

Use of Linear Programming Model to Determine the Optimum Cropping Pattern, Production and Income Level: A Case Study from Dera Ghazi Khan Division

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ABSTRACT

Linear Programming model was applied to calculate the crop acreage, production and income of the Dera Ghazi Khan Division of Punjab province. The study was conducted on 3913 thousand acres of the irrigated areas from the four districts. Crop included were wheat, Basmati rice, IRRI rice, cotton and sugar cane. The results showed that cotton was the only crop which gained acreage by about 10% at the expense of all other crops. Overall optimal crop acreage decreased by 1.64% while the income increased by 2.91% as compared to the existing situations.

Key Words: Linear Programming; Optimal solution; Cropping pattern; Gross margin

INTRODUCTION

Pakistan's agriculture has four sub-sectors. Crops and livestock sectors are notable contributing 64.4 and 34.4% of the value added, respectively. The other two sectors are fishery and forest sectors, which contribute only 0.67 and 0.47%, respectively (Malik *et al.*, 1994).

The province of Punjab accounts for about 73.4% of Pakistan's agriculture both in terms of cropped acreage and income originating from the crop sector. Over 95% of agricultural income comes from the irrigated areas of Pakistan. Out of this 73% is contributed by the irrigated areas of the Punjab, while irrigated areas of D.G. Khan contribute just 13.05% (Government of Pakistan, 2000).

The province of the Punjab comprises four distinct crop zones. In the north lies the rain fed area, next to it is the rice zone, in the centre is the mixed crop zone where sugarcane and maize dominate, while the southern part comprises the cotton zone (Ahmad *et al.*, 1994).

In the past, agriculture was improved through input and credit supply and their subsidization, price fixation, procurement, crop zoning, rural infrastructure. No doubt good results were achieved but only part of the real potential of agriculture was realized. Many of the development instruments, however, have been exhausted, withdrawn and/or have little relevance or potential in the times ahead.

The most decisive option would comprise selection of optimum cropping patterns as a pre-requisite to efficient utilization of available resources of land, water and capitals. This has never been done in the past for Pakistan's agriculture. Farmer's profit cannot be maximized without optimum cropping patterns, which ensure efficient

utilization of available resources. The main objectives of the study were i) to develop optimal cropping pattern and production for the D.G. Khan Division and ii) to assess the farmer's income level under optimal cropping pattern and its comparison with the existing income level.

METHODOLOGY

The study was carried out in whole of the D.G. Khan Division. The study was conducted on 3913 thousands acres which roughly accounted for more than 82% of irrigated area of the D.G. Khan Division. The data used in the study aggregate farm resources availability in the D.G. Khan Division, relative profitability and input-output, coefficients of various crop activities. Linear Programming Model of the following form was used.

Mathematical presentation of the model. The objective of the model was to maximize total net income (gross margin). Algebraically the model is summarized below:

Basic assumptions

- All producers in a Division are having only the choice to produce certain product mixes.
- All producers in a Division have identical input – output coefficients.
- Total production of various commodities is limited by the resources availability in the Division.
- An acre of production can be substituted for an acre of other type of production.
- The economic objective of the producer is to maximize profit, i.e. gross margin.
- The production period is agricultural calendar year.

- (g) Crops covering up-to 2% or above of the total cropped area would be included in the optimal solutions.
- (h) Farm labor supply does not pose limitation on crop production.
- (i) Maximum and minimum area in optimal solution has been assumed not more than 1.1 and not less than 0.9 times respectively of the existing area under crops.

The model. Linear programming model of the following form was used as an analytical tool to explore the possibilities of optimizing farm returns.

The objective function was to maximize profit, where

$$Y = \sum_{i=1}^m \sum_{J=1}^n C_{ij} X_{ij}$$

Subject to the following constraints

Kharif land availability.

$$\sum_{J=1}^n a_{ij} X_{ij} \leq SL_i \text{ for all } i$$

Rabi land availability.

$$\sum_{J=1}^n a_{ij} X_{ij} \leq WL_i \text{ for all } i$$

Water availability.

$$\sum_{J=1}^n W_{ijg} X_{ij} \leq W_{ig} \text{ for all } i \text{ and } g$$

Capital availability.

$$\sum_{J=1}^n K_{jj} X_{ij} \leq K_i \text{ for all } i$$

Maximum acreage constraint.

$$\sum_{i=1}^m a_{iJ} X_j \leq Max_j \text{ for all } i \text{ and } J$$

Minimum acreage constraint.

$$\sum_{i=1}^m a_{iJ} X_j \geq Min_j \text{ for all } i \text{ and } J$$

Non-negativity constraints.

$$X_{ij} \geq 0$$

Where Y = Gross margin i.e. gross income - variable cost
 C_{ij} = Gross margin from J-th activity in the i-th districts.

i = 1, D.G. Khan District

i = 2, Rajanpur District

i = 3, Layyah District

i = 4, Muzaffargarh District

J = 1, wheat

J = 2, Basmati Rice

J = 3, IRRI Rice

J = 4, Cotton

J = 5, Sugarcane

X_{ij} = Level of J-th activity in the i-th district

a_{ij} = Amount of land needed per unit of J-th activity in the i-th district

SL_i = Amount of land available during the kharif season in the i-th district

WL_i = Amount of land available during the Rabi season in the i-th district

w_{ijg} = Quantity of water required per unit of j-th activities in the i-th district during the g-th month

g = 1, January

g = 2, February

g = 3, March

g = 4, April

g = 5, May

g = 6, June

g = 7, July

g = 8, August

g = 9, September

g = 10, October

g = 11, November

g = 12, December

X_{ijg} = Level of J-th activity in the i-th district during the g-th month

W_{ig} = Total amount of water available in the i-th district during the g-th month.

k_{ij} = Amount of capital required for the J-th activity in the i-th district

K_i = Total amount of capital available in the i-th district

X_j = Level of j-th activity

Max_j = Maximum level of j-th activity

Min_j = Minimum level of j-th activity

RESULTS AND DISCUSSION

Optimal solutions. Optimal cropping pattern resulting from the gross margin driven LP model in comparison to the existing cropping patterns for D. G. Khan Division are presented in Table I. It was noted that cotton gained about 10% additional area at the expense of all other crops Wheat lost its acreage by 8%, Basmati rice by 9.10%, IRRI by 10% and sugar cane by 9.42%. On the whole optimal cropped acreage decreased by 1.64% as compared to the existing situation.

Table I. Comparison of Cropping Pattern under Optimal Solutions with Existing Condition

Crops	Existing(000 acres)	Optimal solutions (000 acres)	% of Existing
Wheat	2269	2087	91.98
Basmati Rice	22	20	90.90
IRRI Rice	130	117	90.0
Cotton	1407	1548	110.02
Sugar Cane	85	77	90.58
Total	3913	3849	98.36

Table II. Comparison of Crop Production under Optimal Solutions with Existing Condition

Crops	Existing (000 maund)	Optimal solutions (000 maund)	% of Existing
Wheat	57814.1	53176.8	91.97
Basmati Rice	398.2	362	90.90
IRRI Rice	5460	4914	90.0
Cotton	25762.17	28343.88	110.02
Sugar Cane	53230.7	23055.34	90.58

Table III. Comparison of Income Level under Optimal Solutions with Existing Condition

Existing Income Rs. Billion	Optimal solutions Rs. Billion	% of Existing
14.862	15.295	102.91

Optimal production levels as compared to the existing ones are presented in Table II. The results show that production of various crops in the D.G. Khan Division generally behaved in the order of acreage variations discussed above.

As a result of optimal solution farmer's income was increased by Rs. 0.433 billion in the D.G. Khan Division. Optimal income increased from existing level of Rs.14.62 billions to Rs. 15.295 billion showing an improvement of 2.91%. The optimal income level as compared to the existing one is presented in Table III. The results show that the LP model suggestions are worth-exercising. These results are in line with those of Saini, (1975), Radhakrishnan and Sivandhran, (1975), Jolayemi and Olaomi, (1995), Neto *et al.* (1997) and Carvalho *et al.* (2000). They found that the optimal solution increased income.

CONCLUSION

D.G. Khan Division is more or less operating at the optimal level. Cotton was the only crop which, gained acreage. As a result of optimal cropping pattern, farm income increased by 2.91%.

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