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Optimal Cropping Pattern for Jaisamand command of Udaipur district in Rajasthan, India

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Abstract

This paper presents an application of LINGO software to allocate the area for production maximization in Jaisamand command area of Udaipur district. The linear programming model was developed and solved in LINGO software. The area allocated for different crop activities in 9,18,21,24 and 30 canal running days was obtained. The optimal food production for maize, soyabean, moong, wheat, mustard, gram and barley in 9,18,21,24 and 30 canal running days obtained as 33454.94, 70278.44, 68502.53, 71987.65 and 72082.02 tonnes with investment of 403.00, 773.78, 797.67, 845.09 and 851.22 million Rs. respectively. The net benefit obtained as 219.55, 58.02, 451.89, 456.06 and 455.43 million Rs. for 9,18,21,24 and 30 canal running days respectively.

Keywords: Optimal, Jaisamand command, LINGO.

Introduction

To fulfil the high demand food fibre and fuel to an increasing population it is necessary to bring more area under cultivation or to increase production per unit area of available land and water resources. Due to urbanization and a reluctance to disturb natural environments there is difficult to bring the additional area under cultivation. Therefore, it is important to optimize the available land and water resources to achieving maximum production. The existing cropping pattern has been same for many years and may not utilize resources at maximum economic efficiency. Linear programming model can handle a large number of constraints and thus, are an effective tool to aid in the optimization process. Some of the reviews about optimal allocation of canal water are discussed below.

Santhi and Pundarikanthan suggested a new planning model for canal scheduling of rotational irrigation[1]. Srinivas and Nagesh developed a linear programming (LP) irrigation planning model for the evaluation of irrigation development strategy and applied to a case study of Sri Ram Sagar project, Andhra Pradesh, India with the objective of maximization of net benefit[2]. Anwar and Clarke presented a mixed integer program for scheduling canal irrigation among a group of users where the users specified the duration of flow of each outlet and a target start time[3]. Vries and Arif presented an integer program solution for sequential irrigation scheduling problem of two different models to reflect different management options at the tertiary level[4]. Bhabagrahi S. and Anil K.L. developed a linear programming and fuzzy optimization models for planning and management of available land-water crop system of Mahanadi-Kathajodi delta in Eastern India[5]. Khare *et al.* developed conjunctive use linear programming model for planning in a link canal command area[6]. Brian and Marshall studied the use of a coupled groundwater simulation and optimization model to guide groundwater management in the upper Klamath basin, Oregon and California[7]. Saafan *et al.* carried out study on a multi-objective optimization approach to groundwater management using genetic algorithm[8]. Ajay Singh carried out study on optimization modelling applications. The comprehensive reviews on the use of various programming techniques for the solution of different optimization problems have been provided in his paper[9]. Regulwar and Pradhan developed fuzzy Linear programming model by using surface and groundwater for irrigation planning[10]. Li and Guo used a multi-objective optimal allocation model for irrigation water resources under multiple uncertainties[11]. Raul *et al.* developed conjunctive use planning model for optimal cropping under hydrological uncertainty[12].

Material and Methods

The Jaisamand Lake was constructed by the rular of Mewar in the year 1711-1730, near village Veerpura, Tehsil Sarada, Disrict Udaipur. The lake was constructed for wildlife and recreation but after independence, the canal system is developed and about 16000 ha area included as command area. The detail information is given in table-1. The command area is having good soil characteristics and two crops (Kharif, Rabi) can be grown up.

Existing cropping patterns: In Jaisamand command area general crops like maize, soyabean, moong, wheat, mustard etc. are grown. The total cultivable area is 17900 in kharif and rabi season. The total production obtained is 43446.2 tonnes with investment of 469.74 million Rs. and net benefit obtained is 275.72 million Rs. as shown in table-2. The cost of cultivation

of different crops collected from Directorate of Economics and Statistics, Udaipur (Rajasthan). The command area population data collected from Sarada and Salumber Tehsil of Udaipur district. The month wise data of labour requirement of different crops collected from Water resource Department Salumber. Monthly crop water requirement was calculated on the basis of FAO-56 by using thirty four years pan evaporation data. The details of monthly crop water requirement of different crops as shown in table-3.

The monthly water available in LMC and RMC of canal running different days as shown in table-4.

Linear programming model: The linear programming model consisting of three major components: an objective function for maximization of production, a set of linear constraints and a set of non-negativity constraints was developed. The model was formulated to allocate land among the different crops, in order to maximize the production from the command area. The crop model developed is solved using LINGO package. The water supply available at inlet was considered as the only source of available water in the command.

Objective Function: Production Maximization: The production is to be maximized in order to safeguard the interest of the country so that self-sufficiency in food production is achieved.

$$\text{Max } Z_p = \sum_{i=1}^{2}\sum_{j=1}^{7} P_j X_{ij}$$

Where: P_j Stands for production of j^{th} crop activity in q/ha X_{ij} stands for the area under i^{th} canal, j^{th} crop activity in ha
i = 1 to 2 (LMC and RMC)

Constraints: A planning should take care of needs of the people. To take care of all these factors, the following constraints need to be imposed.

Area constraints: The area under cultivation in Kharif and Rabi season cannot exceed the total cultivable area. This can be mathematically expressed as under,

$$\sum_{i=1}^{2}\sum_{j=1}^{7} X_{ij} \leq A$$

Where: A= stands for total cultivable area in the project command area in ha

Water constraints: Water requirement for different crop must be less than or equal to the water resources available during the season. If W_{jt}, X_{ij} represents the product of water requirement per hectare and the area under j^{th} crop activity in the t^{th} month, then

$$\sum_{i=1}^{2}\sum_{j=1}^{7} W_{jt} X_{ij} \leq W$$

for t= 1,2,3…….12

Labour requirement constraints: Labour requirement for different crops on the field in a particular month must be less than or equal to the labour-days available in the month so that there will not be any need to bring labour from outside. If l_{jt} represents the labour requirement for j^{th} crop in t^{th} month in a growing season,

$$\sum_{i=1}^{2}\sum_{j=1}^{7} l_{jt} X_{ij} \leq L$$

for t= 1,2,3…….12

Food requirement constraint: Total production of Maize, Soyabean, Moong, Wheat, Mustard, Gram and Barley should meet the actual requirement of the total population of the command area. These are the social constraints and can be expressed as

$$\sum_{i=1}^{2}\sum_{j=1}^{7} P_j X_{ij} \geq P_f$$

Where: P_j stands for yield of j^{th} crop activity in q/ha, P_f stands for bulk requirement of food in quintal.

Results and Discussion

Considering the objective of food production maximization, the area allocated to different crop activities found out for various levels of water availability i.e. number of canal running days (9,18,21,24,30 days). The area allocated to different crop activities in kharif and rabi season are presented in table-5. The optimal food production for maize, soyabean, moong, wheat, mustard, gram and barley in 9,18,21,24 and 30 canal running days obtained as 33454.94, 70278.44, 68502.53, 71987.65 and 72082.02 ton with investment of 403.00, 773.78, 797.67, 845.09 and 851.22 million Rs. respectively. The net benefit obtained as 219.55, 58.02, 451.89, 456.06 and 455.43 million Rs. for 9,18,21,24 and 30 canal running days respectively. Table-5 shows that the area allocated for different crop activities with available water by using linear programming model. Figure-2 shows that in the command area maximum area under wheat then maize and small amount of barley crop taken for cultivation. But after developing linear programming model for production maximization there is observed changes in cropping pattern.

From figure-3 it is observed that the area allocated for the soyabean is more than gram, wheat, barley, moong, mustard and maize for 9 days canal running for production maximization. In canal running 18 days area allocated for soyabean and wheat is more than other crops. Mustard crop allocated least area (figure-3). Linear programming model is developed for the 21 canal running days and area allocated is more for wheat then maize, soyabean, mustard, barley, moong and gram (figure-3). In 24 canal running days, maize crop allocated more area then wheat, soyabean, moong, gram, barley and small amount of mustard crop (figure-3). In similar way solution of linear programming model in LINGO-package shows the area allocated for maize and wheat crop is more than other crops for canal running in 30 days.

Figure-1
Location map of Command area

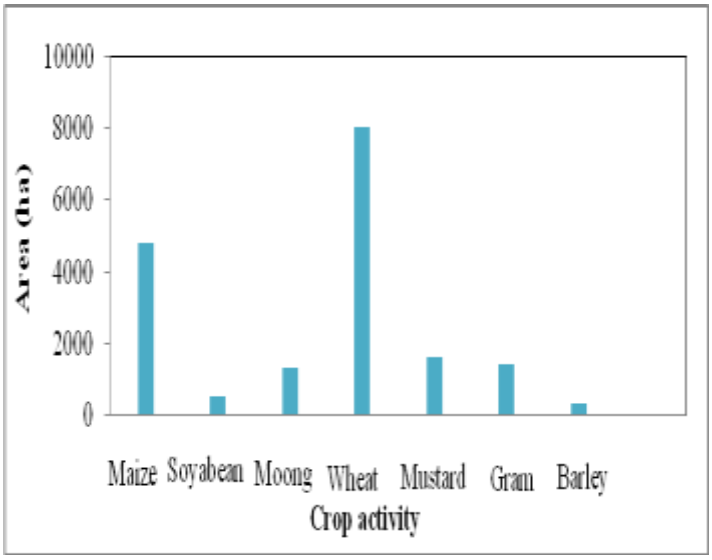

Figure-2
Existing cropping pattern in the command area

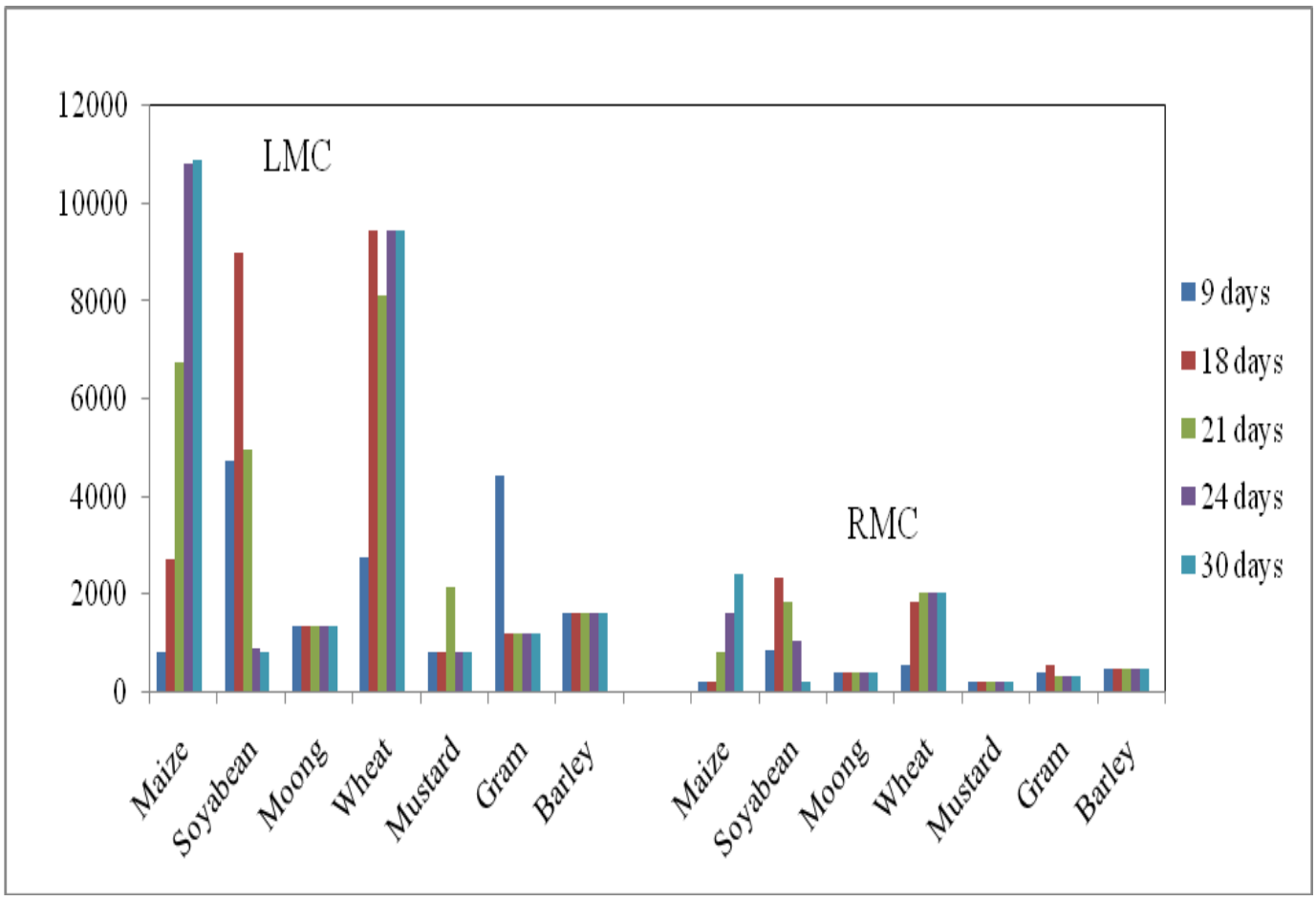

Figure-3
Optimal allocation of surface water in LMC and RMC for different canal running days

Table-1
Description of canal network

Sr.no.	Particular	Remarks
1	**Location of site**	
	I .State	Rajasthan
	ii. District	Udaipur
	iii. Tehsil	Sarada
	iv. Village	Gatod
	v. Longitude	73°57'10"E
	Vi. Latitude	24°14'30"N
2	**Hydrology**	
	i. Name of river	Gomati
	ii. Gross catchment area	1858 sq.km.
	iii. Catchment area intercepted	159 sq.km.
	iv. Free catchment area	1654 sq.km
	v.75% dependable monsoon rainfall	556mm.
	vi.75% dependable runoff yield from free C.A.	64.24M.cum.
	vii.50% dependable yield	155.45M.cum.
	viii. Maximum probable flood	18876 cumecs
	Routed flood	5405 cumecs
3	**Utilization**	
	1. Irrigation	
	i. G.C.A.	37282 ha
	ii. C.C.A.	16000ha
	iii. .Annual irrigation	14400ha
	iv. Additional	8353ha.
	2. Irrigation utilisation	
	i. Kharif	25.86 M.cum.
	ii. Rabi	58.44 M.cum.
	Total	84.30 M.cum.
	Total evaporation	54.70 M.cum.
	Total utilisation	139.00 M.cum.
		Duty-7.25Ac/M.cum.
4.	**Storage planning**	
	i. Gross storage	414.60 M.cum.
	ii. Live storage	296.14 M.cum.
	iii. Dead storage	118.46 M.cum.
5	**Control elevations**	
	i. T.B.L.	303.10 m
	ii. M.W.L.	301.10 m
	iii. F.R.L.	295.47 m
	iv. Crest level of spillway	295.47 m
	v. M.D.D.L.	287.70 m
6	**Submergence detail**	
	i. Area under submergence at F.R.L.	5260 ha
	ii. Culturable area under submergence	2752 ha
	iii. Submergence ratio with respect to C.C.A	32.88%
7	**Dam**	
	i. Type of dam	Composite section consisting of two massive masonry walls on U/s and D/s faces earth filling in between
	ii. Length of dam	399 m
	iii. Top width of dam	94 m to 100 m
	iv. Maximum height above bed level of river	42.06 m
	v. Free board above M.W.L.	2 m

Sr.no.	Particular	Remarks
8	**Spillway**	
	i. Gated spillway Sill R.L. of gates	2 no. gates (3.05×5.03) 289.97
	ii. Type of spillway	Ungated situated on L/S of main dam in three saddles
	iv. Byewash in saddles	Three saddles
	Saddle no.1	30.50 m
	Saddle no.2	90 m
	Saddle no.3	20 m
	Total	**140.50 m**
	v. Crest level	295.47 m
	vi. Discharging capacity	5405 cumecs
9	**Canals**	
	Type of canals	Lined
	Length of main canal	
	Left canal	51.09 km
	Right canal	22.86 km
10	**Discharge at head**	
	Left canal	7.56 cumecs
	Right canal	1.53 cumecs
11	**Free board**	
	Left canal	0.60 m
	Right canal	0.30 m
12	**Side slope**	
	Left canal	Vertical
	Right canal	Vertical
13	**Bed levels**	
	Left canal	287.16 m
	Right canal	289.83 m
14	**Bed width**	
	Left canal	3 m
	Right canal	2.45 m
15	**Full supply depth**	
	Left canal	1 m
	Right canal	0.72 m

Table-2
Existing cropping pattern in command area

Sr. No.	Crop Activity	Area under the crop (ha)
	Kharif	
1	Maize	4800
2	Soyabean	500
3	Moong	1300
	Rabi	
4	Wheat	8000
5	Mustard	1600
6	Gram	1400
7	Barley	300
Total (ha)		**17900**
Investment in million Rs.		469.74
Achievement level		
Production in tonnes		43446.2
Labour in man-day		1601000
Net Benefit in million Rs.		275.72

Source: Water resource Deparment Salumber

Table-3
Monthly water requirement of different crops (cm)

Month	Maize	Soyabean	Moong	Wheat	Mustard	Gram	Barley
Jan				6.3	5.98	5.61	7.51
Feb				8.84	4.18	2.51	12.62
March				8.45			17.00
April							4.37
May							
June							
July	3.07	6.59	1.75				
August	6.74	8.07	4.00				
Sept	12.86	8.03	8.16				
Oct	3.77	4.73	7.47		1.67	2.56	
Nov				1.4	3.67	4.98	
Dec				5.38	7.46	7.42	0.38
Total	**26.44**	**27.42**	**21.38**	**30.37**	**22.96**	**23.08**	**41.88**

Table- 4
Canal water available in different days in the month (ha-cm)

Days	9	18	21	24	30
LMC	58864.32	117728.64	137350.08	156971.	196214.4
RMC	11897.28	23794.56	27760.32	31726.08	39697.6

Table-5
Optimal allocation of surface water using linear programming model for production maximization in different canal running days

	Crop	Number of canal running days				
		9	18	21	24	30
LMC (Area allocated)						
Kharif	Maize	781.20	2692.63	6755.04	10817.45	10910.82
	Soyabean	4729.98	8999.39	4936.98	874.57	781.20
	Moong	1327.97	1327.97	1327.97	1327.97	1327.97
Rabi	Wheat	2743.13	9462.41	8115.02	9462.41	9462.41
	Mustard	781.20	781.20	2128.58	781.20	781.20
	Gram	4434.43	1174.31	1174.31	1174.31	1174.31
	Barley	1602.07	1602.07	1602.07	1602.07	1602.07
RMC						
Kharif	Maize	178.80	178.80	783.29	1604.36	2408.65
	Soyabean	823.24	2304.84	1830.61	1009.54	205.25
	Moong	366.08	366.04	366.08	366.08	366.08
Rabi	Wheat	519.43	1824.81	2035.82	2035.82	2035.85
	Mustard	178.80	178.80	178.80	178.80	178.80
	Gram	392.21	534.43	323.72	323.72	323.72
	Barley	441.65	441.65	441.65	441.65	441.65
Total (ha)		19300.19	31869.35	31999.94	31999.95	31999.98
Investment in million Rs.		403.00	773.78	797.67	845.09	851.22
Achievement level						
Production in tonnes		33454.94	70278.44	68502.53	71987.65	72082.02
Labour in man-day		1455642	2867726	2769329	2788370	2778499
Net Benefit in million Rs.		219.55	58.02	451.89	456.06	455.43

Conclusion

In the present study linear programming model is developed for the production maximization and solved in LINGO software tool. The area allocated for wheat crop for canal running days 24 and 30 days is maximum. Mustard crop allocated same area in 9, 18, 24 and 30 canal running days in the month. Wheat, soyabean and maize are the major crops for which maximum area allocated for the production. Net benefit obtained as 455.43 million Rs. for 30 canal running days. So for achieving maximum production wheat, soyabean and maize crops taken for cultivation in allocated area.

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