

Formulation of Linear Programming model for Crop planning in command area of Gangapur Irrigation Project

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ABSTRACT

The study of formulation of linear programming model for net benefit maximization was carried out at the command area of Gangapur irrigation project in Nashik district, Maharashtra. The results of this study shows that the irrigation requirement for wheat, gram, soybean, fodder and grape are 36.3 cm, 29.7 cm, 30.9 cm, 21.2 cm and 42.5 cm, respectively. In Jalalpur minor, at 50 per cent, 60 per cent, and 70 per cent probability level, for net benefit maximization, the area allocated are 119.66 ha, 141.70 ha and 141.70 ha respectively. The net benefit found to be 71759.64 Rs/ha, 74333.80 Rs/ha and 74333.80 Rs/ha for 50 per cent, 60 per cent, and 70 per cent probability level respectively.

Keywords: *Linear Programming, Irrigation requirement, Command area*

Introduction

Water is most vital input in modern agriculture. Its restricted supply not only affects the yield of a crop directly but also hinders the availability of other nutrients to the plants. If the availability of water is limited, then it is necessary that a farmer should choose a cropping pattern such that the peak water demand is met satisfactorily out of the existing availability of irrigation water. Water is a limited resource; its efficient use is necessary for the survival of increasing population. For the conservation and development of water resources there is necessary to consider different factors. These include availability of water, its quality, location, distribution and variation in its occurrence, climatic conditions, nature of the soil, competing demand and social-economic conditions. There is need to make the efficient use of water for the increasing the crop production.

There is need to develop the model for the optimal allocation of area using available water for the crop planning. The model in this study was developed in command area of Gangapur Irrigation project in India. Singh and Wolkewitz (1983) used linear programming technique for crop planning for winter season in the canal command area of Hissar Major

Distributary of Western Jamuna Canal System. Prasad (1987) developed a linear programming model for irrigation planning of Damodar – Barakar river basin considering periodical inflow of 10 days and evaporation losses for the whole year to serve as a guideline. Chandra and Heady (1996) developed a linear programming model for optimal canal scheduling of Gambhiri irrigation system. Gupta et al.(2000) formulated multi-objective fuzzy linear programming (MOFLP) area allocation model. Singh *et al.* (2001) estimated the irrigation water requirements of major crops and the total available water through canal and ground water in the command of Shahi distributary. Cheng yun *et al.* (2008) proposed a linear programming model to study the conjunctive use of surface water and groundwater for optimal water allocation in Taiwan. Regulwar and Pradhan (2013), Li and Guo (2014) and Raul *et al.*(2014) developed fuzzy Linear programming model, multi-objective optimal allocation model and conjunctive use planning model respectively for optimal cropping.

Material and Methos

Description of study area:

Gangapur Dam: Gangapur Irrigation Project is the multipurpose Project of Nashik district. This earthen dam is situated near the village Gangapur, eight miles to the north-west of Nashik city. It is built on the confluence of the Godavari and Kashyapi rivers. The salient features of Gangapur Irrigation Project is shown in Table 1.

Climate

The climate of this district is characterized, by dryness except in the south-west monsoon season. The mean daily maximum temperature and minimum temperature is 37.4 °C (99.3 °F) and the mean daily 10.2 °C (50.4 °F) respectively. The relative humidity in summer varies between 20 to 25 per cent.

Soil and Topography:

The deccan trap parent material is present in the district. The soil formation is mainly affected by the climatic conditions and topography of the district. The soils in the heavy rainfall zone are neutral in reaction, contain higher amounts of organic matter and are low in their base status. The soils are slightly alkaline, moderate amount of organic matter. They are slightly alkaline in reaction and contain moderate amounts of organic matter.

Canal system

Gangapur irrigation project consist of two canals, viz., right bank canal and the left bank canal with a total length of 19 miles and 29 miles respectively. The right bank canal commands a gross area of 11,000 acres and the left bank canal 33,000 acres.

Selection of Minor

Jalalpur minor is selected for the present study which is located in the upper part of the command. Jalapur minor having Culturable Command Area is 141.70 ha. with discharge carrying capacity 0.8648 Mm³.

Population of Jalalpur minor

The inhabitant's belonged to different age groups in Jalalpur minor are given in table . Total population of Jalalpur minor is 840. The livestock is about 360 (Table 2)

Cost of Cultivation of Crops:

Cost of cultivation of crop i.e. wheat, gram, soyabean, fodder and grape were estimated. The following parameters were considered in the cost of cultivation.

Hired human labour: Hired human labour cost was estimated at their actual wages paid in cash. The wages paid in kind were calculated at prevailing price in the market on an average basis.

Bullock labour: Hired and owned bullock labour cost was estimated at the actual rate period for hiring of bullock labour in local market from time to time.

Machinery charges: Machineries are required for ploughing, harrowing, sowing, harvesting, threshing, transporting of seed, fertilizers etc, Machinery charges were taken into consideration on the basis of actual expenditure incurred by the growers.

Seed: The actual cost paid for purchasing of seed from the market was taken into account for its evaluation.

Manures: The cost of farm yard manure produced on the farm was estimated at the prevailing rates in the locality. In case of purchased farm yard manure the actual price paid was taken into account.

Fertilizers: The actual price paid for the fertilizers was taken into account.

Plant Protection: Actual cost for purchase of insecticides and pesticides was taken into account.

Interest on working capital: The interest on working capital was worked out @ 14 per cent per annum for the entire life period of crop as per prevailing rate of interest.

Land Revenue: It includes actual land revenue paid by the farmers.

Implements: Owned implements used for the crop were charged at the hiring rates prevailing in the locality from time to time.

Imputed value of family labour:

Wages for the work done by the family labour should be imputed on the basis of average wages rate of permanent labour .however in view of the difficulties in calculating average wage rate of permanent farm labour, the family labour was imputed on the basis of wage rate of casual labour prevailing in the locality for various farm operations.

Gross return: It comprises of value of main product and byproducts.

Net return: Net return was computed by deducting respective costs from the gross return.

Formulation of general linear programming model

Linear Programming deals with that class of programming problems for which the constraints as well as the function to be optimized are linear relations among the variables. When the resources are scarce, there is a need for allocation of limited resources to priorities or activities. Linear programming technique is used to maximize or minimize a given objective function. The general linear programming problem can be stated in the following form:

1. In scalar form

Maximize (or minimize):

$$Z = C_1 X_1 + C_2 X_2 + \dots + C_n X_n. \quad \dots (1)$$

Subject to the constraints

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

and

$$X_1 \geq 0, X_2 \geq 0, \dots, X_n \geq 0 \quad \dots (3)$$

2. The linear programming model in scalar form may also be stated in compact form by using summation sign as:

$$\text{Maximize (or minimize) } Z = \sum_{j=1}^n C_j X_j \quad \dots(4)$$

Subject to the constraints:

$$\sum_{j=1}^n a_{ij} X_j (\leq, = \text{ or } \geq) b_i \quad i = 1, 2, \dots, m \quad \dots(5)$$

$$\text{and } X_j \geq 0, \quad j = 1, 2, \dots, n \quad \dots (6)$$

Where,

C_j = Cost coefficient of X_j

X_j = decision variable

a_{ij} = Coefficient for i^{th} resource and j^{th} variable

b_i = Total available resource

3. In a more convenient matrix notation, a typical LP problem (Maji and Heady, 1980) can be written as

$$\text{Maximize (or minimize) } Z = C^T x \quad \dots (7)$$

$$\text{Subject to constraints } Ax = B \quad \dots (8)$$

and $x \geq 0$ (9)

Where,

$$x \begin{vmatrix} x \\ 1 \\ \vdots \\ x \\ 2 \end{vmatrix} \quad B \begin{vmatrix} B \\ 1 \\ \vdots \\ B \\ 2 \end{vmatrix} \quad C \begin{vmatrix} C \\ 1 \\ \vdots \\ C \\ 2 \end{vmatrix} \quad \dots (10)$$

$$A = \begin{vmatrix} a_{11} & a_{12} & a_{13} & \dots & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & \dots & a_{2n} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \end{vmatrix} \text{ mxn} \quad \dots(11)$$

All the notations are same and the superscript ‘T’ is used to indicate the transpose. C is the vector of known constants. x is a vector of decision variables. The problem is to find a set of x, the decision variables, that maximize (or minimize) the objective function Z (equation 7) and satisfies the equations 2 and 3.

Development of linear programming model

Linear programming is a versatile tool in system analysis and it finds its application whenever two or more activities are competing for limited resources. 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 command area of Jalalpur minor. For the development of LP model, the subscripts used are ‘i’ representing crop activity. Particulars of the subscripts are given in the Table 3.

Objective function

In order to maximize the objective of net benefit, a mathematical model is developed for optimal allocation of land for the watershed. The objective function is subjected to the various constraints (Table 3).

Objective: Net benefit maximization

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

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

Where,

NB_i – Net benefit from i^{th} crop, Rs/ ha

X_i – Area under i^{th} crop, ha

Objective: Area Maximization

Area is to be maximized in order to consider the water availability in the reservoir and the water requirement of crop.

$$\text{Max. A} = \sum X_i$$

Where,

X_i – Area under i^{th} crop, ha

Constraints**1. Area constraint:**

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

$$\sum X_i \leq A$$

Where,

A – 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.

$$\sum W_i X_i \leq W$$

Where,

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

W – Total water availability in the command, ha-cm

3. Food requirement constraint

Food available from the crops grown in the watershed should fulfill the actual food and nutritional requirement of people in the command area.

$$\sum N_i X_i \geq N$$

Where,

N_i – Production of i^{th} crop, qtl/ha

N – Quantity of crop to be produced to fulfill nutritional need of population, qtl.

4. 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:

Bounds of area are fixed for Grape crop.

Software:

LINDO 6.1

The LINDO 6.1 optimization package used to solve the linear optimization model. The LINDO 6.1 package is capable of solving linear, integer, and quadratic optimization models. The LINDO 6.1 uses the revised simplex method to solve the linear optimization models.

CROPWAT

It was developed by FAO, is written in BASIC, and runs in the DOS environment. It is a decision support system developed by the land and water development division of FAO. Its main function is calculation of reference evapotranspiration, crop water requirement, and crop irrigation requirement.

Results and Discussion**Cost estimation of different crop:**

Cost estimation of wheat, gram, soyabean fodder and grape crop are given in Table 4. Wheat crop due to its highest production per hectare has maximum net benefit of Rs.18313 and fodder has minimum net benefit of Rs. 10000. The Investment in wheat, soyabean, gram, fodder and grape is Rs. 11843, Rs. 10009, Rs. 7960, Rs. 5000 and Rs. 215000 respectively and corresponding yield or production in qt/ha is 27, 12, 12, 500 and 186 respectively. The minimum support prize by Government of India for wheat is Rs. 1150, gram is Rs 1860, soyabean is Rs. 1700, fodder is Rs. 30 and grape is Rs. 2500. Also the net benefit for wheat is Rs. 18313, gram is Rs 14360, soyabean is Rs. 10392, fodder is Rs. 10000 and grape is Rs. 250000. The irrigation water requirement is calculated with help of software CROPWAT and is presented in Table 5. The table revealed that the irrigation requirement of grape for November and February is 42.5 cm. The total irrigation requirement of wheat, gram, soyabean and fodder is 36.3 cm, 29.7 cm, 30.9 cm and 21.2 cm respectively.

Actual water available for irrigation (ha-cm):

Water available for irrigation was calculated by considering different losses i.e. Evaporation loss of 18.08 Mm³ and the reservations of water for drinking and industrial purpose i.e. 103.53 Mm³. The share of water is divided on area basis, as Jalalpur minor has 0.86% area of total culturable area of Gangapur irrigation project hence 0.86 % share of water is taken as water available for irrigation. The water available for Jalalpur minor of 141.70 ha CCA at 50 per cent, 60 per cent, and 70 per cent Probability level was estimated to be 4324 ha-cm, 5188.8 ha-cm, and 6053.60 ha-cm respectively.

Food requirement:

In order to achieve self sufficiency in food production, minimum requirement of the crops are estimated as per demand of the population. Food requirement for Jalapur minor was calculated as per norms prescribed by CFMRI. The cereal requirement is fulfilled by wheat crop, pulse requirement is fulfilled by gram crop and oil requirement is fulfilled by soyabean and fodder requirement from (Maize) as the preference of the populations. For Jalapur minor wheat requirement is 839.72 qt/year, gram requirement is 45.32 qt/year, soyabean requirement 22.66 qtl/year and fodder requirement is 6480 qt/season

Optimum area allocation and net benefit**Jalapur Minor :**

The cropping pattern for Jalapur minor of 141.70 ha CCA is given in table 4.5 For net benefit maximization, at 50 per cent probability level, it shows that wheat crop occupies 66.66 ha area which is 47.04 per cent of CCA. The area under gram, soyabean and fodder is 3.77 ha, 1.88 ha and 12.96 ha respectively having 2.66, 1.32 and 9.14 per cent of CCA. The grape crop was fixed at 24.70 per cent of total area and hence it occupies 35 ha area. At this level the area under cultivation is 83.8% of total CCA. The income level at this level was found to be Rs.10168341.71.

For 60 per cent probability level, the area under grape, wheat, gram, soyabean, and fodder are 35 ha, 88.07 ha, 3.77 ha, 1.88 ha and 12.96 ha respectively. It is seen that the area under wheat crop was increased up to 88.07 ha as water availability increased. Area under other crops remains same. At this level 100 per cent area is irrigated. The net benefit in this level is Rs. 10566100.07.

For 70 per cent probability level all the area remains same. The net benefit in this level is Rs. 7066100.07.

In case of area maximization, at 50 per cent probability level, the results shows that area under wheat crop was found to 66.66 ha which is 47.04 per cent of CCA and area under fodder was 12.96 ha which is 9.14 per cent of CCA. For 60 per cent probability level, the area under wheat crop is increased to 88.07 ha which is 62.15 per cent of CCA while area under other crops remained constant. Also for 70 per cent probability level, the area under all the crop remained same. The area under irrigation at 50 per cent, 60 per cent and 70 per cent

probability levels were found to be 119.66 ha, 141.70 ha and 141.70 ha respectively (Table 6). Thus in net benefit maximization, the area under wheat crop increase with increases in probability level of storages as wheat crop is having maximum net returns per ha.

Conclusion

On the basis of results it is concluded that at 50 per cent, 60 per cent, and 70 per cent probability level, for net benefit maximization, the area allocated are , 119.66 ha, 141.70 ha and 141.70 ha respectively. The net benefit for the rabi season found to be 71759.64 Rs/ha, 74333.80 Rs/ha and 74333.80 Rs/ha for 50, 60 and 70 per cent probability level respectively.

Table: 1 Salient features of Gangapur Irrigation Project

1	Name of dam	Gangapur Irrigation Project
2	Name of river	Godavari
3	Location	
A	Village	Gangapur
B	Tehsil	Nashik
C	District	Nashik
D	State	Maharashtra
E	Latitude	20 37’N
F	Longitude	73 19’E
4	Category of project	Large
5	Nearest city of the project	Nashik, 13 Km
6	Year of construction	1961
7	Year of completion of dam	1965-66
8	Category of project Irrigation or multipurpose	Irrigation
9	Catchment area	357.40 sq.Km

10	Average annual rainfall	824
11	Storage capacity	
A	Gross	214.50 Mm ³
B	Dead	11.33 Mm ³
C	Live	203.17 Mm ³
12	Gross command area	38400 ha
13	Culturable command area	29900 ha
14	Irrigable command area	23940 ha
15	Annual evaporation	18.08 Mm ³

Table 2: Number of Adults and Children in Jalalpur Minor

Sr. No.	Food item	Below 18 yrs		Male	Female	Grant Total
		Boys	Girls			
1	Jalalpur	141	98	329	272	840

Table 3: Subscripts for crops in rabi season used in the model with notations

Sub-script 'i'	Crop for rabi season
1	Wheat (WH)
2	Gram (GR)
3	Soybean (SO)
4	Fodder (FO)
5	Grape (GP)

Table 4: Cost estimation of crop

Crop	Investment (Rs)	Production (qt/ha)	Minimum support price (Rs)	Net benefit (Rs)
Wheat	11843	27	1150	18313
Gram	7960	12	1860	14360
Soyabean	10009	12	1700	10392
Fodder	5000	500	30	10000
Grape	215000	186	2500	250000

Table 5: Irrigation requirement of different crop

Month	Grape	Wheat	Gram	Soyabean	Fodder
November	9.50	4.80	4.70	5.30	4.50
December	11.50	10.70	10.50	9.30	8.30
January	11.00	11.85	11.95	10.25	8.40
February	10.50	8.95	3.55	5.05	—
Total	42.50	36.3	29.7	30.9	21.2

Table 6: Proposed cropping pattern for Jalalpur minor

Probability level (%)	CCA (ha)	Crop	Allocated area (ha)	%CCA	Net benefit (Rs)	Area max. (ha)
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50	141.70	Grape	35	24.70	10168341.71	119.66
		Wheat	66.66	47.04		
		Gram	3.77	2.66		
		Soyabean	1.88	1.32		
		Fodder	12.96	9.14		
		Total		83.8		
60	141.70	Grape	35	24.70	10566100.07	141.70
		Wheat	88.07	62.15		
		Gram	3.77	2.66		
		Soyabean	1.88	1.32		
		Fodder	12.96	9.14		
		Total		100		
70	141.70	Grape	35	24.70	10566100.07	141.70
		Wheat	88.07	62.15		
		Gram	3.77	2.66		
		Soyabean	1.88	1.32		
		Fodder	12.96	9.14		
		Total		100		

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