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 types of expenditures like ploughing, seeds per kg, plantation, labour, fertilizers, water, rent, picking charges, storage per quintal, etc 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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How to cite this article: Padi, T.R., Paidipati, K.K. and Oram, M. (2020). Optimal Land Allocation Programming Problems for Agricultural Revenue Maximization in Andhra Pradesh. Agricultural Science Digest. 40(3): 275-279.
Submitted: 17-08-2019 Accepted: 15-01-2020 Published: 18-06-2020
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 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 optimal land allocation as a decision variable. Minimum supportive price, Market competitive price, Break even revenue, yield and break even cost and minimum investment costs with available area of each crop are given as constraints.

Max \( z = \sum_{i=1}^{m} R_i A_i \)

Subject to constraints

\[ R_i A_i \geq S_i Y_i, i = 1,2,\ldots, m \]
\[ R_i A_i \leq M_i Y_i, i = 1,2,\ldots, m \]
\[ R_i A_i \geq E_i Y_i, i = 1,2,\ldots, m, \quad E_i \geq S_i \]
\[ \sum_{i=1}^{m} C_i A_i \geq T_i, i = 1,2,\ldots, m, \quad \text{where } T_i = L_i A_i \]
\[ \sum_{i=1}^{m} C_i A_i \leq P_i, i = 1,2,\ldots, m, \quad \text{where } P_i = H_i A_i \]
\[ Y_i \geq B_i, i = 1,2,\ldots, m \]
\[ \sum_{i=1}^{m} A_i \leq D_i, i = 1,2,\ldots, m \]
\[ \sum_{i=1}^{m} A_i \geq A_i, i = 1,2,\ldots, m \]
and \( A_i \geq 0, \text{ where } i = 1,2,\ldots, m \)

**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.

Max \( z = d^+ \)

Subject to constraints

\[ R_i A_i \geq S_i Y_i, i = 1,2,\ldots, m \]
\[ R_i A_i \leq M_i Y_i, i = 1,2,\ldots, m \]
\[ R_i A_i \geq E_i Y_i, i = 1,2,\ldots, m, \quad E_i \geq S_i \]
\[ \sum_{i=1}^{m} C_i A_i \geq T_i, i = 1,2,\ldots, m, \quad \text{where } T_i = L_i A_i \]
\[ \sum_{i=1}^{m} C_i A_i \leq P_i, i = 1,2,\ldots, m, \quad \text{where } P_i = H_i A_i \]
\[ Y_i \geq B_i, i = 1,2,\ldots, m \]
\[ \sum_{i=1}^{m} A_i \leq D_i, i = 1,2,\ldots, m \]
\[ \sum_{i=1}^{m} A_i \geq A_i, i = 1,2,\ldots, m \]
and \( A_i \geq 0, \text{ where } i = 1,2,\ldots, m \)

**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 \( i = 1,2,3,\ldots, 10 \). 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                               | 18056              | 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       |

### Table 3: Various expenditures on all types of Crops.

| 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 | 15500| 22000           | 800           | 338650 |
Rent, Picking Charges and Storage; where \( j = 1,2,\ldots,9 \). Cost per unit for \( i \) type of crop cultivated with \( j \) type of expenditure \((C_{ij})\) were given in the said matrix for \( i=1,2,\ldots,m \) \((m=10); j=1,2,\ldots,n \) \((n=9)\).

Data also considered the minimum requirement cost for \( i \) crop on all types of expenditure \((T_i)\); the maximum affordable investment cost for \( i \) on all type of expenditure \((P_i)\); the land availability for each crop \((A_i)\), \( i=1,2,\ldots,m \) 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 | 30.76923     |
| 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), corn (45.20548), 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(6988500) 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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