Economic optimum crop planning for maximization of farm net income in central dry zone of Karnataka: An application of linear programming model

H. K. R .; V. Bellundagi; S.M. P. S.

UAS GKVK BENGALURU, DEPARTMENT OF AGRICULTURAL ECONOMICS, India

Corresponding author email: hmmshamsa@gmail.com

Abstract:

This study aimed to develop an optimum crop planning for maximization of farm net income in central dry zone of Karnataka by assessing scarce resources like land, labour, groundwater and capital availability. It evaluates the potential of the land resources for recommending optimum, sustainable and appropriate land utilization in agriculture development. The study used quantitative analytical approach using microsoft excel premium solver in optimal crop plan allocation analysis. A total of 90 structured questionnaires were used to gather data necessary for analysis. The Linear programming model with an objective function that seeks to maximize net farm income subject to land, labour, capital, groundwater and minimum area for production constraints was run. Linear programming technique indicated that, at market prices, as per the optimum crop plan, the area allocated for rainfed crops was about 1,03,100 ha and for borewell irrigated area it was 41,361 ha. According to Economic pricing criteria, 40,900 ha is to be allocated under borewell irrigated and 10,3673 ha for rainfed situation. Total optimum area allocated to different crops would be 14,4461 ha and 14,4574 ha which maximizes net returns at Rs. 185.1 crores and Rs. 73 crores at market prices and economic prices, respectively.

Acknowledgement: This study is part of my M.Sc work under the National Institute of Agricultural Economics and policy Research, Government of India.

JEL Codes: Q12, R14

#85

ECONOMIC OPTIMUM CROP PLANNING FOR MAXIMIZATION OF FARM NET INCOME IN CENTRAL DRY ZONE OF KARNATAKA : AN APPLICATION OF LINEAR PROGRAMMING MODEL

ABSTRACT

This study aimed to develop an optimum crop planning for maximization of farm net income in central dry zone of Karnataka by assessing scarce resources like land, labour, groundwater and capital availability. It evaluates the potential of the land resources for recommending optimum, sustainable and appropriate land utilization in agriculture development. The study used quantitative analytical approach using microsoft excel premium solver in optimal crop plan allocation analysis. A total of 90 structured questionnaires were used to gather data necessary for analysis. The Linear programming model with an objective function that seeks to maximize net farm income subject to land, labour, capital, groundwater and minimum area for production constraints was run. Linear programming technique indicated that, at market prices, as per the optimum crop plan, the area allocated for rainfed crops was about 1,03,100 ha and for borewell irrigated area it was 41,361 ha. According to Economic pricing criteria, 40,900 ha is to be allocated under borewell irrigated and 10,3673 ha for rainfed situation. Total optimum area allocated to different crops would be 14,4461 ha and 14,4574 ha which maximizes net returns at Rs. 185.1 crores and Rs. 73 crores at market prices and economic prices, respectively.

Keywords: Linear programming, optimum crop plan, land allocation, market prices, economic prices.

I. INTRODUCTION

Day-today growing population of world has increased the need for agricultural products and consequent increased pressure on utilization of resources that is required for those products. Agriculture continues to play an important role in the Indian economy as it supports 57 per cent of population. Agriculture and allied sectors contribute 17.8 per cent to the total GDP and employed 52 percent of the country's population. (NABARD, 2016).

In the wake of food shortages, food security was assigned top priority. Hence, result oriented strategy to achieve impressive growth in production has been the guiding principle which was preferred over suitability in terms of agro-economic factors and natural resource endowments. In the process, rice has spread to those areas where it was never cultivated before. Sugarcane has shifted from water abundant region to water stress regions. Price and marketing policies and input subsidies have distorted relative advantages for various crops in various regions over the natural choice crops. Consequently, policy options available for optimizing profitability of farmers have lacked objectivity and precision. Due to lack of proper crop planning, problems of soil and water degradation are aggravating. Thus the need for economic crop planning consistent with natural and economic endowments achieving resource use efficiency.

Water is a vital natural resource and its increasing scarcity influences efficient use, management and sustainability. Only 2.7 per cent of the global water is available as fresh water and the demand is increasing exponentially due to increasing population, rising demand for food, urbanization and industrialization. Agricultural activities are the main user of water from surface to ground water in rural areas. 80 per cent of irrigated agriculture in India is supported by groundwater (Rohith *et al.,* 2015). Groundwater accounts for more than 60 per cent of India's irrigated area (Gandhi and Namboodiri, 2009). In addition to rational water use, there is a need for selecting economically viable cropping patterns for a given area and available resources. Those cropping patterns can be attained through the use of optimization models.

Farm planning problems are much more complex. Farmers not only produce different crops but have to choose among a variety of ways of producing them. Crop planning may involve choices about varieties, planting dates, fertilizer and pesticide treatments. Linear programming (LP) has proved a very flexible tool for modeling these kinds of complexities (Hazell and Norton, 1986). Sustainable management and allocation in crop production plays vital role for economic growth and development. Hence the question of allocation and distribution of resources need to consider sustainability and optimization of crop plans across regions and production environments. This study is a modest attempt to find the optimum allocation of resources in central dry zone of Karnataka.

II. METHODOLOGY

a. Nature and sources of data

Random sampling technique was employed in the selection of farmers for the study based on major crops grown *i.e.,* field crops, commercial crops and other crops, nature of the crops grown that is water intensive or otherwise and also based on production and area under the irrigation of crops grown. Tumakuru district which comes under Central Dry of Karnataka (CDZ) was selected purposively because the major crops grown under irrigated condition were paddy, ragi, maize and groundnut and some of these crops are water intensive and more fertilizer responsive. Primary data were collected from the 90 sample farmers comprises of rainfed and borewell irrigated with 45 respondents in each group for the agricultural year 2013-14. Secondary data were collected from the District website and Directorate of Economics and Statistics (DES), Government of India for the year 2013-14.

b. Net returns according to market prices

The cost of cultivation according to market prices considers the subsidy on inputs such as fertilizers and water. Thus, the energy used for pumping irrigation water is also subsidized by the State. Thus, these are the two major inputs provided by the state/centre. The net returns according to market prices are then calculated by deducting cost A_1 plus imputed value of family labour from the gross returns. It is obvious that the net returns according to market prices includes subsidy on nutrients and energy for pumping irrigation water.

c. Net returns according to economic prices

The net returns according to economic prices include the value of fertilizer subsidy[1] as a cost. And, in the case of borewell irrigated crops, the net returns according to economic prices, includes the pumping expenditure as irrigation subsidy.

---

[1] Provided by National Institute for Agricultural Economics and Policy research, IARI, New Delhi that the subsidy per kg of N_2 = Rs. 20.87; that per kg of P_2O_5 =Rs. 18.67; per kg of K_2O = Rs. 15.50.

Estimation of subsidy on irrigation water

Considering water for irrigation, in case of groundwater irrigation, the subsidy is in terms of pumping cost. This pumping cost subsidy is estimated as equal to the number of pump hours for each crop X HP of the pump X 0.75 X Rs. 3.5. Here, if a pump of 1 HP capacity is run for one hour, then it consumes the energy equal to 0.75 KWH. At present, the cost of one KWH is Rs. 3.5.

Linear Programming

In linear programming analysis, the linear function of a number of variables (objective function) is maximized (or minimized) subjected to number of constraints in the form of linear equalities or in-equalities. In this study it was employed to develop the optimum regional crop plan at two levels of net returns namely net returns at market prices and net returns at economic prices using solver in excel. The activities considered for developing the optimum crop plan at two levels of net returns were identical in CDZ of Karnataka. Where the activities considered were area under rainfed condition, area under borewell irrigation, labour availability, variable capital requirement for cultivation of crops, groundwater available for agriculture, area under food crops namely paddy, maize, ragi and groundnut as minimum food consumption requirement.

A. Selection of the typical farm

The average area under different crops (ha), labour utilization (man-days), water applied to crops (acre inch), capital expenditure (Rs.) excluding labour cost incurred and net returns realized by farmers with borewell irrigation and rainfed were calculated and used for development of the optimum regional crop plan. The computational procedure is as follows

1. **Mathematical formulation of model**

In mathematical form, one year linear program can be expressed in the following way**.**

Maximize $Z = \sum_{i=1}^{n} N_i X_i$ for i=1, 2, 3, 4 ….N is the number of crops

Subject to the constraints,

1. $\sum_{i=1}^{n} W_i X_i \leq W_u$(i=1, 2, 3, 4 ….N)

2. $\sum_{i=1}^{n} X_i \leq I$(i=1, 2, 3, 4………N)

3. $\sum_{i=1}^{n} X_i \leq R$(i=1, 2, 3, 4………N)

4. $\sum_{i=1}^{n} X_i \geq F_i$(i=1, 2, 3, 4……....N)

5. $\sum_{i=1}^{n} D_i X_i \leq L$(i=1, 2, 3, 4…..…N)

6. $\sum_{i=1}^{n} T_i X_i \leq B$(i=1, 2, 3, 4…….N)

7. $X_i \geq 0$

Where,

Z =Total net return (Rs.) from all crops grown by the farmer

Ni =Net return from the i^{th} crop (Rs./ha)

Xi =Crop area under i^{th} crop (ha) (decision variable)

Wi =Water requirement for i^{th} crop (ha cm)

Wu = Total ground water availability (ha cm)

I= Borewell area availability for cultivation in the region (ha)

R= Rainfed area availability for cultivation in the region (ha)

Fi= Food requirement of i^{th} crop in terms of area (ha)

Di = Labour requirement for i^{th} crop (mandays/ha)

L =Total Agricultural labour availability per year in the region (district)

Ti = variable capital required to produce i^{th} crop (Rs./ha)

B = Total budget availability of the farmers in the region (Rs.) or total cost of production per hectare of all crops multiplied with area under all crops.

2. Objective function

Objective function was to maximize aggregate net income from crops grown in the Tumukuru district, CDZ of Karnataka. The objective function was subjected to linearity and non-negativity constraints.

3. Resource level and constraints for Tumukuru district

(i) Ground water availability

The total ground water availability for Tumakuru district was taken from the central ground water board as equal to 96,352.03 ha metres which was converted in to acre inch by taking conversion factor of 1 hectare meter = 97.28 acre inches which is equal to 93,75,052 acre inches per year for the district.

(ii) Land area

Land area availability and utilization: Land is one of the limiting resources on all farm situations. It is defined as operational area, which was equal to owned-land plus leased-in land minus leased-out land. The average size of operational holding was 2.48 ha (rainfed farmers), 2.69 ha (borewell irrigated farmers) from the data collected. The total area under rainfed cultivation in Tumakuru district was 4,64,800 ha and 1,20,790 ha was under irrigation.

(iii) Minimum area for production

Paddy is one of the important food grain crop under bore well irrigated condition. Whereas, maize is the cereal crop grown under both rainfed and bore well irrigated conditions. Groundnut was the important oilseed crop grown under both rainfed and bore well irrigated conditions. Rainfed ragi was not considered for optimum crop planning because of negative net returns at market prices. Bore well irrigated ragi was considered for optimum crop planning as an important staple food crop. Paddy, ragi, maize and groundnut were taken as fixed constraints equal to or more than the existing area under crop in the last year from DES data to fulfill the demand for food grains and pulses to the increasing population.

(iv) Agricultural labour availability

The labour availability for agriculture work was 3,52,286 man days as per the district data 2014, multiplied with 180 days (Average working days of agricultural labour per year). The total agricultural labour availability was 6,34,11,480 days per year.

(v) Working capital /budget availability

To calculate capital use on the farm, the costs of seed, manures, fertilizers, pesticides, insecticides, hiring of bullocks and machinery, irrigation charges, etc. were added up and the cash requirements for rainfed, borewell irrigated farms were worked out separately. For estimating capital availability on the farm, it was assumed that the expenditure incurred on variable inputs was taken as per data collected from sample farmers from the respective crops and multiplied with the existing area of sample data which gives total capital availability to the entire district, which was Rs. 482.96 crores.

(vi) Non-negativity constraints:

The variables in the linear programs must be greater than or equal to zero and the returns or inputs should not be negative.

$$X_i \geq 0$$

III. RESULTS AND DISCUSSION

Regional crop plan for central dry zone considering net returns at market prices and economic prices, 2014

The major crops cultivated in CDZ and the activities considered for regional crop plan were constrained and subjected to linear programming in order to obtain the economic optimum cropping plan at two levels namely, market prices and economic prices. The activities considered for the regional crop plan at two levels (Table 1) and allocation of the area for different crops according to the two regional crop plans (Table 2).

The results indicated that, regional crop plan at market prices considers the net returns at market prices and allocated 1,44,461 ha as optimum crop area, out of which 41,361 ha area has to be under borewell irrigation and 1,03,100 ha should be under rainfed cultivation. The area allocated for rainfed crops was two-and-a-half times higher than the area allocated for borewell irrigated crops. When market prices were considered, the economic optimal crop plan allocated land for rainfed maize, rainfed groundnut, borewell irrigated paddy, borewell irrigated ragi and borewell irrigated maize. The optimum area allocated for rainfed maize and groundnut were, 9,900 ha and 93,200 ha, respectively. Remarkably area allocated to borewell paddy in the optimal crop pattern has increased compared to the existing plan. The area allocated for borewell irrigated groundnut did not increase since the crop is a major rainfed crop in Tumakuru district. By adopting the proposed optimal crop plan, the estimated net returns from crop production in Tumakuru district would be about Rs. 185 crores (Table 1) and the average maximized net returns per hectare would be Rs. 12,815.

The Regional crop plan at economic prices considered 1,44,574 ha as optimum cropped area, out of which 40,900 ha has to be under borewell irrigation and 1,03,673 ha needs to be under rainfed cultivation. Allocation of area following economic prices criterion also allocated two-and-a-half time higher area for rainfed crops when compared to borewell irrigated crops. Under economic prices criterion optimal crop plan included allocation of area for maize and groundnut crops under rainfed condition and paddy, ragi and maize crops under borewell irrigated condition. The existing crops of paddy, ragi, maize and groundnut were considered to be compulsorily included since they are major food crops (Table 2). The optimum area allocated for the rainfed crops maize and groundnut is 10,474 ha and 93,200 ha, respectively. The area under borewell irrigated paddy was less and area under borewell rainfed maize was more as compared to the allocation made with market price criterion. The optimum crop plan under economic prices criterion did not allocate any area for borewell irrigated groundnut. With this proposed optimum crop plan, the net returns are expected to be maximised at Rs. 73 crores (Table 1). Thus, the net returns at economic prices would be less by around 40 per cent when compared to net returns under market price criterion, and the average maximized net returns per hectare would be Rs. 5,083.

IV. CONCLUSION AND POLICY IMPLICATIONS

The market prices subsume subsidies on inputs such as fertilizers. At market prices, as per the optimum crop plan, the area allocated for rainfed crops was about 1,03,100 ha and for borewell irrigated area was 41,361 ha. The total area allocated under different crops in Tumakuru district was about 1,44,461 ha. This optimum crop plan would maximize the net returns at Rs. 185.1 crores at market prices and average net private benefit per hectare at 12,815 rupees.

At economic prices, exclusion of subsidies from net returns realised at market prices, the total area allocated to different crops was 1,44,574 ha, out of which 1,03,673 ha area was under rainfed cultivation and under borewell irrigation 40,900 ha were allocated. Above allocation of the crops, would maximize the net returns at Rs. 73.0 crores, where this net return is devoid of distortion of subsidies and the average returns per hectare at economic prices was Rs. 5,083.

Thus, the net returns at economic prices would be less by around 40 per cent when compared with the net returns under market price criterion. Policy makers can make use of the optimum crop plan developed to restrict the production of output which faces the problem of recurrent production and over production through support schemes and other fiscal incentives or disincentives.

V. REFERENCES

Anonymous, 2016, https://www.nabard.org/ Accessed on 2017.

Gandhi, V. P. and Namboodiri, N. V., 2009, Groundwater irrigation in India: Gains, costs and risks, *Indian Institute of Management,* Ahmedabad, W. P. No. 2009-03-08.

Hazell, P. B. R. and Norton, R. D., 1986, Mathematical programming for economic analysis in agriculture. *New York: Macmillan Publishing Company.*

Majeke, F., 2013, Optimum combination of crop farm enterprises: A case study of a small-scale farm in Maronderea, Zimbabwe. *International Researchers.* **2** (1) : 60-65

Rohith, G. V., Rashmi, K. S., Hamsa, K. R., Divya Lekshmi, U., Rajeshwari, D., Manjunatha, A. V., Rashmi, N. and Jagannath Olekar, 2015, Incorporating cost of irrigation water in the currently underestimated cost of cultivation: An empirical treatise. *Indian Journal of Agricultural Economics,* **70** (3).

Table 1. Regional crop planning for central dry zone considering inputs and outputs at market prices and economic prices, 2014

Regional crop plan activities	Constraints	Right hand side value	Optimum allocation of activities	
			Market prices	Economic prices
Borewell irrigated area (ha)	=	120790	41361	40900
Rainfed area (ha)	≥	464800	103100	103673
Total agricultural labor availability (mandays)	≤	63411480	7027475	7033067
Variable capital (Rs.)	≤	4829573700	4829573700	4829573700
Ground water availability (acre inches)	≤	9375053	3517921	3472350
Maize (RF)	≥	9900	9900	10474
Groundnut (RF)	≥	93200	93200	93200
Paddy (BI)	≥	33100	33561	33100
Ragi (BI)	≥	7600	7600	7600
Maize (BI)	≥	200	200	200
Total area of the regional crop plan (ha)			144461	144574
Net returns realized from above allocation (Rs.)			1851281022	735003566

NOTE: BI = Borewell irrigated ; RF= Rainf

Table 2. Regional crop plan for different crops under central dry zone using resource use efficiency and sustainability, 2014

Source of irrigation	Crop	Net returns (Rs./ha)		Area under crop 2013-14	Regional optimum crop plan area (ha)	
		Market prices	Economic prices		Market prices	Economic prices
Rainfed	Maize	11570	7086	9900	9900	10474
Borewell	Maize	31405	22560	200	200	200
Borewell	Paddy	34091	17278	33100	33561	33100
Borewell	Ragi	13552	6822	7600	7600	7600
Rainfed	Groundnut	5186	349	93200	93200	93200
Borewell	Groundnut	17131	9363	6400	NA	NA
Total allocated Area (ha)				150400	144461	144574
Total net returns from above allocation (Rs.)					1851281022	735003566
Average Net returns per ha (Rs.)					12815(NPB)	5083

NOTE: NA= Not allocated; NPB= Net Private Benefit