40	12-20	16-30

(Adopted from Michael, 1978)

2) Deep Percolation

The Soil water between the strata below crop root zone and above ground water is percolated water. This water is not useful for agricultural crops. From the study conducted by (Taley 1990, Jadhav, 1999) the average annul percolation for Akola is 2.5% of a. a. r.

3) Groundwater recharge

According to the past study conducted by (Reddy 1991, Jadhav, 1999), the percentage of average annual ground water recharge is 11.7%, interception and depression storage is 1.8% and soil evaporation is 15.5% of a. a. r.

4.2.2.3. Runoff

It is that portion of rainfall, which makes its way towards streams rivers etc. after satisfying initial losses such as interception. Infiltration, depression storage etc. is called runoff. Runoff of selected region is computed from daily rainfall data using SCS curve number method. The details of method are as below.

1) Estimation of runoff by curve number technique

In order to determine runoff following steps are to be followed.

a) First the hydrological soil groups of the catchments area are determined according to infiltration rate of soil.

b) Curve number (CN) for antecedent moisture condition (AMC) II is determined according to land use, tretment given, hydrologic condition and hydrological soil groups. Then CN for AMC I and AMC III are obtained by using the given table.

c) Potential maximum retension (S) is determined from curve number by using equations.

$$CN = \frac{25400}{254 + S} \qquad \text{..... (4.2)}$$

Where,
CN = Curve number
S = Potential maximum retention, mm

d) AMC has been determined by using 5 days antecedent rainfall using Table 4.4.

e) Then runoff is determined by using formula

$$Q = (P-0.2S)^2 / (P+0.8S) \qquad \text{..... (4.3)}$$

Where,
Q = Runoff, mm
P = Rainfall, mm

2) Antecedent moisture condition (AMC)

The antecedent moisture condition (AMC) is the index of wetness which denotes the sum of past 5 days rainfall, previous to current day rainfall. The limits of 5 days antecedent rains for the three AMC are given in Table 4.3.

Table 4.3. Five days antecedent rainfall for estimating antecedent moisture condition for different seasons

AMC	Dormant season	Growing season
I	Less than 12.5	Less than 35
II	1.25 to 27.5	3.5. to 52.5
III .	Over 27.5	Over 52.5

3) Runoff curve number (CN)

A curve number is an index that represents the combination of hydrologic soil groups. Land use and treatment classes. The composite curve number for an area having more than are land use treatment or soil type can be found by weighing each curve number according to its area and is given by.

$$\text{Weighted CN} = \frac{A_1CN_1 + A_2CN_2 \ldots\ldots\ldots A_nCN_n}{A_1 + A_2 + A_3 + \ldots\ldots\ldots A_n} \qquad \ldots\ldots (4.4)$$

4.2.2.4 Runoff water harvesting

The land pressure is increasing day by day due to population growth. Causing more and more marginal lands are being used for agriculture. Agriculture is only possible when there is availability of water. Although at every places there is ground water, but its exploration needs money as result become a constraint. However in rainy season most of the runoff goes waste. If this runoff is stored and harvested, water availability can be formed, which can be used for irrigation purpose. The collection and storage of any farm water either runoff or creek flow for irrigation use is denoted as water harvesting. Water conservation techniques includes a wide range of methods like cement nala bandhara, loose boulders, gabian structures contour trenches in which long term runoff harvesting is mainly done for building a big water stock for purpose of irrigation, fish farming, electricity generation etc. It is done by constructing the reservoirs and big size ponds in the area. For the study area the sample design of Cement Nala bund and farm pond is suggested for storage of runoff water for irrigation purpose.

To design cement nala bund following steps are involved -

1) Estimation of peak runoff rate

To estimate peak runoff rate by rational formula

$$Q = \frac{CIA}{360} \qquad \text{.....(4.5)}$$

Where,

Q = Peak runoff rate, m^3/s
C = Runoff coefficient
I = Rainfall intensity (mm/hr) for duration equal to time of concentration
A = Area, ha

2) Design dimensions of bund

The dimensions of nala bund are designed by standard formulae.

To design the farm pond following points are to be considered.

1) Estimation of runoff

The daily runoff is estimated from rainstorm, using curve number technique for last 25 years. 80% of the average estimated runoff in different meteorological weeks is taken for design of farm pond.

2) Evaporation and seepage losses

Pond evaporation and seepage are the two major losses from pond. To study evaporation losses from the pond, last 25 years weekly open pan evaporation data was collected and then average weekly evaporation rate of pan and pond calculated considering pan coefficient as 0.70. Considering the soil strata, seepage losses were taken as 10 mm/day.

3) Size, shape and capacity of farm pond

The size of pond will depend on required storage capacity. For designing farm pond we assume square shape with 3 m depth having side slope 1 vertical : 1 horizontal. The volume of runoff to be stored in the pond can be calculated by using Prisomoidal formula as follows.

$$V = (D/6)\ (A_1+4A_m+A_2) \qquad \text{..... (4.6)}$$

Where,

V	=	Volume of water stored, m^3
D	=	Depth of the pond, m.
A1	=	Top area, m^2
Am	=	Mid area, m^2
A2	=	Bottom area, m^2

4.2.3 Evaporation

It includes soil evaporation and evaporation from open water bodies. Daily pan evaporation data of Meteorological Department, Dr. PDKV, Akola for 25 years (1983-2007) was used for design of farm pond and estimation of different crop water requirements.

4.2.4 Crop water requirements

Crop water requirements are defined as the depth of water needed to meet the water losses through transpiration (ET crop) of a disease free crop growing in a large field under non-restricting soil condition including soil, water and fertility.

1) Actual evapotranspiration

To compute ET of crop, three stage procedure has been proposed by Food and agricultural Organisation is given by crop coefficient (Kc) which represents the relationship between the reference evapotranspiration (ETo) and crop evapotranspiration (ETc).

$$ETc = ETo.Kc \qquad \text{..... (4.7)}$$

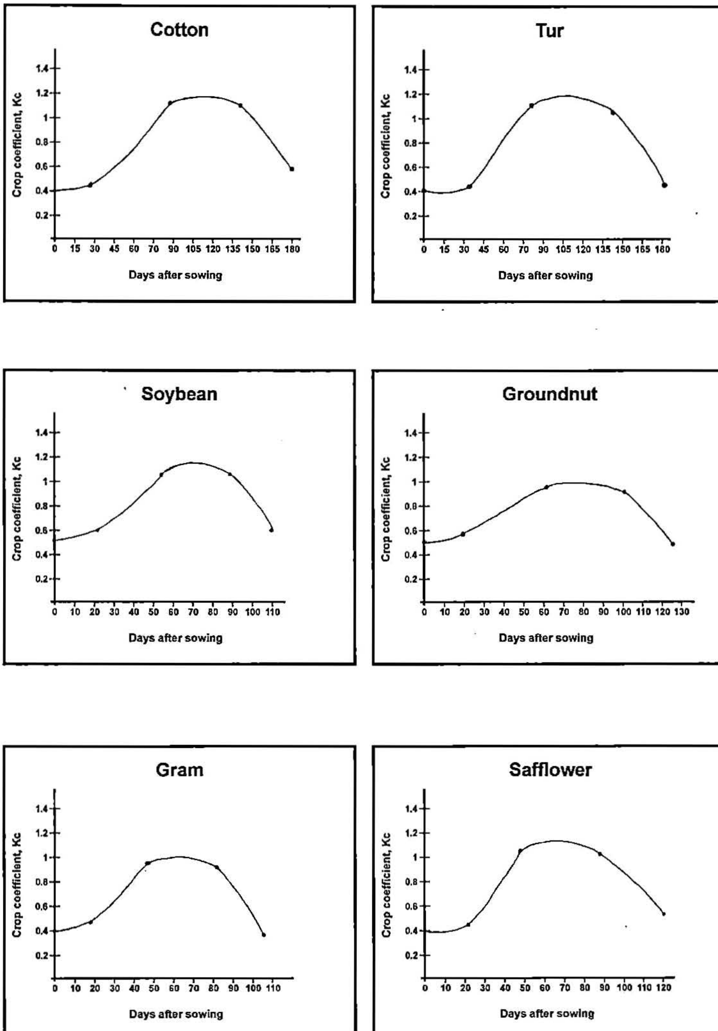

Fig. 2. Crop coefficient (Kc) curves of different crops

Values of Kc are dependent on the crop, its stage of growth, growing season and the weather condition, ETc can be determined in mm per day as mean over the some 10 to 30 days periods.

2) Reference evapotranspiration

Reference evapotranspiration (ETo) is equal to pan evaporation (Ep) multiplied by an empirically derived pan coefficient (Kp= 0.7) which takes into account climate and pan environment. Thus,

$$ETo = Kp \times Ep \quad \text{.... (4.8)}$$

Where,

EP = Pan evaporation in mm/day represents the mean daily value of the period considered

Kp = Pan coefficient

Crop coefficient (Kc) of different crops at various crop growth stages are presented in Appendix B. Average value of Kc at different stages of crop are taken to compute crop evapotranspiration. The calculation of ETo for last 25 years data is given in Appendix B. The general rainfed crop growth stages for soybean are as below.

Length of growth stages -

Initial stage	:	15 days
Crop development	:	25 days
Mid season	:	40 days
Late season	:	25 days

4.2.5 Food requirement of the people in the districts

Recommended balanced diets to adult and children is given in Table 4.4 The requirement for cereals, pulses, oilseeds, fruits and vegetables is estimated based on the population is the district. In order to satisfy the demand of food minimum area requirement for crops were estimated as per the demand of the population.

Table 4.4 Recommended balanced diet, gm

Food groups	Children (1- 9)	Adoles cent (10-18)	Rural		Urban	
			Male	Female	Male	Female
Cereals	270	450	650	475	480	360
Pulses	60	70	80	70	90	75
Green leafy vegetables	75	100	125	125	125	125
Other vegetables	50	75	100	100	75	75
Fruits	50	30	30	30	30	30
Milk	250	250	200	200	200	200
Fastsand oils	30	45	65	55	40	35
Sugar and jaggary	50	40	55	40	40	30

(Shubhangini Joshi, 2002)

Sample calculation of total food requirement for peoples of Akola district is given in Appendix J.

4.4.6 Formulation of linear programming model

The method and data used to formulate linear programming model are discussed in following sections. A MATLAB, HCL, computer system in which optimization toolbox is used for land allocations to different crops were worked out for each criteria.

Optimal allocation of area to various crops were estimated to maximize the net benefits from the crops grown in kharif, rabi, summer season in the district. Net benefits obtained from various crops were computed. The sample calculation of investment required and estimated net benefit from soybean is presented in Appendix C. Models are developed for each districts and described below.

Linear programming model for Akola district

Net benefit maximization

For economic upliftment of farmers net benefits are to be maximized.

MAX Z = 5910 CK + 4220 JK + 6225 C_TK + 5630 S_TK + 4860 MK + 5610 GK + 5120 SK +4405 SuK + 5060 VGK + 6460 VOK + 7070 WR+ 4580 GR + 4230 SAR + 7500 VGR + 7980 VOR + 8460 VGS + 8220 VOS + 12500 FA + 3750 AA + 7500 DA.

Constraints

1) Area Constraint

The area under crops during each season should not exceed total area available for cultivation in the selected district

For kharif season -

CK + JK + C_TK + S_TK + MK+ Gk + SK + SuK + VGK + VOK + FA + F + AA + DA ≤ 477778

For rabi season -

CK + C_TK + S_TK + WR + GR + SAR+ VGR + VOR + FA + AA + DA ≤ 477778

For summer season -

VGS + VOS + FA + AA + DA ≤ 477778

2) Water Constraint

The water requirement for various crops in the area should be fulfilled by the existing water resource in the district in each season.

For kharif season -

44 CK + 45.36 JK + 42 C_TK + 35 S_TK + 27 MK + 38.91 GK + 41.23 SK + 35.53 SuK + 33.74 VGK + 30.98 VOK + 45 FA + 37.2 AA + 47.9 DA ≤ 24352872.34

For rabi and summer season -

11.68CK + 11.51 C_TK + 11.29 S_TK + 42.37 WR + 25 GR + 28.10 SAR + 49.1 VGR + 14.97 VOR + 60.1 VGS + 52.96 VOS + 105 FA $\leq$ 12201001.97

3) Food requirement constraint

Minimum area of different crops grown in the district should fulfill the food requirement of the people.

a) Wheat 25 WR $\geq 2.036232 \times 10^6$

b) Jowar 27.5 JK $\geq 6.78744 \times 10^5$

c) Tur 3 C_TK+ 35S_TK $\geq 2.62233 \times 10^5$

d) Gram 10 GR $\geq 8.7411 \times 10^4$

e) Mung/Udid 7.5 MK $\geq 8.7411 \times 10^4$

f) Groundnut 7.5 GK $\geq 1.51657 \times 10^5$

g) Soyabean 15 SK $\geq 5.5148 \times 10^4$

h) Sunflower 10 Suk $\geq 1.3787 \times 10^4$

i) Safflower 7 SAR $\geq 5.5148 \times 10^4$

j) Fruits 150 FA $\geq 1.98207 \times 10^5$

k) Green leafy vegetables 65 VGK $\geq 2.21096 \times 10^5$, 70 VGR $\geq 2.21096 \times 10^5$, 65 VGS $\geq 2.21096 \times 10^5$ in kharif, rabi and summer, respectively.

l) Other vegetables 100 VOK$\geq 1.59133 \times 10^5$, 105 VOR $\geq 1.59133 \times 10^5$, 100 VOS $\geq 1.59133 \times 10^5$ in kharif, rabi and summer, respectively.

4) Capital constraint

In developing country like India capital in the biggest constraint for any planning. The capital available from the entire. Source should not be less than the total expenditure involved in planning.

The LP model is solved for obtaining results without considering capital constraints. After maximization the, results obtained give the net capital requirement problem is solved by considering the capital availability less than the obtained without capital constraint for three cases, 11,500, 12,500 and 13,500 Rs/ha and the constraints are.

For investment 11,500 Rs/ha

$12280\ CK + 8850\ JK + 11605\ C_TK + 9440\ S_TK + 5920\ GK + 9395\ SK + 6115\ SuK + 16580\ VGK + 15955\ VOK\ 11830\ WR + 6250\ GR + 1490\ SAR + 19280\ VGR + 18655\ VOR + 20180\ VGS + 19555\ VOS + 15000\ FA + 3000\ AA + 4000\ DA \leq 5.4945 \times 10^9$

For investment 12,500 Rs/ha

$12280\ CK + 8850\ JK + 11605\ C_TK + 9440\ S_TK + 5920\ GK + 9395\ SK + 6115\ SuK + 16580\ VGK + 15955\ VOK\ 11830\ WR + 6250\ GR + 1490\ SAR + 19280\ VGR + 18655\ VOR + 20180\ VGS + 19555\ VOS + 15000\ FA + 3000\ AA + 4000\ DA \leq 5.97 \times 10^9$

For investment 13,500 Rs/ha

$12280\ CK + 8850\ JK + 11605\ C_TK + 9440\ S_TK + 5920\ GK + 9395\ SK + 6115\ SuK + 16580\ VGK + 15955\ VOK\ 11830\ WR + 6250\ GR + 1490\ SAR + 19280\ VGR + 18655\ VOR + 20180\ VGS + 19555\ VOS + 15000\ FA + 3000\ AA + 4000\ DA \leq 6.45 \times 10^9$

5) Non-negatively constraint

$CK \geq 0$, $JK \geq 0$, $C_TK \geq 0$, $S_TK \geq 0$, $MK \geq 0$, $GK \geq 0$, $SK \geq 0$, $SuK \geq 0$, $VGK \geq 0$, $VOK \geq 0$, $WR \geq 0$, $GR \geq 0$, $SAR \geq 0$, $VGR \geq 0$, $VOR \geq 0$, $VGS \geq 0$, $VOS \geq 0$, $FA \geq 0$, $DA \geq 0$.

6) Other Constraint

Considering land capability, affinity of farmers towards crops, risk of failure, market rate fluctuation following lower and upper limits proposed to area under different crops are given.

Season	Crops	Area under different crops, %	
		Lower limit (%)	Upper limit (%)
Kharif	Cotton	≥ 10	≤ 20
	Jowar	≥ 5	≤ 20
	Cotton + Tur	≥ 10	≤ 20
	Soybean + Tur	≥ 10	≤ 20
	Mung/ Udid	≥ 5	≤ 15
	Groundnut	≥ 5	≤ 10
	Soybean	≥ 10	≤ 30
	Sunflower	≥ 1	≤ 5
	Green Leafy vegetable	≥ 1	≤ 2
	Other vegetable	≥ 0.5	≤ 1
Rabi	Wheat	≥ 17	≤ 20
	Gram	≥ 2	≤ 20
	Safflower	≥ 2	≤ 10
	Green vegetable	≥ 1	≤ 2
	Other vegetable	≥ 0.5	≤ 1
Summer	Green vegetable	≥ 1	≤ 2
	Other vegetable	≥ 0.5	≤ 1
Annual	Fruits	≥ 1	≤ 5
	Silivipasture	= 1	-
	Dryland Horticulture	= 2	-

Linear programming model for Amravati district

Net benefit maximization

For economic upliftment of farmers net benefits are to be maximized.

MAX Z = 5250 RK + 5910 CK + 4220 JK + 6225 C_TK + 5630 S_TK + 4860 MK + 5610 GK + 5120 SK +4405 SuK + 5060 VGK + 6460 VOK + 7070 WR+ 4580 GR + 4230 SAR + 7500 VGR + 7980 VOR + 8460 VGS + 8220 VOS + 12500 FA + 3750 AA + 7500 DA.

Constraints

1) Area Constraint

The area under crops during each season should not exceed total area available for cultivation in the selected district

For kharif season -

$RK + CK + JK + C_TK + S_TK + MK + Gk + SK + SuK + VGK + VOK + FA + F + AA + DA \leq 827524$

For rabi season -

$RK + CK + C_TK + S_TK + WR + GR + SAR + VGR + VOR + FA + AA + DA \leq 827524$

For summer season -

$VGS + VOS + FA + AA + DA \leq 827524$

2) Water Constraint

The water requirement for various crops in the area should be fulfilled by the existing water resource in the district in each season.

For kharif season -

$60.34\ RK + 44\ CK + 45.36\ JK + 42\ C_TK + 35\ S_TK + 27\ MK + 38.91\ GK + 41.23\ SK + 35.53\ SuK + 33.74\ VGK + 30.98\ VOK + 45\ EA + 37.2\ AA + 47.9\ DA \leq 62173169.94$

For rabi and summer season -

$17\ RK + 11.68CK + 11.51\ C_TK + 11.29\ S_TK + 42.37\ WR + 25\ GR + 28.10\ SAR + 49.1\ VGR + 14.97\ VOR + 60.1\ VGS + 52.96\ VOS + 105\ FA \leq 32023942.14$

3) Food requirement constraint

Minimum area of different crops grown in the district should fulfill the food requirement of the people.

a) Wheat $25\ WR \geq 3.077185 \times 10^6$

b) Rice $28\ RK \geq 4.39598 \times 10^5$

c) Jowar $27.5\ JK \geq 8.79196 \times 10^5$

d) Tur 3 C_TK+ $3S_TK \geq 4.20518 \times 10^5$

e) Gram 10 GR $\geq 1.40173 \times 10^5$

f) Mung/Udid 7.5 MK $\geq 1.40173 \times 10^5$

g) Groundnut 7.5 GK $\geq 2.45731 \times 10^5$

h) Soyabean 15 SK $\geq 8.9857 \times 10^4$

i) Sunflower 10 Suk $\geq 2.2339 \times 10^4$

j) Safflower 7 SAR $\geq 8.9357 \times 10^4$

j) Fruits 150 FA $\geq 2.95952 \times 10^5$

k) Green leafy vegetables 65 VGK $\geq 3.55269 \times 10^5$, 70 VGR $\geq 3.55269 \times 10^5$, 65 VGS $\geq 3.55269 \times 10^5$ in kharif, rabi and summer, respectively.

l) Other vegetables 100 Vok $\geq 2.56936 \times 10^5$, 105 VOR $\geq 2.56936 \times 10^5$, 100 VOS $\geq 2.56936 \times 10^5$ in kharif, rabi and summer respectively

4) Capital constraint

In developing country like India capital in the biggest constraint for any planning. The capital available from the entire. Source should not be less than the total expenditure involved in planning.

For investment 11,000 Rs/ha

12280 CK + 8850 JK + 11605 C_TK + 9440 S_TK + 5920 GK + 9395 SK + 6115 SuK + 16580 VGK + 15955 VOK 11830 WR + 6250 GR + 1490 SAR + 19280 VGR + 18655 VOR + 20180 VGS + 19555 VOS + 15000 FA + 3000 AA + 4000 DA $\leq 5.4945 \times 10^9$

For investment 13,000 Rs/ha

12280 CK + 8850 JK + 11605 C_TK + 9440 S_TK + 5920 GK + 9395 SK + 6115 SuK + 16580 VGK + 15955 VOK 11830 WR + 6250 GR + 1490 SAR + 19280 VGR + 18655 VOR + 20180 VGS + 19555 VOS + 15000 FA + 3000 AA + 4000 DA $\leq 5.97 \times 10^9$

For investment 14,500 Rs/ha

12280 CK + 8850 JK + 11605 C_TK + 9440 S_TK + 5920 GK + 9395 SK + 6115 SuK + 16580 VGK + 15955 VOK 11830 WR + 6250 GR + 1490 SAR + 19280 VGR + 18655 VOR + 20180 VGS + 19555 VOS + 15000 FA + 3000 AA + 4000 DA $\leq 6.45 \times 10^9$

5) Non-negatively constraint

CK ≥ 0, JK ≥ 0, C_TK ≥ 0, S_TK ≥ 0, MK ≥ 0, GK ≥ 0, SK ≥ 0, SuK ≥ 0, VGK ≥ 0, VOK ≥ 0, WR ≥ 0, GR ≥ 0, SAR ≥ 0, VGR ≥ 0, VOR ≥ 0, VGS ≥ 0, VOS ≥ 0, FA ≥ 0, DA ≥ 0.

6) Other Constraint

Considering land capability, affinity of farmers towards crops, risk of failure, market rate fluctuation following lower and upper limits proposed to area under different crops are given.

Season	Crops	Area under different crops, %	
		Lower limit (%)	Upper limit (%)
Kharif	Rice	≥ 2	≤ 3
	Cotton	≥ 10	≤ 20
	Jowar	≥ 5	≤ 20
	Cotton + Tur	≥ 10	≤ 20
	Soybean + Tur	≥ 10	≤ 20
	Mung/ Udid	≥ 5	≤ 15
	Groundnut	≥ 5	≤ 10
	Soybean	≥ 10	≤ 30
	Sunflower	≥ 1	≤ 5
	Green Leafy vegetable	≥ 1	≤ 2
	Other vegetable	≥ 0.5	≤ 1
Rabi	Wheat	≥ 13	≤ 30
	Gram	≥ 2	≤ 30
	Safflower	≥ 2	≤ 10
	Green vegetable	≥ 1	≤ 2
	Other vegetable	≥ 0.5	≤ 1
Summer	Green vegetable	≥ 1	≤ 2
	Other vegetable	≥ 0.5	≤ 1
Annual	Fruits	≥ 1	≤ 5
	Silivipasture	= 1	-
	Dryland Horticulture	= 2	-

Linear programming model for Buldhana district

Net benefit maximization

For economic up liftman of farmers net benefit are to the maximized

MAX Z = 5910 CK + 4220 JK + 6225 + C_TK + 5630 S_TK + 4860 MK + 5610 GK + 5120 SK + 4405 S_UK + 5060 VGK + 6460 VOK + 7070 Wr + 4580 GR + 4230 SAR + 7500 VGR + 7980 VOR + 8460 VGS + 8220 VOS + 12500 FA + 3750 AA + 7500 DA

Constraints

1) Area constraint

The area under crops during each season should net emceed total area available for cultivation in the selected district.

For Kharif season

CK + JK + C_TK + S_TK + Mk + GK + SK + SuK + VGK + VOK + FA + AA + DA ≤ 7,70,300

For rabi season

CK + C_TK + S_TK + WR+ GR + SAR + VGR + VOR + FA + AA + DA ≤ 7,70,300

For summer season

VGS + VOS + FA + AA + DA ≤ 7,70,300

2) Water constraint

The water equipment for various crops in the are should be fulfilled by the existing water resources in the district in each season.

For Kharif season

44 CK + 45.36 JK + 42 C_TK + 35 S_TK + 27 MK + 38.91 GK + 41.23 SK + 35.53 SuK + 33.74 VGK + 30.98 VOK + 45 FA + 32.2 AA + 47.9 DA ≤ 48602328

For rabi and summer season

$11.68\ CK + 11.51\ C_TK + 11.29\ S_TK + 42.37\ WR + 256\ R + 28.10\ SAR + 49.1\ VGR + 41.97\ VOR + 60.1\ VGS + 52.96\ VOS + 105\ EA \leq 23587212.13$

3) Food requirement constraint

Crops grown in the district should fulfill the actual food and notational requirement of people in district.

a) Wheat $25\ WR \geq 2.822557 \times 10^6$

b) Jowar $27.5\ JK \geq 7.05639 \times 10^5$

c) Tur $3C_TK + 3S_TK \geq 3.58129 \times 10^5$

d) Gram $10\ GR \geq 1.19376 \times 10^5$

e) Mung/Udid $7.5\ MK \geq 1.19376 \times 10^5$

f) Groundnut $7.5\ GK \geq 2.11088 \times 10^5$

g) Soybean $15\ SK \geq 7.6759 \times 10^4$

h) Sunflower $10\ SUK \geq 1.9190 \times 10^4$

i) Sallower $7\ SAR \geq 7.6759 \times 10^4$

j) Fruits $150\ PA \geq 2.73791 \times 10^5$

k) Green leafy vegetables $65\ VGK \geq 3.01496 \times 10^5$, $70\ VGR \geq 3.01496 \times 10^5$, $65\ VGS \geq 3.01496 \times 10^5$ in kharif rabi and summer season.

l) Other vegetables $100 \geq 2.19332 \times 10^5$, $105 \geq 2.19332 \times 10^5$, $100 \geq 2.19332 \times 10^5$ in kharif, rabi and summer season

4) Capital Constraint

In a developing country like India, capital is the biggest constraint for any planning. The capital available from the entire south should not be les than the total expenditure involved in planning.

For investment 9,500 Rs/ha

$12280\ CK + 8850\ JK + 11605\ C_TK + 9440\ STK + 5920\ MK + 5920\ GK + 9395\ SK + 6115\ SUK + 16580\ VGK + 15955\ VOK + 11830\ WR + 6250\ GR + 4190\ SR + 19280\ VGR\ 18655\ VOR + 20180\ VGS + 19555\ VOS + 15000\ FA + 3000\ AA + 4000\ DA \leq 7.31\ 785 \times 10^9$

For investment 11,000 Rs/ha

12280 CK + 8850 JK + 11605C_TK + 9440 S_TK + 5920 MK + 5920 GK + 9395 SK + 6115 SUK + 16580 VGK + 15955 VOK +11830 WR + 6250 GR + 4190 SR + 19280 VGR 18655 VOR + 20180 VGS + 19555 VOS + 15000 FA + 3000 AA + 4000 DA ≤ 8.4733 x 10^9

For investment 13,000 Rs/ha

12280 CK + 8850 JK + 11605C_TK + 9440 S_TK + 5920 MK + 5920 GK + 9395 SK + 6115 SUK + 16580 VGK + 15955 VOK +11830 WR + 6250 GR + 4190 SR + 19280 VGR 18655 VOR + 20180 VGS + 19555 VOS + 15000 FA + 3000 AA + 4000 DA ≤ 1.00139 x 10^9

5) Other Constraint

Considering land capability, affinity of farmers towards crops, risk of failure, market rate fluctuation following lower and upper limits proposed to area under different crops are given.

Season	Crops	Area under different crops, %	
		Lower limit (%)	Upper limit (%)
Kharif	Cotton	≥ 10	≤ 20
	Jowar	≥ 5	≤ 20
	Cotton + Tur	≥ 10	≤ 20
	Soybean + Tur	≥ 10	≤ 20
	Mung/ Udid	≥ 5	≤ 15
	Groundnut	≥ 5	≤ 10
	Soybean	≥ 10	≤ 30
	Sunflower	≥ 1	≤ 5
	Green Leafy vegetable	≥ 1	≤ 2
	Other vegetable	≥ 0.5	≤ 1
Rabi	Wheat	≥ 17	≤ 25
	Gram	≥ 2	≤ 25
	Safflower	≥ 2	≤ 10
	Green vegetable	≥ 1	≤ 2
	Other vegetable	≥ 0.5	≤ 1
Summer	Green vegetable	≥ 1	≤ 2
	Other vegetable	≥ 0.5	≤ 1
Annual	Fruits	≥ 1	≤ 5
	Silivipasture	= 1	-
	Dryland Horticulture	= 2	-

CHAPTER V

SOCIO-ECONOMICS FEATURES

This chapter deals with brief description of the study area. It includes the population, literacy rate, land holding pattern, land utilization and existing crop plan of study area. It reveals the basic information regarding study area. The study area comprises of three selected districts namely Akola, Amravati and Buldhana of Vidarbha region, District wise detail information was collected and given below

5.1 Akola district

5.1.1 Location

Akola district lies between 20.17° to 21.16° East longitudes and 76.7° to 77.4° North latitudes. It occupies about 5430 km^2 of total geographic area. Akola district comprises of seven tahsils namely, Telhara, Akot, Balapur, Akola, Murtizapur, Patur and Barshitakli.

5.1.2 Population and education in district

Total population of district is 16.30 lakh and about 13.2 lakh number of peoples are literate in district. The details are as below.

Table 5.1 Population and literacy of Akola district

	Population			Literacy		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**
Rural	517465 (51.61)	485277 (48.39)	1002747 (61.51)	454697 (87.87)	335472 (69.13)	790169 (78.80)
Urban	323788 (51.60)	303709 (48.40)	627497 (38.49)	293190 (90.55)	243544 (80.19)	536734 (85.53)
Total			1630239 (100)			1326903 (81.41)

Note : Figures in parenthesis are percentage values (Census, 2001)

5.1.3 Land holding pattern of Akola District

Land holders and area of land holding in Akola district is given in table below.

Table 5.2 Land holding pattern of Akola District

Sr. No.	Land holding (ha)	Land holders (%)	Area of land holding (%)
1.	0-2	52.93	22.11
2.	2-5	32.68	33.61
3.	5-10	11.28	27.23
4.	10-20	2	12.98
5.	20 and above	2	2.05

(District economics Bulletin, 2006-2007)

5.1.4 Land utilization and existing crop plan

The Akola district comprises of 5430 Km^2 of total geographic area. Details of land utilization of district is given in Table 5.3.

Table 5.3 Land utilization pattern of Akola district

Sr. No.	Particulars	Area "00" ha	% to total geographic area
1.	Total geographic area	5430	100
2.	Land under forest	403	7.41
3.	Land not available for cultivation	249	4.59
	a) Land put to non agricultural use	85	1.56
	b) Barren and uncultivated land	164	3.03
4.	Land not cultivated other than barren land	86	1.59
	a) Permanent pasture and grazing land	32	0.59
	b) Land under miscellaneous tree crops	20	0.37
	c) Cultivable waste land	34	0.63
5.	Fallow land	335	6.17
	a) Current fallow	271	4.99
	b) Other fallow	64	1.18
6.	Net sown area	4357	80.24
7.	Area sown more than once	803	14.79
8.	Gross cropped area	5160	95.03

Area under different crops in kharif, rabi and summer seasons are given in Table 5.4.

Table 5.4 Existing crop plan of Akola district

Sr. No.	Name of crops	Area"00"ha
Kharif Crops		
1.	Cotton	2076
2.	Jowar	822
3.	Cotton + Tur	261
4.	Soyabean + Tur	261
5.	Mung/ Udid	655
6.	Soybean	503
7.	Sesamum s	29
8.	Sunflower	15
9.	Other kh. Cereals (bajra, maize)	22
10.	Other kh. Pulses	4
Total		**4648**
Rabi crops		
1.	Wheat	34
2.	Gram	240
3.	Safflower	19
4.	Sunflower	15
5.	Jowar	1
Total		**309**
Summer crops		
1.	Groundnut	5
2.	Sunflower	4
Total		**9**
Total Cultivable area		**4778**

5.2 Amravati District

5.2.1 Location

Amravati district lies at 20.32° to 21.46° East longitudes and 76.37° to 78.27° North latitudes. It comprises of 12210 km^2 of total geographic area. There are 14 tehsils namely Dharni, Chikhaldara, Anjangaon Surji, Achalpur, Chandurbazar, Morshi, Warud, Tiwsa, Amravati, Bhatkuli, Daryapur, Nandgaon Khandeshwar, Chadur Rly, Dhamangaon Rly.

5.2.2 Population and education of district

Total population of district is 2607160 and about 2150907 number of peoples are literate in district. The details are as below.

Table 5.5 Population and literacy of Amravati district

	Population			Literacy		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**
Rural	880387 (51.56)	827194 (48.44)	1707581 (65.50)	762415 (86.60)	588135 (71.10)	1350550 (79.20)
Urban	465227 (51.75)	434352 (48.28)	899579 (34.50)	432196 (92.90)	368593 (84.40)	798789 (88.80)
Total			**2607160**			**2149339 (82.50)**

Note : Figures is parenthesis are percentage values (Census, 2001)

5.2.3 Land holding pattern of Amravati district

Land holders and area of land holding in Amravati district is given in Table 5.6.

Table 5.6 Land holding pattern of Amravati district

Sr. No.	Land holding (ha)	Land holders (%)	Area of land holdings (%)
1.	0-2	54.39	27.68
2.	2-5	29.3	35.87
3.	5-10	14.75	54.60
4.	10-20	2.06	0.1
5.	20 and above	0.14	1.38

(District economics Bulletins, 2006-07)

5.2.4 Land utilization and existing crop plan

The Amravati district comprises of 12210 km^2 of total geographic area. Details of land utilization of district is given in Table 5.7

Table 5.7 Land utilization pattern of Amravati district

Sr. No.	Particulars	Area "00" ha	%to total geographic area
1.	Total geographic area	12210	100
2.	Land under forest	3241	26.54
3.	Land not available for cultivation	696	5.70
	a) Land put to non agricultural use	210	1.72
	b) Barren and uncultivated land	486	3.98
4.	Land not cultivated other than barren land	554	4.54
	a) Permanent pasture and grazing land	304	2.49
	b) Land under miscellaneous tree crops	70	0.58
	c) Cultivable waste land	180	1.47
5.	Fallow land	202	1.65
	a) Current fallow	114	0.93
	b) Other fallow	88	0.72
6.	Net sown area	7519	61.57
7.	Area sown more than once	2148	17.59
8.	Gross cropped area	9667	79.16

Area under different crops in kharif, rabi and summer are given in Table 5.8.

Table 5.8. Existing crop plain of Amravati district

Sr. No.	Name of Crops	Area"00"ha
Kharif crops		
1.	Rice	96
2.	Cotton	2682
3.	Jowar	928
4.	Cotton + Tur	455
5.	Soybean + Tur	454
6.	Mung/Udid	650
7.	Groundnut	14
8.	Soybean	1671
9.	Sesamum	10
10.	Sunflower	3
11.	Other kh. Cereal (bajra, maize)	21
12.	Other kh. Pulses	42
13.	Sugarcane	14
Total		**7040**
Rabi Crops		
1.	Wheat	103
2.	Gram	372
3.	Safflower	34
4.	Sunflower	17
Total		**526**
Summer crops		
1.	Groundnut	6
2.	Sunflower	1
Total		**7**
Total Cultivable area		**8275**

5.3 Buldhana district

5.3.1. Location

Buldhana district lies between 19.51° to 21.17° East longitudes and 75.57° to 76.40° North latitudes. It occupies of about 9771 km^2 of total geographic area. Buldhana district comprises of thirteen tehsils namely, Jalgaon Jamod, Sangrampur, Shegaon, Nandura, Malkapur, Motala, Khamgaon, Mehkar, Chikhali, Buldhana, Deulgaonraja, Sindhkedraja, Lonar,

5.3.2 Population and literacy of Buldhana district

Total population of district is 22.32 and about 14.44 number of peoples are literate in district. The details of area are shown in Table 5.9.

Table 5.9 Population and literacy of Buldhana district

	Population			Literacy		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**
Rural	902445 (51.30)	865652 (48.70)	1759097 (78.80)	655175 (72.60)	447172 (52.17)	1102347 (62.65)
Urban	244958 (51.75)	228425 (48.25)	473383 (21.20)	191900 (78.35)	149847 (65.55)	341747 (72.17)
Total			2232480			1444094 (65.67)

Note : Figures in parenthesis are percentage values (Census, 2001)

5.3.3 Land holding pattern in Buldhana district

Land holders and area of land holding in Buldhana district is given in Table 5.10.

Table 5.10 Land holding pattern in Buldhana district

Sr. No.	Land holding (ha)	Land holder (%)	Area of land holdings (%)
1.	0-2	56	25
2.	2-5	31	37
3.	5-10	10	26
4.	10-20	02	10
5.	20 and above	01	02

5.3.4 Land utilization and existing crop plan

The Buldhana district is having 9661 km^2 of total geographic area. Details of land utilization of the district is given in the Table 5.11.

Table 5.11 Land utilization pattern of Buldhana district

Sr. No.	Particulars	Area "00" ha	% to total geographic area
1.	Total geographic area	9671	100
2.	Land under forest	970	10.03
3.	Land not available for cultivation	998	10.32
	a) land put to non agricultural use	499	5.16
	b) Barren and uncultivated land	499	5.16
4.	Land not cultivated other than barren land	276	2.85
	a) Permanent pasture and grazing land	70	0.72
	b) Land under miscellaneous tree crops	131	1.37
	c) Cultivable waste land	75	0.76
5.	Fallow land	310	3.21
	a) current fallow	143	1.48
	b) Other fallow	167	1.73
6.	Net sown area	7117	73.59
7.	Area sown more than once	1252	12.96
8.	Gross cropped area	8369	86.54

Area under different crops in kharif, rabi and summer seasons are given in Table 5.12.

Table 5.12 Existing crop plan of Buldhana district

Sr. No.	Name of crops	Area "00" ha
Kharif crops		
1.	Cotton	1087
2.	Jowar	1019
3.	Cotton + Tur	308
4.	Soybean + Tur	308
5.	Mung/Udid	1624
6.	Groundnut	4
7.	Soybean	1412
8.	Sesamum	15
9.	Sunflower	58
10.	Other kh. Cereal (bajra, maize)	382
11.	Other kh. Pulses	11
12.	Sugarcane	7
Total		**6236**
Rabi Crops		
1.	Wheat	265
2.	Gram	301
3.	Jowar	197
4.	Maize	9
5.	Safflower	19
6.	Sunflower	10
Total		**801**
Summer crops		
1.	Maize	1
2.	Groundnut	2
3.	Sunflower	1
Total		**4**
Total Cultivable area		**7703**

CHAPTER VI

RESULTS AND DISCUSSION

The chapter deals with the results of the study carried out and presented in following sub section.

6.1 Socio-economic status

The socio-economics feature were studied to know the present status of the peoples in the districts.

6.1.1 Akola district

The total population of Akola district is 16.30 lakhs. The major population is rural i.e. 61.51% and remaining 38.49% urban population. Out of total population, 13.2 lakhs is literate, and out of which about 78.80% rural and 85.53% urban. The landholding pattern of district shows that majority of land holders i.e. 52.93% have land 0-2 ha, followed by 32.68% have land 2-5 ha, 11.28% have 5-10 ha and only 4% have land more than 10 ha. The total geographic area of district is 5430 km^2 and total cultivable area is 4778 km^2. The land utilization pattern of the district is shown in Table No. 5.3 Major crops grown in kharif season are Jowar, cotton, mung, udid, soyabean. In rabi season wheat, gram, safflower, and in summer season groundnut and sunflower. At present the total area under kharif, rabi and summer season is 4648, 309 and 9 hundred ha, respectively.

6.1.2 Amravati District

The district comprises of 12210 km^2 of total geographic area. The total population of the district is 26.07 lakh. Out of which 65.50% is rural and 34.50% is urban in which 82.50% is literate out of which 79.20% is rural and 88.80% urban. According to landholding pattern land holding between 0-2, 2-5, 5-10 and above 10 ha are 54.30, 29.3, 14.75 and

2.20% respectively. The total cultivable area of district is 8275 hundred ha. Major crops grown in kharif season are cotton, tur, mung, udid, soyabean, in rabi season wheat, gram, safflower and in summer groundnut and sunflower. The total area under kharif, rabi and summer season is 7040, 526 and 7 hundred ha,respectively.

6.1.3 Buldhana district

The district comprises of 9661 km^2 of total geographic area. The total population of the district is 22.32 lakh. Out of which 78.80% is rural and 21.2% is urban in which 64.67% is literate out of which 62.65% is rural and 72.17% urban. According to landholding pattern land holding between 0-2, 2-5, 5-10 and above 10 ha are 56, 31, 10 and 3% respectively. The total cultivable area of district is 8275 hundred ha. Major crops grown in kharif season are cotton, tur, mung, udid, soyabean, in rabi season wheat, gram, safflower and in summer groundnut and sunflower. The total area under kharif, rabi and summer season is 6236, 801 and 4 hundred ha,respectively.

6.2 Land capability classification and crop planning

In Akola district it is observed that 4076 hundred ha land is under I to IV and 186 hundred ha land is under V to VII land capability classes. When the land of Akola district is classified according to depth as shallow (< 7.5 cm) moderately shallow (7.5-25 cm) moderate (25-50 cm), deep (50-100 cm) and very deep (> 100 cm). It is observed that major area is under very deep i.e. 2246.9 hundred ha and total area under shallow and moderately shallow is 812.8 hundred ha.

In Amravati district 7252.2 hundred ha and 210.4 hundred ha comes under I to IV and V to VIII land capability classes respectively.

Major area is under very deep soil depth i.e. 3185.5 hundred ha and total area under shallow and moderately shallow is 2315.1 hundred ha. respectively.

In Buldhana district about 7382.1 and 1055.3 hundred ha land comes under I to IV and V to VIII land capability classes. Area under moderate, deep and very deep soil depth is 2586.2, 1481.5 and 812.7 hundred ha. Area under shallow, moderately shallow soil depth is 786.4 and 2770.7 hundred ha.

Considering the land capability classes in moderate soil Jowar, mung, udid crops are proposed and in deep and very deep type soil deep rooted crops like cotton tur are proposed. Whereas, in shallow and moderately shallow soil in class V to VIII class type silvipasture and other dry land horticultural trees such as custard apple, ber are suggested. Rice is suggested only in kharif season in heavy rainfall areas of Amravati district. Rabi crops are wheat, gram, safflower, green vegetables, other vegetables, in summer vegetables and annual orange fruits and silvipasture crops are suggested.

6.3 Water Resource Study in districts

Rainfall and evaporation data was collected and analyzed to predict effective rainfall, crop water requirement and evaporation losses from pond.

6.3.1 Rainfall

25 years (1983-2007) daily rainfall of different tahsils, for Akola, 10 years (1998-2007) for Amravati and Buldhana districts was collected and analysed. In Akola district tahsil wise variation is negligible hence average was used for analysis. Whereas, in Amravati and

Buldhana there is variation in tahsil wise rainfall. Therefore a group of tahsils of about equal rainfall is made as below to estimate runoff by curve number technique.

Weighted weekly average rainfall is calculated for Amravati and Buldhana district and presented in Table 6.1. Estimated weighted rainfall and runoff for Buldhana district is given in Appendix E.

Table 6.1. Group of tahsils and its average annual rainfall of Amravati and Buldhana districts

District	Group of tahsils	Avg. annual rainfall (mm)
Amravati		
Group 1	Achalpur, Daryapur, Morshi, Anjangoan, Amravati, Bhatkuli, Nandgoan, Dhamangoan and Dharni	923.7
Group 2	Warud, Tiwsa, Chandurbazar and Chandur railway	689.6
Group 3	Chikhaldara	1187.16
Buldhana		
Group 1	Mehkar, Sangrampur, Deulgaon Raja, Shegaon, Chikhali, Jalgaon Jamod, Motala, Nandura, Malkapur, Khamgaon and Sindkhed Raja	851
Group 2	Lonar and Buldhana	978.5

Details of estimated weekly average rainfall for Akola, Amravati and Buldhana is presented in Table 6.2.

Table 6.2. Weekly average rainfall for Akola, Amravati and Buldhana district, mm

SMW	Akola	Amravati	Buldhana
23	21.33	22.92	20.19
24	44.47	58.71	46.20
25	42.92	40.79	42.41
26	31.82	72.49	64.28
27	28.57	80.80	33.92
28	60.79	33.97	29.92
29	61.14	53.42	62.30
30	42.57	70.43	37.60
31	43.93	75.10	84.59
32	60.98	80.71	91.83
33	62.02	28.04	16.72
34	38.87	30.71	52.80
35	43.82	23.7	37.44
36	33.01	56.32	44.21
37	21.49	33.71	29.54
38	25.70	33.12	30.32
39	22.68	22.21	27.39
40	27.56	24.74	51.87
23 MW - 40 MW	683.67	841.79	803.51
41 MW - 5 MW	62.95	51.65	43.04
6 MW - 22 MW	44.16	35.68	23.68
Annual	790.78	929.1	870.23

6.3.2 Runoff

Tahsil wise runoff is estimated by using curve number method from daily rainfall data of the different tahsils of selected districts. Weighted average of rainfall and runoff was estimated and considered to be average rainfall and runoff for the whole district.

Akola district

Runoff estimated by CNT from 25 years daily rainfall data (1983-2007) considering land use, treatment, hydrological condition and hydrologic soil group, CN for AMC-II is found to be 79, CN for AMC-I and AMC-III has been obtained by using multiplying factors which is taken as 0.784 and 1.147, respectively using equation 4.2 potential maximum retention (S) found to be 156.34 mm and 28.03 mm for AMC-I, AMC-II and AMC-III, respectively. Sample calculation of estimation of runoff for Akola district for year 1983 is presented in Appendix E.

Estimated average runoff for Akola was found to be 108.67 mm i.e. 15.90% of average kharif rainfall. Weekly runoff coefficient during kharif season varies between 0.04 to 0.28 with an seasonal average value as 0.16.

Table 6.3. **Weekly rainfall, runoff and runoff coefficient for Akola district, mm (1983-2007)**

SMW	Period	Rainfall	Runoff	Runoff coefficient
23	4-10 June	21.33	0.83	0.04
24	11-17	44.47	6.26	0.14
25	18-24	42.92	12.04	0.28
26	25-1 July	31.82	4.16	0.13
27	2-8	28.57	3.29	0.12
28	9-15	60.79	7.08	0.12
29	16-22	61.14	11.34	0.19
30	23-29	42.57	6.77	0.16
31	30-5 Aug	43.93	7.63	0.17
32	6-12	60.98	15.17	0.25
33	13-19	32.02	1.77	0.06
34	20-26	38.87	10.80	0.28
35	27-2 Sept	43.82	4.64	0.11
36	3-9	33.01	3.88	0.12
37	10-16	21.49	3.75	0.18
38	17-23	5.70	1.91	0.07
39	24-30	22.68	1.16	0.05
40	1-7 Oct	27.56	6.24	0.23
Total		**683.67**	**108.67**	**0.16**

Amravati district

Considering the soil type and land use and hydrological condition and hydrologic soil group for Group 1, Group 2 and Group 3 AMC-II was found to be 75.63, 82 and 75.63 mm respectively. CN for AMC-I and AMC-III are obtained as 57.71, 66.42, 57.71 and 89.17, 88.88, 89.17 mm respectively. Potential maximum retension (S) for Group 1, Group 2 and Group 3 are found to be 186.13, 81.85, 30.85, 128.41, 55.76, 31.78 and 186.13, 81.85, 30.85 mm,respectively.

Table 6.4. Weekly rainfall, runoff, and runoff coefficient for Amravati district, mm (1998-2007)

SMW	Period	Rainfall	Runoff	Runoff coefficient
23	4-10 June	22.92	1.75	0.08
24	11-17	58.71	15.41	0.26
25	18-24	40.79	8.17	0.20
26	25-1 July	72.49	20.06	0.28
27	2-8	80.80	26.79	0.33
28	9-15	33.97	5.89	0.17
29	16-22	53.42	13.49	0.25
30	23-29	70.43	14.55	0.21
31	30-5 Aug	75.00	17.02	0.23
32	6-12	80.71	26.28	0.33
33	13-19	28.04	4.27	0.15
34	20-26	30.71	3.67	0.12
35	27-2 Sept	23.70	2.93	0.12
36	3-9	56.32	8.00	0.14
37	10-16	33.71	5.28	0.16
38	17-23	33.12	4.56	0.14
39	24-30	22.21	2.66	0.12
40	1-7 Oct	24.74	3.13	0.13
Total		**841.79**	**183.91**	**0.22**

Average kharif rainfall, runoff and runoff coefficients are shown in Table 6.4. Average runoff for Amravati district was 183.91 mm i.e. 21.85% of average rainfall.

Buldhana district

Considering the soil type and land use and hydrological condition and hydrologic soil group for Group 1 and Group 2 AMC-II was found to be 81 and 79.5 mm, respectively. CN for AMC-I and AMC-III are obtained as 64.64, 87.24 and 58.27, 90.95, respectively. Potential maximum retension (S) for Group 1 and Group 2 are found to be 138.95, 59.58, 37.15

mm and 190.9, 65.5, 25.27 mm respectively, weekly rainfall, runoff and runoff coefficient are shown in Table 6.5.

Table 6.5. Weekly rainfall, runoff and runoff coefficient for Buldhana district, mm (1998-2007)

SMW	Period	Rainfall	Runoff	Runoff coefficient
23	4-10 June	20.19	1.60	0.08
24	11-17	46.20	7.59	0.16
25	18-24	42.41	2.97	0.07
26	25-1 July	64.28	13.39	0.21
27	2-8	33.92	2.81	0.08
28	9-15	29.92	3.23	0.11
29	16-22	62.30	7.84	0.13
30	23-29	37.60	3.78	0.10
31	30-5 Aug	84.57	24.40	0.29
32	6-12	91.83	37.37	0.41
33	13-19	16.72	1.13	0.07
34	20-26	52.80	12.19	0.23
35	27-2 Sept	37.44	5.97	0.16
36	3-9	44.21	9.27	0.21
37	10-16	29.54	4.19	0.14
38	17-23	30.32	5.64	0.19
39	24-30	27.39	3.38	0.12
40	1-7 Oct	51.81	14.42	0.28
Total		**803.51**	**161.17**	**0.20**

Average runoff for Buldhana was 161.17 mm i.e. 20.06% average rainfall. The runoff coefficient varies from 0.08 to 0.41 with seasonal average value to be 0.20.

6.3.3 Other parameters of water balance study

In Akola Amravati and Buldhana districts seasonal average rainfall during kharif, rabi and summer season were calculated. Runoff is estimed by CNT and other parameter of water balance are taken as annual percolation 2.5%, recharge to the ground water 11.5%, interception and depression storage 1.8%, soil evaporation 15.5% (Taley 1990, Reddy 1991, Jadhav 1999).

Water potential available in different seasons of Akola, Amravati and Buldhana districts is shown in Table 6.6. Sample calculation of water potential available in different seasons of Akola district is presented in Appendix F. Optimal crop plan and water harvesting planning was done considering water potential available in different districts.

Table 6.6. Water potential available in different seasons of Akola, Amravati and Buldhana districts, Mm^3

Sr. No.	Season	Akola	Amravati	Buldhana
1	Kharif season	2435.29	6217.32	4860.23
2	Rabi season	1048.68	2762.03	2030.76
3	Summer season	171.42	440.36	319.99

6.3.4 Water harvesting

Rainfall data was analysed to estimate runoff for Akola, Amravati and Buldhana districts. Table 6.7 presents the existing water potential in major, medium and minor irrigation projects and the total estimated runoff with total runoff to be harvested. Tahasilwise details of major, medium and minor irrigation projects and sample calculation of Total runoff and rainfall to be harvested for Akola district is given in Appendix G.

Table 6.7. Existing water potential, total runoff and runoff to be Harvested in the districts (Mm^3)

Districts	Water potential harvested				Total runoff	Runoff to be harvested
	Major	Medium	Minor	Total		
Akola	86.35	81.99	78.89	247.23	590.24	343.01
Amravati	548.14	122.66	97.81	768.62	2245.54	1476.92
Buldhana	84.22	95.36	100.08	279.66	1557.06	1277.4

From the total estimated runoff deducting total water potential in major, medium and minor projects there is a scope to harvest about 343.01, 1476.92 and 1277.4 Mm^3 of runoff in Akola, Amravati and Buldhana district, respectively. As there is scope to harvest runoff harvesting structures can be designed. A sample design of cement nala bund and farm pond is proposed.

Design of Nala bund for 200 ha catchment area

A cement nala bund for 200 ha catchment area is proposed. The sample design for nala bund with cost is given in Appendix H. The peak runoff rate was estimated by rational formula and which was use as discharge capacity to design dimensions of weir. Length of bund is 11.20 m height 2.26 m with water storage height 1.2 m, respectively. The total cost for nala bund is Rs. 1,99,170.

Design of farm pond for 2 ha catchment area

Design of pond for 2 ha catchment area, with estimated cost is presented in Appendix H for Akola district weekly rainfall and runoff are obtained from the Table 6.3 from which runoff volume for 2 ha. Catchment area is calculated considering 80% of runoff volume from 2 ha catchment area plus rainfall in pond and deducting storage losses runoff at end of week is calculated. Storage losses consist of evaporation and seepage losses. Surface area of ponded water is obtained. Pond evaporation losses are calculated by multiplying surface area of pond water with average open pan evaporation of that week and pan coefficient i.e. 0.70 seepage losses are taken as 10 mm/day and calculated by multiplying seepage rate to total wetted area of the pond.

Estimated cumulative runoff volume at end at 29th MW was found to be 802.52 m^3, assuming 682.42 m^3 stored water to be applied as protective irrigation to 1 ha area of 5 cm depth considering 75 % irrigation efficiency. Stored volume remains in ponds is 120.38 m^3. Similarly one more irrigations proposed in 34^{th} MW. The total runoff volume collected from the 2 ha catchment plus rainfall in pond after deducting storage losses during rainy season is found to be 1958.84 m^3. Thus, the design size of pond for 2 ha is found to be 20 m x 20 m with 3 m depth and 1:1 side slope. The cost for 20 m x 20 m x 3 m pond is Rs. 46,863.12.

Table 6.8. Average weekly rainfall and evaporation for Akola district during 1983-2007

Week No.	Period	Rainfall, mm	Evaporation, mm
23	4-10 June	21.33	91.7
24	11-17June	44.47	67.9
25	18-24 June	42.92	56.7
26	25-1 July	31.82	53.2
27	2-8 July	28.57	45.5
28	9-15 July	60.79	41.3
29	16-22 July	61.14	32.9
30	23-29 July	42.57	30.8
31	30-5 Aug	43.93	29.4
32	6-12 Aug.	60.98	27.3
33	13-19 Aug	62.02	30.8
34	20-26 Aug	38.87	28.7
35	27-2 Sept	43.82	29.4
36	3-9 Sept	33.01	30.8
37	10-16 Sept	21.49	33.6
38	17-23 Sept	25.70	33.6
39	24-30 Sept	22.68	32.2
40	1-7 Oct	27.56	35.35
Seasonal total		**683.67**	**731.5**
Annual		**790.78**	**2600.15**

6.3.5 Crop water requirements

Monthly average pan evaporation data of 25 years (1983-2007) was used for estimating crop evapotranspiration crop water requirements.

From the data presented in Appendix C it is seen that the reference evapotranspiration is maximum in the month of May (483.98 mm) followed by April (374.34 mm) and June (311.28 mm). Planning was made to meet the seasonal water requirement of all the selected crops and the calculated values of water requirement are given in Appendix I.

6.4 Optimal crop planning by linear programming

Following the methodology explained in previous chapters, a computer programme in MATLAB using optimization tool using HCL computer system was solved. Land allocation to different crops were worked out for each criteria. The input and output data for Akola district is presented in Appendix K.

Net benefit maximization without capital constraint

For Akola district

In proposed plan in kharif season major area is allocated to soybean crop (30%), followed by cotton + tur (20%), Cotton (12.87%) and groundnut (10%) where as in existing plan major area us under cotton (43.45%) followed by Jowar (17.2%), mung/udid (13.7) and Soybean (10.52%) of total cultivable area (Table 6.9).

Table 6.9. Existing and proposed crop plan for net benefit maximization (without and with capital constraint) for Akola district

Crops	Area under different crops, ha									
	Existing crop plan		Without capital constraint		Proposed crop plan with capital constraint					
					11500/-		12500/-		13500/-	
Cotton	207600	(43.45)	61493	(12.87)	47778	(10.00)	47778	(10.00)	47778	(10.00)
Jowar	82200	(17.20)	23889	(5.00)	23889	(5.00)	23889	(5.00)	23889	(5.00)
Cotton + Tur	26100	(5.46)	95556	(20.00)	47778	(10.00)	47778	(10.00)	47778	(10.00)
Soybean + Tur	26100	(5.46)	47778	(10.00)	47778	(10.00)	83872	(17.55)	47778	(10.00)
Mung/ Udid	65500	(13.71	23889	(5.00)	71667	(15.00)	71667	(15.00)	71667	(15.00)
Ground nut	-		47778	(10.00	47778	(10.00)	47778	(10.00)	47778	(10.00)
Soybean	50300	(10.52)	143333	(30.00)	47778	(10.00)	47778	(10.00)	123841	(25.92)
Sunflower	1500	(0.32)	4778	(1.00)	4778	(1.00)	23889	(5.00)	23889	(5.00)
Sesamum	2900	(0.61)	-		-		-		-	
0th Kh. Cereals	2200	(0.46)	-		-		-		-	
0th Kh. Pulses	400	(0.08)	-		-		-		-	
Green vegetables	-		4779	(1.00)	4778	(1.00)	4778	(1.00)	4778	(1.00)
0th Vegetable	-		4778	(1.00)	2389	(0.5)	2389	(0.5)	2389	(0.5)
Wheat	3400	(0.71)	95556	(20.00)	81222	(17.00)	81222	(17.00)	89128	(18.65)

contd......

Crops	Area under different crops, ha				
	Existing crop plan	Without capital constraint	Proposed crop plan with capital constraint		
			11500/-	12500/-	13500/-
Gram	24000 (5.2)	95556 (20.00)	85844 (18.00)	95556 (20.00)	95556 (20.00)
Safflower	1900 (0.39)	47778 (10.00)	47778 (10.00)	47778 (10.00)	47778 (10.00)
Rb. Sunflower	1500 (0.32)	-	-	-	-
Rb. Jowar	100 (0.02)	-	-	-	-
Rb. Green Vegetables	-	9556 (2.00)	4778 (1.00)	4778 (1.00)	4778 (1.00)
Rb. 0^{th} Vegetables	-	4778 (1.00)	2389 (0.5)	2389 (0.5)	2389 (0.5)
Su. Green Vegetables	-	9556 (2.00)	4778 (1.00)	4778 (1.00)	4778 (1.00)
Su. 0^{th} Vegetables	-	4778 (1.00)	2389 (0.5)	2389 (0.5)	2389 (0.5)
Su. Groundnut	500 (0.10)	-	-	-	-
Su. Sunflower	400 (0.08)	-	-	-	-
Fruits	-	5393 (1.13)	23889 (5.00)	21188 (4.44)	21879 (4.58)
Silvipastur	-	4778 (1.00)	4778 (1.00)	4778 (1.00)	4778 (1.00)
Dry land Horticulture	-	9556 (2.00)	9556 (2.00)	9556 (2.00)	9556 (2.00)
Gross investment, Rs/ha	10341	14864	11500	12500	13500
Total net return	248.63×10^7	422.00×10^7	354.38×10^7	384.197×10^7	409.27×10^7
Net return, Rs/ha	5203	8833	7417	8041	8566
Net return increases over existing	-	3630	2214	2838	3363

In rabi season in proposed plan major area is under wheat (20%) gram (20%) followed by safflower (10%) in proposed plan where as in existing plan major area is under gram (5.2%). In summer and annual crops in existing plan area is 0.91% while in proposed plan area is allocated to summer green vegetable (2%) and fruits crops (1.13%), respectively.

The investment and net benefit per ha in proposed plan were Rs14867 and Rs8833 where as in existing Rs10341 and Rs5203. In proposed plan net benefit increase by Rs3630 per ha over existing.

Harvest of runoff, conservation of rainwater and rise in groundwater and proposed to use it in rabi and summer season will result into increase the cropping intensity.

For Amravati district

In proposed plan in kharif season the major area is allocated to soybean (30%) followed by cotton (10%), Jowar (10%), cotton + tur (10%) and soybean + tur (10%) where as in existing plan major area is under cotton (32.41%) followed by soybean (20.19%) and Jowar (11.21%).

In rabi season in proposed plan major area is under wheat (30%) followed by gram (27%) whereas, in existing plan major area is under gram (4.50%) followed by wheat (1.25). In summer and annual crops in proposed plan area is allocated to summer vegetable (2%) and fruits crops (5%), respectively where as in existing plan only 0.08%.

The investment and net benefit in per ha in proposed plan is Rs16057 and Rs9642 whereas, in existing Rs9268 and Rs4906 benefit in proposed plan increases by Rs4736 per ha over existing.

Table 6.10. Existing and proposed crop plan for net benefit maximization (without and with capital constraint) for Amravati district

Crops	Area under different crops, ha									
	Existing crop plan		Without capital constraint		Proposed crop plan with capital constraint					
					11000/-		13000/-		14500/-	
Rice	9600	(1.16)	24826	(3.00)	16551	(2.00)	24719	(2.99)	24826	(3.00)
Cotton	268200	(32.41)	82752	(10.00)	82752	(10.00)	82752	(10.00)	82752	(10.00)
Jowar	92800	(11.21)	82752	(10.00)	82752	(10.00)	82752	(10.00)	82752	(10.00)
Cotton + Tur	45500	(5.00)	82752	(10.00)	82752	(10.00)	82752	(10.00)	82752	(10.00)
Soybean + Tur	45400	(5.40)	82752	(10.00)	82752	(10.00)	82752	(10.00)	82752	(10.00)
Mung/ Udid	65000	(7.85)	41378	(5.00)	124129	(15.00)	124129	(15.00)	124129	(15.00)
Ground nut	1400	(0.17)	82752	(10.00)	82752	(10.00)	82752	(10.00)	82752	(10.00)
Soybean	167100	(20.19)	248257	(30.00)	82752	(10.00)	82752	(10.00)	103444	(12.50)
Sunflower	300	(0.04)	8275	(1.00)	8275	(1.00)	82752	(10.00)	82752	(10.00)
Sesamum	1000	(0.12)	-		-		-		-	
0th Kh. Cereals	2100	(0.25)	-		-		-		-	
0th Kh. Pulses	4200	(0.51)	-		-		-		-	
Sugarcane	1400	(0.17)	-		-		-		-	
Green leafy vegetables	-		16551	(2.00)	8275	(1.00)	8275	(1.00)	8275	(1.00)
0th Vegetable	-		8275	(1.00)	4136	(0.5)	4136	(0.5)	4136	(0.5)
Wheat	10300	(1.25)	248257	(30.00)	107578	(13.00)	107578	(13.00)	225510	(27.25)

contd....

Crops	Area under different crops, ha				
	Existing crop plan	Without capital constraint	Proposed crop plan with capital constraint		
			11000/-	13000/-	14500/-
Gram	37200 (4.50)	22332 (27.00)	66318 (8.00)	248257 (30.00)	192393 (23.25)
Safflower	3400 (0.41)	16551 (2.00)	82752 (10.00)	82752 (10.00)	82752 (10.00)
Rb. Sunflower	1700 (0.20)	-	-	-	-
Rb. Green Vegetables	-	16551 (2.00)	8275 (1.00)	8275 (1.00)	8275 (1.00)
Rb. 0^{th} Vegetables	-	8275 (1.00)	4136 (0.05)	4136 (0.5)	4136 (0.5)
Su. Green Vegetables	-	16551 (2.00)	8275 (1.00)	8275 (1.00)	8275 (1.00)
Su. 0^{th} Vegetables	-	8275 (1.00)	4136 (0.5)	4136 (0.5)	4136 (0.5)
Su. Groundnut	600 (0.07)	-	-	-	-
Su. Sunflower	100 (0.01)	-	-	-	-
Fruits	-	41376 (5.00)	41376 (5.00)	41376 (5.00)	41376 (5.00)
Silvipastur	-	8275 (1.00)	8275 (1.00)	8275 (1.00)	8275 (1.00)
Dry land Horticulture	-	16551 (2.00)	16551 (2.00)	16551 (2.00)	16551 (2.00)
Gross investment, Rs/ha	9268	16057	11000	13000	14500
Total net return	405.977×10^7	797.878×10^7	578.82×10^7	699.24×10^7	767.6×10^7
Net return, Rs/ha	4906	9642	6995	8450	9278
Net return increases over existing	-	4736	2089	3544	4372

For Buldhana district

In proposed crop plan in kharif season major area allocated to soybean (18%) followed by groundnut (15%), cotton (10%), Jowar (10%), cotton + tur (10%), soybean + tur (10%). Where as in existing plan major area is under mung/udid (21.08%) followed by soybean (18.33%) cotton (14%) and Jowar (13.25%).

In rabi-season in proposed plan major area is under wheat (25%) followed by gram (24%) whereas, in existing major area is under gram (3.9%) followed by wheat (3.44%). In summer and annual crops in proposed plan area is allocated to summer green vegetables (2%) and fruit crops (5%), respectively.

Harvesting of runoff, conservation of rain water and rise in ground water and proposed to use will result in increasing crop intensity.

The investment and net benefit in proposed plan per ha is Rs14460 and Rs9221 where as in existing Rs7921 and Rs4608. The net benefit increases by Rs4614 per ha in proposed plan over existing.

Table 6.11. Existing and proposed crop plan for net benefit maximization (without and with capital constraint) for Buldhana district

Crops	Area under different crops, ha									
	Existing crop plan		Without capital constraint		Proposed crop plan with capital constraint					
					9500/-		11000/-		13000/-	
Cotton	108700	(14.00)	77030	(10.00)	77030	(10.00)	77030	(10.00)	77030	(10.00)
Jowar	101900	(13.23)	77030	(10.00)	77030	(10.00)	77030	(10.00)	77030	(10.00)
Cotton + Tur	30800	(4.00)	77030	(10.00)	77030	(10.00)	77030	(10.00)	77030	(10.00)
Soybean + Tur	30800	(4.00)	77030	(10.00)	77030	(10.00)	77030	(10.00)	77030	(10.00)
Mung/ Udid	162400	(21.08)	46218	(6.00)	46218	(6.00)	64141	(8.33)	11693	(14.50)
Ground nut	400	(0.05)	115545	(15.00)	77030	(10.00)	115545	(15.00)	115545	(15.00)
Soybean	141200	(18.33)	138654	(18.00)	77030	(10.00)	77030	(10.00)	77030	(10.00)
Sunflower	1500	(0.19)	15406	(2.00)	15406	(2.00)	15406	(2.00)	15406	(2.00)
Sesamum	5800	(0.75)	-		-		-		-	
0^{th} Kh. Cereals	38300	(4.97)	-		-		-		-	
0^{th} Kh. Pulses	1100	(0.14)	-		-		-		-	
Sugarcane	700	(0.09)	-		-		-		-	
Green leafy vegetables	-		7703	(1.00)	7703	(1.00)	7703	(1.00)	7703	(1.00)
0^{th} Vegetable	-		7703	(1.00)	3852	(0.5)	3852	(0.5)	3852	(0.5)
Wheat	26500	(3.44)	192575	(25.00)	115545	(15.00)	115545	(15.00)	129805	(16.85)
Gram	30100	(3.9)	184872	(24.00)	15406	(2.00)	15406	(2.00)	189869	(24.65)

contd....

Crops	Area under different crops, ha				
	Existing crop plan	Without capital constraint	Proposed crop plan with capital constraint		
			9500/-	11000/-	13000/-
Safflower	1900 (0.24)	7703 (1.00)	7703 (1.00)	77030 (10.00)	77030 (10.00)
Rb.Green leafy vegetables	-	15406 (2.00)	7703 (1.00)	7703 (1.00)	7703 (1.00)
0^{th} Vegetables	-	7703 (1.00)	3852 (0.5)	3852 (0.5)	3852 (0.5)
Rb. Jowar	19700 (2.56)	-	-	-	-
Rb. Maize	900 (0.12)	-	-	-	-
Rb. Sunflower	1000 (0.13)	-	-	-	-
Su. Green Vegetables	-	15406 (2.00)	7162 (0.93)	7703 (1.00)	7703 (1.00)
Su. 0^{th} Vegetables	-	7703 (1.00)	3852 (0.15)	3852 (0.5)	3852 (0.5)
Su. Maize	100 (0.013)	-	-	-	-
Su. Groundnut	200 (0.025)	-	-	-	-
Su. Sunflower	100 (0.013)	-	-	-	-
Fruits	-	38515 (5.00)	3852 (0.5)	38515 (5.00)	38515 (5.00)
Silvipastur	-	30812 (4.00)	30812 (4.00)	30812 (4.00)	30812 (4.00)
Dry land Horticulture	-	61624 (8.00)	61624 (8.00)	61624 (8.00)	61624 (8.00)
Gross investment, Rs/ha	7921	14460	9500	11000	13000
Total net return	355×10^7	710.3×10^7	$460. \times 10^7$	564×10^7	677×10^7
Net return, Rs/ha	4608	9221	5976	7322	8789
Net return increases over existing	-	4614	1368	2715	4182

Net benefit maximization with capital constraint

For Akola district

In proposed plan with, capital constraint in kharif season no change was observed in area of cotton, jowar, cotton + tur, mung/udid, groundnut, green vegetable and other vegetables with capital investment 11,500 to 13,500 Rs./ha there was no definite trend found in the area of soybean and sunflower. The area under soybean increased from 10 to 25.92% as investment increased from 12,500/- to 13,500/- Rs./ha where as when the capital investment increases form Rs11,500/- to Rs12,500/- the area under sunflower increases from 1 to 5 %.

In rabi season as capital investment increases from 12,500/- to 13,500 to area under wheat increases from 17% to 18.65%. Whereas, when capital investment increases from Rs11,500/- to Rs12,500/- the area under gram increases from 18% to 20%.

No change was seen in area of summer crops whereas in annual crops when capital investment increases from Rs11,500/- to Rs13,500/- No definite trend was found in area of fruits crops. Net return increases over existing from Rs2214 to Rs3363 per ha as investment increases from Rs11,500/- to Rs13,500 per ha.

For Amravati district

In proposed plan with, capital constraints in kharif season no change was observed in the area of cotton, Jowar, cotton + tur, soybean + tur, mung/udid, groundnut, green vegetable and other vegetables with capital investment 11000/- to 14000 Rs./ha capital investment increases from 13000/- to 14500/- Rs./ha the area under soybean increases from 10 to 12.50% whereas, as capital investment increases from Rs11,000/- to Rs13,000/- per ha area under sunflower increase by 1 to 10%.

In rabi season as capital investment increases from Rs13,000 to 14,500 per ha area under wheat increases by 13 to 27.25% whereas, no definite trend was observed in area on gram as the capital investment increases form 11000/- to 14500/- Rs./ha.

In summer and annual crops area no change was observed. Net return increases over existing from 2089 to 4372 Rs./ha as capital investment increase from 11000/- to 14500/- Rs./ha.

For Buldhana district

In proposed plan with capital constraint in kharif season no change was observed in area of cotton, Jowar, cotton + tur, soybean + tur, soybean, sunflowers, green vegetables and other vegetables with capital investment of 9500/- to 13000/- Rs./ha.

The capital investment increases from, Rs 9,500/- to Rs 13,000/- per ha the area under mung/udid increases from 6 to 14.50% where as capital investment increases from 9500/- to 11000/- Rs. area under groundnut increases from 10 to 15%.

In rabi season as capital investment increases from 11000/- to 13000/- Rs./ha the area under wheat and gram increases from 15 to 16.85% and 2 to 24.65% whereas, the capital investment increase from 9500/- to 11000/- Rs./ha the area under safflower increases from 1 to 10%.

In summer and annual crops no change was observed in area under summer vegetables where as capital investment increases form 9500/- to 11000/- the area under summer vegetables and fruits crop increases from 0.93 to 1% and 0.5 to 5%, respectively, The net return increase over existing from 5976 to 8789 as the capital investment increase from 9500/- to 13000/- Rs./ha.

Comparison of existing and proposed crop plan

Area under kharif in Akola, Amravati and Buldhana district is 97.28%, 85% and 80.95% in existing plan where as in proposed plan 95.87%, 92% and 83% of total cultivable area, respectively.

Table 6.12. Existing crop plan and proposed crop plan without capital constraint in different season in Akola, Amravati and Buldhana districts

	Area under existing crop plan, ha (%)			Area under proposed crop plan, ha (%)		
	Akola	Amravati	Buldhana	Akola	Amravati	Buldhana
Kharif	464800 (97.28)	704000 (85.00)	623600 (80.95)	458051 (95.70)	761322 (92.00)	639349 (83.00)
Rabi	30900 (6.47)	52600 (6.35)	80100 (10.40)	253222 (53.00)	513066 (62.00)	408259 (53.00)
Summer	900 (0.19)	700 (0.08)	400 (0.05)	14333 (3.00)	24826 (3.00)	23109 (3.00)
Annual	-	-	-	20544 (4.3)	66202 (8.00)	130951 (17.00)
Total	496600 (103.94)	757300 (91.51)	704100 (91.40)	746150 (156.17)	1365416 (165.00)	1201668 (156.00)
Cultivable area	477778	827524	770300	477778	827524	770300
Cropping intensity, %	103.94	91.51	91.41	156.17	165.20	156.00
Gross investment, Rs/ha	10341	9268	7921	16057	14460	14867
Total net return, Rs	248.6×10^7	405.9×10^7	355×10^7	422×10^7	797×10^7	710.3×10^7
Net return, Rs/ha	5203	4906	4607	8842	9642	9221
Net return increases over existing, Rs/ha	-	-	-	3630	4736	4614

In rabi season area in Akola, Amravati and Buldhana district is 6.47%, 6.35% and 10.40% in existing plan and can be raised upto 53%, 62% and 53% as compared to total cultivable area in proposed plan respectively.

Area under summer is very low in existing i.e., 0.19, 0.08 and 0.05% and no annual area were observed where as in proposed plan summer area is 3% in all selected districts and area under annual crops is 4.3, 8% and 17% in Akola, Amravati and Buldhana districts. Area under annual crops in Buldhana district is more due to 12 percent shallow soil on which silvipasture and dry land horticulture crop are proposed.

Cropping intensity in existing plan of Akola, Amravati and Buldhana district is 103.94, 91.51 and 91.41%. Whereas, in proposed plan 156.17, 165 and 156%, respectively cropping intensity increase due to trap of every drop of water and proposed to utilize judiciously.

Total net return in existing plan in Akola Amravati and Buldhana district is Rs 248.6, 405.9 and 355 crore, where as in proposed plan it would increase by Rs 173.4, 391.9 and 355 crore, respectively.

In investment and net return, Rs./ha existing ranges from 7921 to 10341 and 4607 to 5203 Rs./ha in selected district where as in proposed plan it ranges from 14460 to 16057 and 8842 to 9642 Rs./ha. The net benefit increase by 3630, 4736 and 4614 Rs./ha over existing in Akola, Amravati and Buldhana district by investing 4526, 6789 and 6539 Rs./ha more over existing respectively.

CHAPTER VII

SUMMARY AND CONCLUSIONS

A study entitled "Optimal resources allocation for crop plan in selected district of Vidarbha region" is undertaken for optimal crop plan for net benefit maximization without and with capital constraint. The study was carried out for Akola, Amravati and Buldhana districts of Vidarbha region.

Rainfall data was analyzed to determine effective rainfall, estimation of runoff. Pan evaporation data was analyzed to determine water requirement of crops and storage losses from pond and then water balance in carried out to determine availability of water in different season. Considering food requirement of the peoples minimum area to different crops are allocated. Then linear programming model is formulated following conclusions was drawn from the result.

1) Estimated average runoff is 15.90%, 21.85% and 20.01% and effective kharif rainfall is 65.6, 60.49 and 62.61 % of average kharif rainfall for Akola, Amravati and Buldhana districts, respectively.

2) Total water potential in major, medium and minor irrigation projects is 247.23, 768.62 and 279.66 Mm^3 and total water potential can be harvested is 343.01, 1476.92 and 1277.4 Mm^3 in Akola, Amravati and Buldhana district, respectively.

3 Major area under crops proposed in kharif season without capital constraints in Akola districts are soybean 30%, cotton + tur 20%, cotton 12.87% soybean + tur 10% and groundnut 10% of total cultivable area. In rabi wheat and gram 20% each followed by safflower 10%. In summer vegetables 2% and annual fruits 1.13%.

4) Major area under kharif crops in proposed plan without capital constraint in Amravati district are soybean 30% whereas jowar, cotton, cotton + tur, soybean + tur and groundnut 10% each of total

cultivable area. In rabi season wheat 30% followed by gram 27%.

5) Major area under kharif crops in proposed plan without capital constraint in Buldhana district are soybean 18% followed by groundnut 15% and cotton, jowar, cotton + tur, soyabean + tur 10% each of total cultivable area. In rabi wheat 25% followed by gram 24%.

6) In summer area under green vegetables, 2% with annual fruits 5% in Amravati and Buldhana districts, respectively.

7) Cropping intensity of existing and proposed plan of Akola, Amravati and Buldhana is 103.94, 91.51, 91.41 and 156.17, 165.20 and 150.00 % respectively.

8) The gross investment without capital constraint in proposed planning in Akola, Amravati and Buldhana district is Rs16,057, Rs14,460, Rs14,687 per ha, respectively.

9) As the capital investment decreases net return decreases in selected districts.

10) As the capital investment decreases there is no change in area under cotton, cotton + tur, however change is observed in area under soybean and groundnut.

11) From study it is observed that net return Rs/ha increases in proposed plan over the existing plan by Rs. 3,630, Rs. 4,736 and Rs. 4,614 in Akola, Amravati and Buldhana districts respectively. Total net return increases over existing by Rs173.4, Rs391.1 and Rs355.3 crores, respectively.

Implication

Study will be helpful to the District Superintending Agril. Officer for crop planning at district level, Agriculture Development Agencies for water harvest planning. Present study will be helpful for selection of crops to maximize net return per unit area, under different constraints such as water, and capital.

CHAPTER VIII

LITERATURE CITED

Bankar, S. R. and A. A. Atre (1998): Application of linear programming for crop planning in watershed. *J. Maharashtra Agric. Univ.* 23(2): 159-161.

Bharara L P, W. Khan and Y. N. Mathur (1984) Socio economic characteristic of the Upper Lunni Basin in Rajasthan desert. *Annals of Arid Zones*, 23(4) pg.313-322

Carrello, H. O., E. A. Holzapfel, M. A. Loper and M. A. Marino (1998): Irrigated cropping optimization. *J. Irrigation and Drainage Engg.* 124(2): 67-72.

Chhikara, O. P. and I. J. Singh (1986): Optimizing use of land and water resources in semiarid tropics area (Sat.) of Haryana state of India. International seminar on Water management in India and semi-arid zones., organized by H.A.U., Hissar (India). Vol-II Nov. 27-29.

Gorantiwar, S. D., P. S. Pampattiwar and V. R. Salve (1996): Optimum area allocation plans for distributory-4 of Mula left Bank Canal, Maharashtra State, India. Proc. of the International Agric. Engg. Conference, Pune, India, 9-12 December 1996. pp. 517-527.

Gray, D. D. and Katz (1982): Antecedent moisture condition probability. J. Irrigation and Drainage Division. ASCE, 108(IR2): Proc. Paper. 1965: 107-114.

Hassan, Bhashir Ahmad, Manzoom Akhtar and Aslam (2003) Use of linear cropping model to determine the optimum cropping pattern : A case study of Punjab Electron. J. Environ. Agric.Food Chem http://www.sciencedirect.com, pp: 841-855

Jadhav P.W (1999): Assesment of groundwater recharge in a watershed: A modeling approch, M.Tech thesis (unpub.),Deptt of SWCE, Dr.P.D.K.V,Akola.pp.1-81

Jajoo, S. B., G. U. Satpute and K. V. Mahadadalkar (2008) Optimal resources utilization in Belura watershed using linear programming model *XLII ISAE Annual Convention and Symposium* pp-SWCE14

Jat M L, R. Singh, J. K. Baligan and B. S. Kumpawat (2004) Water Balance studies for Agricultural Planning in Udaipur Region. *Annals of Arid Zones*, 13(2) pg.139-143

Kanade D. B. (1989): Optimal cropping pattern for a command of minor using linear programming technique. M. Tech Thesis (unpub.), MPKV, Rahuri.(MS). pp 1-125.

Khare D., M. K. Jat, and Ediwahyunan (2006): Assessment of conjunctive use planning options: A case study of Sapon irrigation command area of Indonesia. Journal of Hydrology. http://www.sciencedirect.com, 328: 764-777.

Khatik G L and H B Singh (1998) Adoption behavior towards Soil and Water Conservation technologies in India *Indian J. soil Cons.* 26(3) pp 269-272

Khepar, S. D. and M. C. Chaturvedi (1982): Optimum cropping plan for groundwater management, Water Resource Bulletin, 18 (4): 655-660.

Kote R. C. (1997): Optimal planning of a community managed lift irrigation scheme in Banswara district. M. E. thesis (unpub.), Rajasthan Agril. University, Bikaner.

Lakshminarayana, V. and S. P. Rajagopalan. (1977) Optimal cropping pattern for a basin in India. *J. Irrigation and Drainage Div*, ASCE, 103(1): 53-70.

Machiwal D. (2001). Stochastic linear programming model for irrigation planning of right main canal of Jakham irrigation project. M. Tech thesis (unpub.), Irrigation and water management Engg., MPUAT, Udaipur. pp 1-171.

Mahadadalkar, K. V. (2007) Optimal resources utilization for sustainable agriculture in Belura Watershed M.Tech (Agri Engg) Thesis (unpub.), Soil and Water Conservation Engg.,Dr P D K V University Akola

Mahadadalkar, K. V., S. B. Jajoo, G. U. Satpute (2008) Selection of optimal cropping pattern using linear programming technique. *XLII ISAE Annual Convention and Symposium* pp-SWCE13

Maji C.C. and E. O. Heady (1978): Intertemporal allocation of irrigation water in the Mayurakshi project (India): An application of chance-constrained linear programming. 14(2): 190-196.

Maji C.C. and E. O. Heady (1980): Optimal reservoir management and crop planning under deterministic and stochastic inflows. Water Resources Bulletin, Vol. 16(3), : 438-443.

Maji, C.C. (1975): Intertemporal allocation of irrigation water in the Mayurakshi project, West Bengal (India). Ph. D. thesis (unpub.), Lowa State University, Ames, U. S. A.

Maji, C.C. and T. K. Sarkar (1976): Optimal cropping system and Irrigation efficiency in an existing canal area. Journal of Agricultural Engineering. XIII(4): 151-156.

Meena, K. C. and P. K. Arya (1999): Optimal cropping pattern for the command area of Jaisamand reservoir. B. E. (Agril.) thesis (unpub.) R.A.U., Bikaner, Udaipur.

Michael, A. M. (1978): Soil-water plant relationship, Irrigation Theory and Practice. Vikas Publi. House Pvt. Ltd., New Delhi.: 520.

Neelam Patel and T. B. Rajpur (2001): Participatory rural appraisal in watershed management, a case study. *Indian J. soil Cons.* 29(2): 152-157.

Panda, S.N., S.D Khepar and M. P. Kaushal (1985): Stochastic irrigation planning. An application of chance constrained linear programming. J. Agril. Engg., ISAE, 22(2): 93-106.

Panda, S.N.,S.D Khepar and M. P. Kaushal (1996): Inter seasonal Irrigation System planning for waterlogged sodic soils. Journal of Irrigation and Drainage Engineering 1996, 122(3): 135-144.

Pandit K. N. and P. C. Senapati (1991): Land and water resources planning for optimal cropping pattern. J. Agricultural Engineering. Vol: 23-24.

Paul.S.,S.Panda and D.K.Nagesh (2000) Optimal Irrigation Allocation:A multilevel approach. Journal of Irrigation and Drainage Engg.Vol.126,No.3,May/June pp:149-156

Pawade, M. N. and A. M. Michael (1988): Water Balance of Agricultural Watershed. Indian J. Dryland Agric. Res. And Dev. 3(2): 236-237.

Pawar and P. P. Suryakant (2001): Integrated water resources planning of Udaisagar reservoir, Udaipur for optimal cropping pattern. M. Tech thesis (unpub.) submitted to Deptt of Irrigation and Water management Engg., MPU, Udaipur, Rajasthan.

Radheyshyam, A. K. Khan and H. S. Chouhan (1997): Optimal land and water resources use planning for Nainital Bjabar. *J. Indian water resources society*, 7(3): 7-12.

Raman H. and S. Vasudevan (1991): Application of linear programming technique for optimal cropping pattern. *J. Irrigation and Power.* 48(4): 49-57.

Raman H. and T. V. Paul (1992): Selection of cropping pattern using LP technique. *Indian J. Agril Engg.* 2(2): 125-131.

Rathod A. M. (2006): Resources mapping and socio-economic survey of village Yawali. M. Sc. Thesis (unpub.), Extension Education, Dr. PDKV, Akola. pp. 1-87.

Reddy, T. Narsimha; P. Praksaham and V.V.S. Gurunadhrao (1991): Estimation of groundwater recharge in a semi-arid watershed.

Indian J. dryland Agric. Res. and Dev. 6(1 & 2): 37-45.

Roy, A. (2008) : Appraisal and planning of land and water resources for sustainable cropping at K.V.K. Farm, Jaspur. M.Tech. (Agril. Engg.) Thesis (Unpub.) I.G.A.U. Raipur. Chattisgad.

Salokhe, V. M. and H. Rahaman (1989): Optimum utilization of land and water for Bharejabi Delta (India), J. Agril. Engg., ASAE, 26(2): 522-524.

Senapati P. C. (1991): Optimal crop planning- a case study for distributing of Kendrapara cana system in Orissa. *J. Indian Water Resources Society.* 11(2): 23-28.

Senapati, S. C., M. K. Khandelwal and Y. P. Rao (1985): Resource management planning for optimal profit. A case study, *J. Agril. Engg.* ISAE. 22(4): 50-65.

Sethi, L. N., D. N. Kumar, S. N. Panda and B. C. Mal. (2002) Optimal crop planning and conjunctive use of water resourece in coastal river basin *Water Resources Research* Vol-16(2) pp 145-169

Shubhangini Joshi (2002): Food and nutritional requirement. Textbook of Food and Nutrition : 143-149.

Singh A. K., J. Singh, R. C. Purohit and Rashmi Singh (2005): Optimal crop planning for Badliya command area in Rajasthan for maximizing crop benefits- A case study. *Indian J. Soil Conservation*, 33(2): 166-169.

Singh P. and H. Wolkewitz (1983): Determination of optimal crop plan using linear programming. *J. Irrigation and Power*, 40(4): 379-383.

Singh, A. K., Jaspal Singh and Rashmi Singh (1999): Optimum utilization of resources for crop production- A case study. *J. Indian Water Resources Society*, 18(4): 66-69.

Singh, Nalini (1996): Optimization study of agricultural benefit in Bijnor district. *Journal of Indian Water Resource Society.*, 2(4): 25-34.

Singh, S. P. and S. K. Sirohi (1976): Optimal cropping pattern for the basin. *J. Irrigation and drainage Division*, Proceedings of ASCE. 103(2): 105-117.

Sivkumar T. K. (1997): Crop planning in watershed using linear programming. B. Tech thesis (unpub.) submitted to Deptt of Agril. Engg., MPK, Rahuri. pp 1-44.

Solanki, A. S. (1997): Impact of Jakham Irrigation Project on Farm economy in a Tribal Belt of Rajasthan, Ph. D. thesis (unpub.), Rajasthan Agril. University, Bikaner.

Srinivasa, R. K. and D. K. Nagesh (2001): Optimum cropping pattern for Shri Ram Sagar Project: A linear programming approach, J. Applied Hydrology, Vol. XIII. Nos.1 & 2, pp. 57-67.

Srinivasa, R. K. and D. K. Nagesh (2004): Irrigation planning using genetic algorithms *Water Resourse manegment* http://www.springer link.com Vol-18(2)pp:163-176

Suresh C. B. (2005): Nutritional Security. Economic reforms: Challenges, options. *The Hindu Survey of Indian Agriculture*, International food policy Research Institute. Washington DC. pp. 16-19.

Taley, S. M. and S. K. Kohale (1990): Water balance study in an agricultural watershed for evaluating groundwater potential during the least rainfall year, *PKV Res. J.*, 14(2): 148-154.

Thakur, A. K., J. K. Singh and A. Kumar (2006): Optimal land use model to minimize soil loss in a Himalayan watershed. *Indian J. Soil Cons.* 34(2): 114-117.

Tyagi N. K. and V. V. Narayana (1984) : Water use planning for alkali soils under Reclamation. Journal of Irrigation and Drainage Engineering 110 (2) : 192-207.

Vedula, S.S. and P. Roger (1981): Multiobjective analysis of irrigation planning in river basin development, *J. Water Resource Research.* 17(5): 1304-1310.

Venkatesan, M. N. and M. T. Ramlingam (1980): Application linear programming for crop benefit maximization - A case study of Bhadar irrigation project, Gujarat (India), Third Afro-Asian Regional Conference ICID, New Delhi (India):1- 16.

APPENDIX A

Tahsil wise land capability classification of Akola district, ha

Sr. No.	Tahsil	Geographic area	Observed area	Cultivable	Land capability classes		Depth				
					I to IV	V to VIII	Shallow (d_1)	Moderately shallow (d_2)	Moderate (d_3)	Deep (d_4)	Very deep (d_5)
1.	Akola	103666	101615	99932	98424	3191	1368	13799	12418	12869	61421
2.	Barshitakli	77216	70961	64939	66702	4259	4830	25925	18782	6889	11238
3.	Murtizapur	78943	69544	70863	68982	562	208	11301	14033	9145	34657
4.	Akot	81284	73960	73504	71527	2433	1700	4323	6209	8241	53887
5.	Telhara	62832	45345	55919	44682	663	547	1320	2070	6814	35694
6.	Balapur	68833	45531	61995	43154	2377	1237	2174	6005	8973	27546
7.	Patur	70110	19326	50626	14139	5187	4991	7526	5064	2792	253
	Total	542884	426282	477778	407610	18672	14881	66401	64581	55723	224696

APPENDIX B

a) Monthly average pan evaporation for Akola district during 1983-2007

Month	Monthly Avg.	Daily Avg.	ETo
Jan	139.65	4.5	3.53
Feb	175.28	6.26	4.38
Mar	272	8.77	6.14
April	374.34	12.48	8.73
May	483.98	15.61	10.92
June	311.28	10.37	7.26
Jully	163.31	5.27	3.68
Aug	125.12	4.04	2.82
Sept	136.89	4.56	3.19
Oct	148.86	4.8	3.36
Nov	132.76	4.4	3.09
Dec	136.68	4.41	3.09
Total	**2600.2**	**85.47**	

b) Estimated crop evapotranspiration of few crops in district

Tur

Month	Kc value	ETo, mm	Days	ETc, mm
Jun	0.40	7.26	15	43.56
Jul	0.48	3.68	31	54.76
Aug	0.78	2.82	31	68.19
Sep	1.1	3.19	30	105.27
Oct	1.2	3.36	31	124.99
Nov	0.98	3.10	30	91.14
Dec	0.55	3.09	15	25.49
Total				513.4

Cotton

Month	Kc value	ETo, mm	Days	ETc, mm
Jun	0.40	7.26	15	43.56
Jul	0.77	3.68	31	87.84
Aug	1.0	2.82	31	87.42
Sep	1.15	3.19	30	110.06
Oct	1.14	3.36	31	118.74
Nov	0.85	3.10	30	79.05
Dec	0.65	3.09	15	30.13
Total				556.8

Soybean

Month	Kc value	ETo, mm	Days	ETc, mm
Jun	0.50	7.26	5	18.15
Jul	1.15	3.68	31	131.19
Aug	1.2	2.82	31	104.90
Sep	1.2	3.19	30	114.84
Oct	0.95	3.36	15	43.26
Total				**412.34**

Groundnut

Month	Kc value	ETo, mm	Days	ETc, mm
Jun	0.49	7.26	5	17.79
Jul	0.90	3.68	31	102.67
Aug	1.1	2.82	31	96.16
Sep	1.1	3.19	30	105.27
Oct	0.80	3.36	25	67.2
Total				**389.09**

Gram

Month	Kc value	ETo, mm	Days	ETc, mm
Oct	0.4	3.36	15	20.16
Nov	0.80	3.10	30	74.4
Dec	1.15	3.09	31	110.15
Jan	0.45	3.53	29	46
Total				**250.71**

Safflower

Month	Kc value	ETo, mm	Days	ETc, mm
Sep	0.40	3.19	25	31.9
Oct	0.80	3.36	31	83.33
Nov	1.2	3.10	30	111.6
Dec	1.15	3.09	31	110.16
Jan	0.80	3.53	23	64.95
Total				**401.94**

APPENDIX C

a) Economic for soybean

Sr. No.	Item	Unit of input	Input/ha	Cost for unit of input	Total cost, Rs
1	Human labour for sowing, weeding, spraying, harvesting etc.	Male, Days	25.2	55	13.86
		Female, Days	44.43	30	1332
2	Bullock labour	Pair days	9.85	140	1379
3	Threshing charges	Hrs	15	65	975
4	Seed	Kgs	8.0	22	1760
5	Manure	qtls	7.5	45	337
6	Fertilizer N	Kgs	30	13.39	401.70
	P	Kgs	75	17.1	1282.50
	K	Kgs	0	7.09	0
7	Irrigation charges	Rs			0
8	Insecticide	Rs			435
9	Incidental charges	Rs			105.28
10	Working capital				9394.88
11	Interest on working capital, 8%	Rs			469.74
12	Land Revenue and taxes	Rs			19.94
13	Depreciation in implements and farm building	Rs			312.46
14	Repairing charges	Rs			111.91
15	Total cost of cultivation/ha				10308.93
16	Yield /ha a) Main produce b) Byproduct	Rs	15 3.96	1000 109.39	15000 433.88
17	Gross return	Rs			15433.18
18	Net return/ha	Rs			5124.25

b) Investment, production and net benefit per ha from different crops

Sr. No.	Crops	Investment, Rs	Production, qtl	Net benefit, Rs
1	Cotton (CK)	12280	10	5910
2	Jowar (JK)	8850	27.5	4220
3	Cotton + Tur (C_TK)	11605	3	6225
4	Soybean + Tur (S_TK)	9440	3	5630
5	Mung/ Udid (MK)	5920	7.5	4860
6	Groundnut (GK)	5920	7.5	5610
7	Soybean (SK)	9395	15	5120
8	Sunflower	6116	10	4405
9	Green vegetables (VK)	16580	65	5060
10	Other vegetables (OK)	15955	100	6460
11	Wheat (WR)	11830	25	7070
12	Gram (GR)	6250	10	4580
13	Safflower (SR)	4190	7	4230
14	Green vegetables (VR)	19280	70	7500
15	Other vegetables (OR)	18655	105	7980
16	Green vegetables (VS)	20180	65	8460
17	Other vegetables (OS)	19555	100	8220
18	Silvipasture (AA)	3000	-	3750
19	Fruits (FA)	15000	150	12500
20	Dryland horticulture (DA)	4000	30	7500
21	Rice(for Amravati dist only)	7650	28	5250

APPENDIX D

Estimation of runoff by CNT for Akola district during 1983, mm

Day	June			July			August			September		
	Rain-fall	AMC	Run-off	Rain-fall	AMC	Run-off	Rain-fall	AMC	Run-off	Rain-fall	AMC	Run-off
1	0	I	0	0	II	0	6.6	III	0	5.6	I	0
2	0	I	0	0	I	0	6.8	II	0	0	I	0
3	0	I	0	0	I	0	12.4	III	0	39.8	I	0.4413
4	15.2	I	0	0	I	0	6.6	III	0	9.5	I	0
5	0	I	0	6.6	I	0	0	III	0	0	III	0
6	0	I	0	0	I	0	0	I	0	0	III	0
7	0	I	0	0	I	0	14.8	I	0	1.8	III	0
8	0	I	0	0	I	0	29.4	I	0	1.8	II	0
9	0	I	0	0	I	0	10.8	II	0	0	II	0
10	0	I	0	4	I	0	10.2	III	0	0	I	0
11	0	I	0	0	I	0	57.2	III	33.43	0	I	0
12	5.2	I	0	12	I	0	37.2	III	16.74	0	I	0
13	4	I	0	32.4	I	0.0081	17.8	III	3.697	0	I	0
14	0	I	0	18.2	II	0.3054	12.2	III	0	4	I	0
15	0	I	0	0	III	0	0	III	0	7.8	I	0
16	0	I	0	8.2	III	0	1	III	0	0	I	0
17	0	I	0	36	III	15.813	11.5	III	0	24.9	I	0
18	0	I	0	1.8	III	0	0	II	0	0	I	0
19	0	I	0	0	III	0	0	I	0	0	II	0
20	0	I	0	15.8	II	0.08	4.6	I	0	0	II	0
21	1.2	I	0	47.5	III	25.10	0	I	0	0	I	0
22	0	I	0	0	III	0	0	I	0	9.2	I	0
23	0	I	0	0	III	0	0	I	0	6.6	I	0
24	0	I	0	0	III	0	0	I	0	0	I	0
25	0	I	0	15.6	III	2.627	0	I	0	22.8	I	0
26	12.2	I	0	0	III	0	0	I	0	9.6	I	0
27	7	I	0	19.4	I	0	0	I	0	1	II	0
28	13.8	I	0	0	I	0	0	I	0	27.4	II	2.3719
29	0	I	0	0	I	0	0	I	0	0	II	0
30	10.4	I	0	0	I	0	9	I	0	0	III	0
31				41.2	I	0.59	11.9	I	0	0		0
Total	69		0	258.7		44.524	260		53.87	171.8		2.813
Total seasonal rainfall = 819.3 mm												
Total seasonal runoff = 101.21 mm												

APPENDIX E

Average rainfall, runoff and estimated weighted average rainfall for Group 1 and Group 2 tahsils of Buldhana district, mm (1998-2007)

Estimated weighted average rainfall

MW	Group1 Avg. rainfall	Group2 Avg. rainfall	Weighted Avg. rainfall
23	17.8	33.625	20.19
24	44.9	53.5	46.20
25	42.78	40.35	42.41
26	64.2	64.74	64.28
27	32.6	41.3	33.92
28	28.93	35.45	29.92
29	64.36	50.75	62.30
30	33.02	63.3	37.60
31	82.11	98.35	84.57
32	88.66	109.65	91.83
33	15.2	25.25	16.72
34	50.62	65.05	52.80
35	36.15	44.7	37.44
36	45.5	37	44.21
37	27.58	40.55	29.54
38	28.6	39.9	30.31
39	28.34	21.9	27.37
40	53.1	44.85	51.85
23-40 MW	784.5	910.22	803.51
41-5MW	40.6	56.7	43.04
6-22MW	25.9	11.2	23.68
Annual	851.0	978.5	870.28

Estimated weighted average runoff

MW	Group1 Avg. runoff	Group2 Avg. runoff	Weighted Avg. runoff
23	0.48	7.91	1.60
24	6.85	11.71	7.59
25	1.94	8.715	2.97
26	12.95	15.85	13.39
27	2.46	4.8	2.81
28	3.35	2.53	3.23
29	8.51	4.10	7.84
30	1.59	16.09	3.78
31	22.95	32.51	24.40
32	34.84	51.86	28.93
33	0.17	6.49	1.13
34	11.26	17.4	12.19
35	5.15	10.59	5.97
36	9.43	8.34	9.27
37	4.41	2.92	4.19
38	5.39	7.07	5.64
39	3.47	2.66	3.35
40	15.50	8.35	14.42
Total	150.70	219.87	161.17

Eg. For 23rd MW considering

1. Rainfall of Group1 and Group2 as R_1 and R_2
2. Area of Group1 and Group2 as A_1 and A_2

A_1=820000ha. A_2=146100 ha

$$\text{Weighted average rainfall for 23rd MW} = \frac{A_1.R_1+A_2.R_2}{A_1+A_2}$$

$$= \frac{820000 \times 17.8+146100 \times 33.625}{966100}$$

$$= 20.19\text{mm}$$

Similarly,

$$\text{weighted average runoff for 23rd MW} = \frac{820000 \times 0.48+146100 \times 7.91}{966100}$$

$$= 1.60\text{mm}$$

APPENDIX F

Calculation of water availability in kharif, rabi and summer season in Akola district

Effective rainfall available in kharif season to the plants

Average annual rainfall for Akola	-	790.78 mm
kharif season rainfall	-	683.67 mm
rabi season rainfall	-	62.95 mm
summer season rainfall	-	44.16 mm
Estimated runoff	-	108.71 mm

Effective rainfall available in kharif season = kharif rainfall - loss of water in kharif season

losses of water in kharif season

a)	Interception	=	2.98%
b)	Percolation	=	2.89%
c)	Recharge	=	13.53%
d)	Runoff	=	15.90%
	Total losses	**=**	**34.4%**

Thus effective rainfall available to plants in kharif season is

100 - 34.4 = <u>**65.6%**</u>

Effective water available in kharif season

= Area of district x Average Rainfall of kharif

= 54300 x (65.6 / 100 x 68.367)

= 24352872.34 ha cm

Available soil moisture in the beginning of rabi season is calculated

Considering clay loam soil in which depth of available water / m depth of soil is 10-18 cm. Thus, average is 14 cm (from Table 4:2). considering 40% water is available to the plants and average soil depth is 50 cm. Then, = 14 x 0.5 x 0.4 = 2.8 cm.

Water potential available for rabi in Akola district

$$= \frac{13.53}{100} \times (683.67) \times \left(\frac{40}{100} + 108.71 \times \frac{70}{100}\right) \times 54300 + (28 + 62.95)\ 47778$$

= 10486829.51 ha cm

Similarly water potential available for summer season in Akola district.

Water Available in summer

= 30% ground water x total geographic area + (Available moisture + summer rainfall) x 6% of total cultivable area

= 27.759 x 543000 + (28 + 44.16) 28667

= 17141724.63 ha mm

= 1714172.46 ha cm

Total water potential available for rabi and summer season in Akola district

= 10486829.51 + 1714172.46

= 12201001.97 ha cm

APPENDIX G

Tahsil wise water potential in major, medium and minor projects of Akola district (Mm3)

Sr. No.	Name of Tahsil	Major	Medium	Minor	Total
1.	Akola			8.105	8.11
2.	Akot			6.378	6.39
3.	Murtizapur	86.35	11.68	7.855	105.89
4.	Patur		28.85	23.66	52.51
5.	Barshitakli		41.46	27.22	68.68
6.	Telhara			0.594	0.594
7.	Balapur			5.074	5.074
	Total	86.35	81.99	78.89	247.25

Total volume of runoff from Akola district = 543000 x 108.71

= 590.24 Mm^3

Total runoff water can be harvested = 590.24-247.23

= 343.01 Mm^3

APPENDIX H

a) Sample design of cement nala bund

1.	Catchment area	200ha
2.	Catchment length	2150 m
3.	Catchment drop	25.50 m
4.	Distance between two nala banks	11.20 m
5.	Nala depth	2.20 m
6.	Bottom width of Nala	5 m
7.	Nala Bed slope	1.13%
8.	Nala bed level	47.20 m
9.	Water storage length	240 m
10.	Full supply level	48.40 m
11.	Water storage height	1.2 m
12.	Length of pillar	0.60 m
13.	Width of wing wall	0.60 m
14.	Width of side wall	0.60 m
15.	Width of header wall	0.60 m
16.	Key wall length	0.60 m

17. Watershed coefficient, $k = (L^3/H)^{0.5} = 19741.84$

18. Time of concentration, $t = \dfrac{0.01947 \times k^{0.77}}{60} = 0.658$ hr

19. Rainfall intensity, $I = \dfrac{KT^a}{(t+b)^n} = 84.14$ mm/hr

    (Taking K= 11.45, T = 10, a = 0.156)

20. Discharge, $Q = \dfrac{CIA}{360} = 10.00\ m^3/sec$ (C = 0.214)

21. Length of weir = Nala width - (2 x length of pillar)

    = 10 m

22. Thickness of flood $= \left[\dfrac{Q}{1.704 \times 10}\right]^{0.667}$

$= 0.70$ m

23. Considering wave height = 0.4

24. Freeboard = 0.3

25. Height of flood level = Water level height + Thickness of flood level

= 1.90 m

26. Top width of bund $= 0.55 \times (HFL)^{0.5}$

= 0.76 m

27. Total height of bund = Water level height + HFL + Freeboard

= 2.26 m

28. Bottom width of bund $= \dfrac{HFL}{1.5} = 1.27$ m

29. Watercushion height = 0.82 x (thickness of flood)$^{1/3}$ x (water level height)$^{1/2}$ = 0.78 m

Water level height in watercushion = watercushion breath/6 = 0.27 m

Water level thickness in watercushion = 0.26 m

30. Watercushion length = length of bund - 2 x side wall width = 10 m

31. Watercushion breath

a = thickness of flood + height of water level in watercushion = 0.96 m

b = a + (water storage - thickness of flood) = 1.4 m

Watercushion breath = (4 x (b x 0.7)$^{0.5}$)/3 = 1.58 m

32. Height of pillar = wave height + freeboard = 0.7 m

33. Length of Apron = 2 x (HFL + water level height) = 3 m

34. Breath of Apron = 2 + Bottom width of nala = 7 m

35 Apron thickness = (2 + (HFL + water level height) x total height of bund)/30 = 0.18 m

36. Length of box shaped foundation = length of bund = 11.20 m

37. Breadthof box shaped foundation = 0.30 + bottom width of bund + watercushion breath + width of header wall + 0.30 = 4.04 m

38. Depth of foundation = water level height /2 = 0.6 m

39. Height of side wall above header wall = Thickness of flood x 1.20 = 1.20 m

40. Length of side wall at top = Breath of watercushion x 1.414 = 2.23 m

41. Length of side wall at bottom = watercushion breath + (base width of main wall - top width of bund) = 2.09 m

42. Length of header wall = length of main wall = 11.20 m

43. Creep length = 6 x water level height = 7.2 m

44. Length of wing wall = creep length - (wing wall breath + 2 x key wall length + top width + length of side wall at bottom) = 1.28 m

Cost estimation of CNB

Sr. No.	Item	cost
1.	Earth work cost	39188
2.	Cement work cost	152718
3.	Layout cost	
	a) Layout	188
	b) Trail pits	261
4.	Layout expenses during construction (3% of earth and cement work)	5757
5.	Labour cost	1058
	Total cost	199170

b) Design of farm pond for 2ha catchment area for Akola (size- 20m x 20m x 3m, side slope 1:1)

MW	Rainfall (mm)	Runoff (mm)	Runoff (m^3)	80 % runoff vol. (m^3)	Rainfall in pond (m^3)	Total vol. of water (m^3)	Seepage losses		Total loss (m^3)	Water storage at end of week (m^3)	Cumulative vol. of water stored (mq)	Remark
							Pond evapo-ration (m^3)	Seepage (m^3)				
23	21.33	0.83	16.6	13.28	8.53	21.81	2.35	3.62	5.97	15.84	15.84	
24	44.47	6.26	125.2	100.16	17.79	117.95	1.33	2.8	4.13	113.82	129.66	
25	42.92	12.04	240.8	192.64	17.17	209.81	2.15	5.36	7.51	202.3	331.96	
26	31.82	4.16	83.2	66.56	12.73	79.29	0.82	2.18	3	76.29	408.25	
27	28.57	3.29	65.8	52.64	11.43	64.07	0.55	1.72	2.27	61.8	470.05	
28	60.79	7.08	141.6	113.28	24.32	137.6	1.02	3.5	4.52	133.08	603.13	
29	61.14	11.34	226.8	181.44	24.46	205.9	1.23	5.28	6.51	199.39	802.52-682.42 = 120.38	Irrigation to 1 ha
30	42.57	6.77	135.4	108.32	17.03	125.89	0.70	0.80	1.5	124.39	244.77	
31	43.93	7.63	152.6	122.08	17.57	139.65	0.78	3.56	4.34	135.39	380.08	
32	60.98	15.17	303.4	242.72	24.39	267.11	1.03	5.34	6.37	260.74	640.82	
33	62.02	1.77	35.4	28.32	24.81	53.13	0.31	1.44	1.75	51.38	692.2	
34	38.87	10.80	216	172.8	15.55	188.35	0.97	4.79	5.76	182.59	874.79-682.42 = 192.37	Irrigation to 1 ha
35	43.82	4.64	92.8	74.24	17.53	91.77	0.53	2.53	3.06	88.71	281.08	
36	33.01	3.88	77.6	62.08	13.20	75.28	0.45	2.1	2.55	72.73	353.81	
37	21.49	3.75	75	60	8.60	68.6	0.45	1.89	2.34	66.71	420.52	
38	25.70	1.91	38.2	30.56	10.28	40.84	0.26	1.09	1.35	39.49	460.01	
39	22.68	1.16	23.2	18.56	9.07	27.63	0.17	0.75	0.92	26.71	486.72	
40	27.56	6.24	124.8	99.84	11.02	110.86	0.66	2.64	3.3	107.56	594.28	

Cost estimation for farm pond

Sr. No.	Item	Cost estimation			
		Depth, m	Excavation vol^{m}, m^3	Rate Rs/m^3	Cost Rs.
1.	Digging cost	0-1	650	28.80	18720
		1-2	120.12	35.00	4204.20
		2-3	105.13	90.60	9524.78
	Total		875.25		32448.98
2.	Inlet		5.40	28.80	155.52
	Outlet		5.40	28.80	155.22
	Total		886.05		32760.02
3.	Transportation		694.76	6.70	4654.892
4.	Lifting	1.5-3	200.30	16.50	3304.95
			225.26	23.70	5338.66
	Total		425.26		8643.61
5.	Dressing cost		298.00	2.70	804.60
	Total earth work cost				46863

APPENDIX I

Water requirement of crops

Sr. No.	Crop	Water requirement, cm
1	Cotton	55.68
2	Jowar	45.36
3	Cotton + Tur	53.34
4	Soybean + Tur	46.29
5	Mung/ Udid	27.00
6	Groundnut	38.91
7	Soybean	41.23
8	Sunflower	35.53
9	Green vegetables (Kharif)	33.74
10	Other vegetables (Kharif)	30.98
11	Wheat	42.37
12	Gram	25.00
13	Safflower	28.10
14	Green vegetables (Rabi)	49.1
15	Other vegetables (Rabi)	41.97
16	Green vegetables (Summer)	60.1
17	Other vegetables (Summer)	52.96
18	Silvipasture	37.2
19	Fruits	150
20	Dryland horticulture	47.9
21	Rice(for Amravati dist only)	77.43

APPENDIX J

Food Requirement for People in Akola District

Food requirement year = per head need x population x days

Cereal requirement average per person = 456.27 gms

1) Cereal requirement	=	$456.27 \times 16.30239 \times 10^5 \times 3.65 \times 10^2$
	=	2.714976×10^6 qtl/yr.
Wheat requirement	=	70% of total cereal requirement
	=	2.036232×10^6 qtl/yr.
Jowar requirement	=	25% of total cereal requirement
	=	6.78744×10^6 qtl/yr.

Pulses requirement average per person = 73.45 gms

2) Pulses requirement	=	$73.45 \times 16.30239 \times 10^5 \times 3.65 \times 10^2$
	=	4.37055×10^5 qtl/yr.
Tur requirement	=	60% of total pulses requirement
	=	2.62233×10^5 qtl/yr.
Gram requirement	=	20% of total pulses requirement
	=	8.7411×10^4 qtl/yr.
Mung/udid requirement	=	20% of total pulses requirement
	=	8.7411×10^4 qtl/yr.

Oilseed requirement average per person = 46.34 gms

3) Oilseed requirement	=	$46.34 \times 16.30239 \times 10^5 \times 3.65 \times 10^2$
	=	2.75740×10^5 qtl/yr.
Groundnut requirement	=	55% of total oilseed requirement
	=	1.51657×10^5 qtl/yr.
Soybean requirement	=	20% of total oilseed requirement
	=	5.5148×10^4 qtl/yr.
Sunflower requirement	=	5% of total oilseed
	=	1.3787×10^4 qtl/yr.
Safflower requirement	=	20% of total oilseed
	=	5.5148×10^4 qtl/yr.

Green leafy vegetables requirement average per person = 111.47 gms

4) Green leafy vegetables requirement	=	$111.47 \times 16.30239 \times 10^5 \times 3.65 \times 10^2$
	=	6.63288×10^5 qtl/yr.
per season	=	2.21096×10^5 qtl/yr.

Fruits requirement average per person = 33.31 gms

6) fruits requirement	=	$33.31 \times 16.30239 \times 10^5 \times 3.65 \times 10^2$
	=	1.98207×10^5 qtl/yr.
per season	=	6.6069×10^4 qtl/yr.

APPENDIX K

Input to the computer for Akola district

MAXZ=5910CK+4220JK+6225CTK+5630STK+4860MK+5610GK+5120SK+4405SuK+5060VGK+6460VOK+7070WR+4580GR+4230SAR+7500VGR+7980VOR+8460VGS+8220VOS+12500FA+3150AA+7500DA

MAX Z= MIN (-Z)

```
f= [-5910;-4220;-6225;-5630;-4860;-5610;-5120;-4405;-5060;-6460;-7070;-4580;-4230;-7500;-
7980;-8460;-8220;-12500;-3750;-7500];
A= [1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 1 1 1;
1 0 1 1 0 0 0 0 0 1 1 1 1 1 0 0 1 1 1;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1;
44 45.36 42 35 27 38.91 41.23 35.53 33.74 30.98 0 0 0 0 0 0 45 37.2 47.9;
11.68 0 11.51 11.29 0 0 0 0 0 0 42.37 25 28.10 49.1 41.97 60.1 52.96  105 0 0;
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
-1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0;
-1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
```

0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1];

b= [477778;477778;477778;24352872.34;12201001.97;95556;-47778;95556;-23889;95556;-47778;95556;-47778;71667;-23889;47778;-23889;143333;-47778;23889;-4778;9556;-4778;4778;-2389;95556;-81222;95556;-4778;47778;-4778;9556;-4778;
4778;-2389;9556;-4778;4778;-2389;23889;-4778;
0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0];

Aeq= [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1];
beq= [4778;9556];

Optimization running.
Optimization terminated.
Objective function value: -4.2256175111187315E9
Optimization terminated.

CK	61308
JK	23889
CTK	95556
STK	47778
MK	23889
GK	47778
SK	143333
SUK	4778
VGK	4779
VOK	4778
WR	95556
GR	95556
SAR	47778
VGR	9556
VOR	4778
VGS	9556
VOS	4778
FA	5578
AA	4778
DA	9556

VITA

1. Name of student : **Miss. Preetam Gautam Kamble**
2. Date of Birth : 1st September 1981
3. Name of the College : Post Graduate Institute,
   Dr. Panjabrao Deshmukh Krishi Vidyapeeth,
   Akola
4. Residential Address : Area No. 2, Line No. 8, R. No. 6,
   Sahakar Chowk, At. Post Daund,
   Dist. Pune (M.S.) PIN - 413801.

   Contact : 02117-280857.
5. Academic Qualification :

Sr. No.	Name of Degrees awarded	Year in which obtained	Division/ Class	Name of awarding University	Subjects
1.	B.Tech.	2006	Second	Dr. PDKV, Akola	Agricultural Engineering

6. Research papers published (if any) : -
7. Field of Interest (in which you desire to work) : Lectureship

Place : Akola
Date :12/06/2009

Kamble
Signature of Student