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Use of Linear Programming Model to Determine Optimum Cropping Pattern in Bahawalpur, Punjab, Pakistan

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Abstract

The study was carried out in the three districts of the Bahawalpur (B. pur). These three districts were collected by purposive sampling technique. Linear Programming Model was applied to calculate the crop acreage, production and income of the cotton zone. The study was conducted on 4652 thousand acres of the irrigated areas from the three districts. Crops included in the model were wheat, basmati rice, IRRI rice, cotton and sugar cane. The results showed that the cotton was the only crop, which gained acreage by about 10 % at the expense of all other crops. Overall optimal crop acreage decreased by 1.76 % while, optimal income was increased by 3.28 % as compared to the existing solutions. The present study reports that B. pur division is more or less operating at the optimal level. The cotton was the only crop which, gained acreage. As a result of optimal cropping pattern, the farm income increased by 3.28 percent.

Key Words: Linear Programming, Optimal Solution, Cropping Pattern, Gross Margin.

Introduction

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

The province of the Punjab accounts for about 73.4% of Pakistan's Agriculture both in terms of cropped acreage and income originating from the crop sector, respectively. Over 95% of agriculture income comes from the irrigated areas of Pakistan, of which 73% is contributed by the irrigated areas of the Punjab, while irrigated areas of Bahawalpur (B. pur) Division contributes about 20% income of the Punjab (Agriculture census, 2000 and Agriculture Statistics, 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 houses 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, etc. No doubt good results were achieved but only part of the real potential of agriculture has been realized. Many of 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 capital. 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 was to develop linear programming model which would give optimal cropping pattern, maximize income from crop production and see the effects of additional capital on cropping pattern and income of the farmers.

Methods and Procedures

The study was carried out in the three districts of the B. pur. These three districts were collected by purposive sampling technique. The study was conducted on 4652 thousands acres which roughly accounts for more than 82% of irrigated area of the B. pur of the cropping year 2004 - 05. The data used in the study aggregate farm resources availability in the B. pur. Relative profitability and input-output, coefficients of various crop activities. We have used Linear Programming Model of the following forms.

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:

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

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f. The production period is agricultural calendar year.
g. Crops covering upto 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 will be used as an analytical tool to explore the possibilities of optimizing farm returns.

The objective function is 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:

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

Capital Availability:

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

Maximum Acreage Constraint:

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

Minimum Acreage Constraint:

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

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, B. Pur District
i = 2, B. Nagar District
i = 3, Rahimyar Khan 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_i = Minimum level of j-th activity

Results and Discussion

Optimal cropping pattern resulting from the application of LP model in comparison to the existing cropping patterns for B. pur division are presented in Table 1.

In the B. pur division, cotton gained area by about 10% at the expense of all other crops, which lost acreage by a margin of 9% to 11%. Wheat lost acreage by a margin of 10.02 percent, Basmati rice by 10.07 percent, IRRI by 10.26 percent, Sugar cane 9.41 percent. Over all optimal cropped acreage decreased by 1.76 percent as compared to the existing solution.

Table 1: Comparison of Cropping Pattern under Optimal Solutions with Existing Condition

Crops	Existing (000 acres)	Optimal solutions (000 acres)	% of Existing
Wheat	2356	2120	89.98
Basmati Rice	159	143	89.93
IRRI Rice	39	35	89.74
Cotton	1959	2147	109.60
Sugar Cane	139	125	90.59
Total	4652	4570	98.24

Optimal production levels as compared to the existing ones are presented in Table 2. The results show that production of various crops in the Bahwalpur division generally behaved in the order of acreage variations discussed above.

Optimal income (gross margin) was up by 0.731 billion in the B. pur division. Optimal income increased from existing level of Rs. 22.260 billions to Rs. 22.991 billion showing an improvement of 3.28 percent. The optimal income level as compared to the existing one is presented in Table 3. The results, therefore, plead that the LP model suggestions are worth trying. The results of this study are in lined with the results of the studies conducted by Saini, 1975. Radhakrishnan and Sivandhram, 1975. Bajwa, 1978. Jolayemi and Olaomi, 1995. Neto *et al*., 1997 and Carvalho *et al*., 2000. They found that the optimal solution increased the income.

Table 2: Comparison of Crop Production under Optimal Solutions with Existing Condition

Crops	Existing (000 maund)	Optimal solutions (000 maund)	% of Existing
Wheat	64742.9	58257.6	89.98
Basmati Rice	2877.9	2588.3	89.93
IRRI Rice	1423.5	1277.5	89.74
Cotton	39571.8	43369.4	109.59
Sugar Cane	53230.05	47868.75	89.92

Table 3: Comparison of Income Level under Optimal Solutions with Existing Condition

Existing Income Rs. Billion	Optimal solutions Rs. Billion	% of Existing
22.260	22.991	103.28

In conclusion the study reports that B. pur division is more or less operating at the optimal level. The cotton was the only crop which, gained acreage. As a result of optimal cropping pattern, the farm income increased by 3.28 percent.

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