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Optimal Land Allocation Programming Problems for Agricultural Revenue Maximization in Andhra Pradesh

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ABSTRACT

This study is on development of programming problems for optimal allocation of agricultural land to different crops with special reference to Andhra Pradesh State. The prime objective of this study is to provide the management planning to farm people for optimal utilization of agricultural land resources with the objective of maximizing the revenue. Three programming problems were formulated for the objectives of optimal crop area scheduling with (i) simple LPP, (ii) single goal programming and (iii) multiple goals programming with crop wise goals. Data from the agricultural farmers of AP were collected for ten crops cultivated with nine different methods of farming. While formulating the models, we have considered the issues of revenue per kg, total yield of the crop, minimum support price per kg, market competitive price per kg, break even revenue, break even cost (in thousand rupees), minimum investment, maximum investment, available area for each crop, crop wise arbitrary target value and cost in rupees, etc. Investment for different types of expenditures like ploughing, seeds per kg, plantation, labour, fertilizers, water, rent, picking charges, storage per quintal, etc are considered. The activity ended with exploring the decision variables of finding the optimal land allocation for each crop.

Key words: Agriculture revenue maximization, Optimal crop planning, Simple and multiple goal programming problems.

INTRODUCTION

Agriculture is the primary source of livelihood for about 58 per cent of India's population. Agriculture is the most important occupation for most of the Indian families. Over 58% of the rural households depend on agriculture as their principal means of livelihood. All measures to increase productivity will need exploiting, amongst them: increasing yields, diversification to higher value crops and developing value chains to reduce marketing costs. While agriculture's share in India's economy has progressively declined to less than 15% due to the high growth rates of the industrial and services sectors. On the other hand the production/ yields of different crops, the selling price on different agricultural products and hence the revenue on the outputs is drastically decreased. Widening gap between investment and revenue is alarming in the context of the farming. It means that the profitability of agriculture is low or nil or negative and therefore, the income derived from these activities are not sufficient enough to meet the expenditure of the cultivators. Generation of revenue through various crops with optimal scheduled area is need of hour. In the present study, we focused on revenue maximization of different types of crops with optimal land allocation through Linear Programming problems with certain crop wise goals.

Most of the optimization problems have the specific objective of maximizing revenue and yield of agricultural crops. Ishtiaq Hassan *et al*. (2005) proposed the model for optimal cropping pattern, land allocation and production for crops such as wheat, basmati rice, IRRI rice, cotton, sugarcane by including the farmer's income as an important parameter. Wankhade and Lunge (2012) proposed a linear programming technique to determine the optimum land allocation to maximize the profit for 10 major crops with various expenditure factors. Gadge (2014) formulated linear programming model to suggest the optimal cropping pattern for surface irrigation in a command area. Main objective of the model was to achieve the maximum net benefits subjected to the constraints such as the total available water and land during different irrigation periods. Sofi *et al*. (2015) developed LP technique for optimum land allocation and achieving efficiency in agriculture production planning of food crops (rice, maize, wheat, pulses and other crops) to maximize the profits with respect to various factors *viz*. Daily wages of labour and machine charges for the period 2004-2011. Pushpavalli *et al*. (2018) developed a linear programming (LP) technique for optimization of resource allocation and achieving efficiency in planning for agricultural production. Mellaku (2018) developed a model for the potential production and profit performance of smallholder crop production systems under alternative cropland-allocation scenarios. Matsyapa *et al*. (2018) formulated a model for optimal cropping pattern and area under the

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different types of rice crop to maximize the profit gain of farmers. Zenis *et al*. (2018) proposed a LP model for optimal land allocation of 4 crops namely rice, corn, soy, peanuts to maximize the net income levels. Manju *et al* (2019) developed a LP model to allocate the optimal crop area of cotton, guar and jowar crops such as to maximize the net return with various expenditure factors.

MATERIALS AND METHODS

Modeling of optimal programming problems

In this paper, we carried out optimization programming problem for maximizing the revenue with optimal allocation of land for different types of crops. We developed 3 models to solve maximizing the profit with crop wise single and multiple goals.

Model-I: LPP for optimal crop area scheduling

The purposed of this LPP model is to maximizing the profit of various crops with optimum land allocation as a decision variable. Minimum supportive price, Market competitive price, Break even revenue, yield and break even cost and minimum and maximum investment costs with available area of each crop are given as constraints.

$$\text{Max } z = \sum_{i=1}^{m} R_i Y_i A_i$$

Subject to constraints

$R_i Y_i A_i \geq S_i Y_i A_i$;i =1,2,....., m

$R_i Y_i A_i \leq M_i Y_i A_i$;i =1,2,....., m

$R_i Y_i A_i \geq E_i Y_i A_i$;i =1,2,....., m, $E_i >= S_i$

$\sum_{j=1}^{n} C_{ij} A_i \geq T_i$; i =1,2,....., m, where $T_i = L_i A_i$

$\sum_{j=1}^{n} C_{ij} A_i \leq P_i$; i =1,2,....., m, where $P_i = H_i A_i$

$Y_i A_i \geq B_i$;i =1,2,....., m

$\sum_{j=1}^{n} C_{ij} A_i \leq D_i$; i =1,2,....., m

$\sum_{i=1}^{m} A_i \leq A_i$; i =1,2,....., m

and $A_i \geq 0$, where i = 1,2,....., m

Model-II: Single goal programming for optimal crop area scheduling

The objective of this single Goal programming is to minimize the deviation in under achievement of maximum revenue for various crops. Here two types of constraints have included as structural constraints which are same as the model-I and second one is goal constraint with deviation of arbitrary target profit.

$$\text{Max } z = d^-$$

Subject to constraints

$R_i Y_i A_i \geq S_i Y_i A_i$;i =1,2,....., m

$R_i Y_i A_i \leq M_i Y_i A_i$;i =1,2,....., m

$R_i Y_i A_i \geq E_i Y_i A_i$;i =1,2,....., m, $E_i >= S_i$

$\sum_{j=1}^{n} C_{ij} A_i \geq T_i$; i =1,2,....., m, where $T_i = L_i A_i$

$\sum_{j=1}^{n} C_{ij} A_i \leq P_i$; i =1,2,....., m, where $P_i = H_i A_i$

$Y_i A_i \geq B_i$;i =1,2,....., m

$\sum_{j=1}^{n} C_{ij} A_i \leq D_i$; i =1,2,....., m

$\sum_{i=1}^{m} A_i \leq A_i$; i =1,2,....., m

$\sum_{i=1}^{m} R_i Y_i A_i + d^- - d^+ = Q$ (Arbitrary Value)

and $A_i \geq 0$, where i = 1,2,....., m

Where

d^+ = Deviation of over-achievement of the Maximizing the revenue goal of Rs. Q

d^- = Deviation of under-achievement of the Maximizing the revenue goal of Rs. Q

Model-III: multiple goals programming with crop wise goals for optimal crop area scheduling

This multiple goal programming model is same as the model-II but the objective function is to minimize the deviations in under-achievements of 10 types of crops. In the goal constraints, we have arbitrary goal values with deviations of various crops.

$$\sum_{i=1}^{m} \text{Min } Z = d^-$$

Subject to constraints

$R_i Y_i A_i \geq S_i Y_i A_i$;i =1,2,....., m

$R_i Y_i A_i \leq M_i Y_i A_i$;i =1,2,....., m

$R_i Y_i A_i \geq E_i Y_i A_i$;i =1,2,....., m, $E_i >= S_i$

$\sum_{j=1}^{n} C_{ij} A_i \geq T_i$; i =1,2,....., m, where $T_i = L_i A_i$

$\sum_{j=1}^{n} C_{ij} A_i \leq P_i$; i =1,2,....., m, where $P_i = H_i A_i$

$Y_i A_i \geq B_i$;i =1,2,....., m

$\sum_{j=1}^{n} C_{ij} A_i \leq D_i$; i =1,2,....., m

$\sum_{i=1}^{m} A_i \leq A_i$; i =1,2,....., m

$\sum_{i=1}^{m} R_i Y_i A_i + d^- - d^+ = Q_i$ (Arbitrary Value)

and $A_i \geq 0$, where i = 1,2,....., m

Methodology for data collection and reporting

Various cost metrics for different crops as well as different type of expenditure were presented in the matrix (Table 3). This part of the study considered the empirical numerical datasets for 10 type of crops namely cotton, mirchi, groundnut, jute, bengal grams, corn, black grams, green grams, red grams and paddy, where i=1,2,3,...,10. Similarly we consider 9 types of expenditures namely Ploughing and Machinery, Seeds, Plantation, Labour, Fertilizers, Water,

Table 1: Various prices on all type of Crops.

Crops	Revenue (Kg)	Yield	Minimum Supportive Price (Kg)	Market Competitive Price (Kg)	Break Even Revenue
Cotton	150	285	150	165	155
Mirchi	85	679	85	100	90
Groundnut	58	787	58	73	63
Jute	55	873	55	70	60
Bengal grams	60	539	60	75	65
Corn	14	475	14	29	19
black grams	80	590	80	95	85
green grams	75	628	75	90	80
Red Grams	125	722	125	140	130
Paddy	18	1967	18	33	23

Crops	Break Even Cost (Rs. In Thousands)	Minimum Investment	Maximum Investment	Available Area
Cotton	8500	27966	93900	19.06
Mirchi	8800	26400	89200	270.16
Groundnut	6600	22566	77700	80.4
Jute	4000	13933	61800	50.97
Bengal grams	5300	18066	74200	100.78
Corn	7300	24800	84400	50.99
black grams	5200	17933	63800	60.33
green grams	9998.979	17666	63000	100.65
Red Grams	8500	36533	96900	250
Paddy	5200	26400	89200	500.58

Table 2: Values of crop wise Arbitrary Targets.

Arbitrary target value	Crop wise (Qi) (Rs)	Arbitrary target value	Crop wise (Qi) (Rs)
Q1	377000	Q6	1715000
Q2	8236220	Q7	1362523
Q3	1886063	Q8	2725000
Q4	1171000	Q9	2024514
Q5	994000	Q10	8988500

Table 3: Various expenditures on all types of Crops.

Crop Name	Ploughing	Seeds (kg)	Plantation	Labour	Fertilizers
Cotton	2950	2000	500	11000	8000
Mirchi	3000	5000	3000	4500	5500
Groundnut	3000	4000	4000	1000	3000
Jute	1500	400	500	1000	1000
Bengal Grams	1400	2000	700	2000	2900
Corn	3500	1900	1000	2700	10000
Black grams	1400	2000	500	2000	2900
Green grams	1400	2000	500	2000	3000
Red Grams	3000	2000	700	1500	15500
Paddy	5000	4000	1000	2000	5000
Total	26150	25300	12400	29700	56800

Crop Name	Water	Rent	Picking charges	Storage (1ql.)	Total
Cotton	2000	15000	1500	0	42950
Mirchi	3000	15000	2000	100	41100
Groundnut	1500	15000	3000	100	34600
Jute	0	15000	1500	0	20900
Bengal Grams	0	15000	3000	100	27100
Corn	2000	15000	2000	100	38200
Black grams	0	15000	3000	100	26900
Green grams	1000	15000	2000	100	27000
Red Grams	0	15000	2000	100	39800
Paddy	1000	20000	2000	100	40100
Total	10500	155000	22000	800	338650

Rent, Picking Charges and Storage; where j=1,2,....9. Cost per unit for i^{th} type of crop cultivated with j^{th} type of expenditure(C_{ij}) were given in the said matrix for i=1,2,...,m (m=10); j=1,2,...,n (n=9).

Data also considered the minimum requirement cost for i^{th} crop on all types of expenditure (T_i); the maximum affordable investment cost for i^{th} on all type of expenditure (P_i); the land availability for each crop (A_i), I=1,2,…,m in Table 2. Further we considered the data on revenue per kg, yield, Minimum Supportive Prize (kg), Market Competitive Prize (Kg) and Break Even Revenue and cost of all type of crops given in Table 1. The values of Table 2 related arbitrary constant related to model-II to model-III. While arriving to the data in Table 1, 2 and 3, the primary data has been collected from the farmers of different regions of Andhra Pradesh as well as data with agricultural colleges. Data is collected during the period (2010-15) yearly and arrived to the averages from the 5 year data.

RESULTS AND DISCUSSION

Results of Model-I:

From this result, we obtained the maximum profit of Rs. 39075930 for 10 types of crops with optimal crop area scheduling which is given in the Table 4.

Results of Model-II:

According to result of model-II, we achieved the target profit of Rs. 30979950 for 10 types of crops with optimal allocations land which is shown in the Table 5.

Table 4: Optimal Land allocation of Crops from the Model-I.

Crop Name	Acres of Land	Crop Name	Acres of Land
Paddy	390.5114	Corn	40.10989
Mirchi	214.1119	Black Grams	30.76923
Red Grams	188.4496	Jute	26.84564
Green Grams	61.90476	Bengal Grams	19.5572
Groundnut	45.20548	Cotton	9.144701

Table 5: Optimal Land allocation of Crops from the Model-II.

Crop Name	Acres of Land	Crop Name	Acres of Land
Paddy	390.5114	Corn	40.10989
Mirchi	214.1119	Black Grams	30.76913
Red Grams	188.4496	Jute	26.84564
Green Grams	61.90476	Bengal Grams	19.5572
Groundnut	45.20548	Cotton	9.144701

Table 6: Optimal Land allocation of Crops from the Model-III.

Crop Name	Acres of Land	Crop Name	Acres of Land
Paddy	351.4153	Corn	40.10007
Red Grams	188.4496	Black Grams	30.76923
Mirchi	185.8101	Jute	26.82212
Green Grams	61.90368	Bengal Grams	19.5572
Groundnut	45.20548	Cotton	9.119497

Results of Model-III:

We achieved all the target profit (Table 3.2) of all crops except Bengal grams crop which is deviated in under-achievement of Rs. 198921.8 to the target revenue. Optimal land allocations for different type of crops are shown in Table 6.

CONCLUSION

Agricultural development is a complex process of interaction between the physical input - output relations of the agricultural system and the social and economic milieu of the national economy in a dynamic equilibrium. Land use planning and irrigation are strategic planning exercise to assess the future potential of the agricultural sector and achieve accelerated growth through judicious management of land resources. From our model-I, there are 991.4586 acres of land for yield of crop in net return of Rs. 39075930 for optimal crop area scheduling are paddy (390.5114), mirchi (214.1119), red grams (188.4496), green grams (61.90476), groundnut (45.20548), corn (40.10989), black grams (30.76923), jute (26.84564), bengal grams (19.5572) and cotton (9.144701). From the model-II, it concludes that there are no changes in optimal crop area when we take single goal profit of Rs. 30979950 for overall crop. In the result of model-III we achieved the all target profit are cotton (377000), Mirchi (8236220), groundnut (1886063), jute (1171000), bengal grams (994000), corn (1715000), black grams (1362523), green grams (2725000), red grams (2024514) and paddy(8988500) with optimal land allocation are paddy (3351.4153), red grams (188.4496), mirchi (185.8101), green grams (61.90368), groundnut (45.20548), corn (40.10007), black grams (30.76923), jute (26.82212), bengal grams (19.5572) and cotton (9.119497).

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