APPLICATION OF LINEAR PROGRAMMING MODEL TO ASSESS THE OPTIMUM CROPPING PATTERN FOR MIXED CROPPING ZONE OF SEMI-ARID AREA

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ABSTRACT: Linear programming model is deemed a pragmatic approach for the estimation of crop acreage, productivity and profit. An investigation was carried out to assess the optimum cropping pattern of mixed cropping zone of Punjab, Pakistan during year 2011. After collection of data, 180 farmers were categorized into three main categories according to the land holding i.e. small land holders (< 5 acre), medium land holders (>5 or ≤10 acre), and large land holders (>10 acre). Optimal solution after the study depicted that if a farmer increased the wheat, cotton and maize area and decreased the area of rice, sugarcane, Rabi and Kharif fodder then he might obtain more profit in contrast to existing cropping pattern. Linear programming model suggested an increase of 1.04%, 1.10 and 1.07% profit over existing cropping pattern. It may be concluded that, profit can be enhanced by increasing area under wheat, cotton and maize and decreasing the area under rice, sugarcane, Rabi and Kharif fodders. Moreover, profit margins, productivity and sustainability of cropping system can be achieved by using resource saving techniques like direct seeding of rice, zero tillage of wheat and inclusion of green manuring crops.

Keywords: Linear programming model, Mixed cropping zone, Punjab, small, Medium and larger farmer.

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INTRODUCTION

Agriculture is the backbone of Pakistan's economy. It contributes 18.9 % in GDP and provides approximately 42.3% employments to the people (Govt. of Pakistan, 2018. In Pakistan, wide gap exists between actual yield and potential yield (Khan, 2004). This yield wide gap in yield is ascribed to numerous factors. Therefore, recurrent gaps in potential and actual yield under similar environmental conditions necessitates the quantitative analysis of factors that causes yield decline. Consequences of site-specific analysis will govern the type and magnitude of variations responsible for yields gap (Ubando *et al.,* 2016). In this perspective, the modeling can assist the farmers through prediction of weather, determining the influential changes in policies and assessing the risks associated with any given cropping pattern (Simic and Branka, 2013). Whereas, most of the research work provided information on the land utilization and allocation of crops in past. The Agriculture land use (AGLU) model was developed to assess the global land-use change and the extent of carbon emission (Saranwong and Likasiri, 2017). Although, linear programming is also extensively utilized around the globe. Accordingly, it is used in vast areas of research *e.g.* investment, mechanized transportation, blending, scheduling, nutritional problems, advertising media selection and feed choice. Henceforth, from 1960s to mid-1980s linear programming model was widely studied and used for farm planning (Zhang *et al.,* 2014). Likewise, the potential use of linear programming model was evaluated to sustain agricultural resources and planning problems. It is the process in which various linear variations are taken into consideration relating to some situation and calculates the "best" value obtainable under those circumstances (Liu *et al.*, 2016). Contrarily, limited numbers of models are available to optimize cropping pattern of an area. Linear programming model possesses the capability to calculate the crop acreage, production and income (Magrama, 2014). A study was conducted to estimate validity of linear programming model. Crops included in the model were cotton, wheat, maize, basmati rice, IRRI rice, potato and sugar cane. The experimental results manifested that the cotton, maize and wheat acreage was enhanced by about 5-10%, while Basmati rice, IRRI rice, sugarcane and potato depicted decline in acreage. Overall optimal crop acreage was increased by 1.88% while, optimal income was enhanced by around 2% as compared to the existing solutions. Moreover, income, crop acreage and production of wheat, cotton, basmati rice, IRRI rice and sugar cane was estimated using linear programming model. It was determined that linear programming model was more or less effective at the optimal level. Hence, linear programming model can be utilized to determine feasible cropping systems for mixed cropping systems to optimize resource use and benefits (Tavallali and Karimi, 2014). A little enhancement in benefit cost ratio was obvious using linear programing model when mode was utilized to collect data. While, significant changes were evident during cropping patterns in optimal solution over the actual one (Sahebi *et al.*, 2014). In another experiment, linear programming model was evaluated for determination of optimal farm plans for small farmers. Constraints used in this model were capital, land and per month supply of canal water. The model devised optimal cropping pattern solution raised the farm income by 2.2% (Tavallali *et al.*, 2014).

The main objectives of the study were: (i) To determine the optimum cropping pattern for Faisalabad region (ii) To maximize the profits of farmer using optimum cropping pattern of Faisalabad and compare with farmer's profit from existing cropping pattern (iii) To enhance sustainability, decrease environmental pollution, optimize resource utilization and thus enhance net benefits.

MATERIALS AND METHODS

Representative samples of 180 farmers were selected for collection of primary information from selected tehsils (Faisalabad, Sumundari, Jaranwala, Tandalanwala and ChakJhumra) of district Faisalabad, Punjab, Pakistan. In order to suggest the optimum cropping pattern, data regarding the farm size, inputs, procedure used for crop production, machinery use, quality of water, method of irrigation and harvesting of crops was collected from the diverse groups of farmers. The farmers were further classified into three categories.

→ **Small land holders:** The farmers who owned less than or equal to 5-hectare land were included in this category. Data was collected from 87 farmers. In Pakistan, majority of the farmers have small land holdings (70,000) due to feudalism and division of heirship. Therefore, optimum cropping pattern has been suggested for small lad holders through the use of linear programming model. Thus, a small farmer can optimize resource utilization employing this optimum cropping pattern.

→ **Medium land holders:** Medium land holders were comprised of farmers whose land holding was greater than 5 hectares and less than or equal to 10 hectares. In the current study, 61 medium land holders were included. By applying the linear programming model optimum cropping pattern has been put forwarded for the medium land holders.

→ **Large land holders:** Farmers having greater than 10 hectares were categorized as large land holders. In Pakistan, this category represents few numbers of farmers. Category of large land holders was comprised of only 32 farmers. With the help of linear programming method, optimum cropping pattern has been proposed for large land holders.

Data entry: The questionnaires were edited every day before moving on to the next day. In this way, a best quality data was recorded. A format was developed on the Microsoft Excel work sheet in order to ensure precise data entry. Moreover, it was also pre-requisite to convert data recorded in different units in the questionnaire to standard units prior to entering in the database. All the data were carefully entered for final analysis.

Unit conversion: After entering the data into the Excel work sheets the units were converted, such as farm size, owner area, rent in and rent out area. Data were converted into hectare before analysis.

Cleaning and organization of data: Cleaning is an integral component of the data management process before using it in the final analysis. The entered data were checked for errors or wrong entries, missing values and zeros. Errors identified during examination of data were immediately corrected. The data were also examined cell by cell to detect any error or omission. Tables were formed for all variables and examined for outliers, errors in coding, as well as other errors. Variables with such errors were sorted and the case number identified and doubtful cases were verified by cross-checking with the questionnaire. Subsequently, each data file was critically examined by individual row or column to identify any error across variables or within a variable.

Assumption of linear programming model: Assumptions of the model are given below

1. The major aim of a grower is to maximize profit on sustained basis.
2. All the growers have similar input-output coefficients.
3. Production in a given area can be replaced by another profitable commodity.
4. Resources impose limitations on the supply of commodities i.e. the supply of a commodity can be stopped in case of scarce resources.
5. Each unit production of output requires a unit if input while given output can be produced with more than one unit of input.
6. Output production follows constant return function. With each unit increment in input enterprises, increase in output will be linear.
7. Agriculture market is highly competitive.
8. It is assumed that the value of decision variable will always be non-negative. There should be a non-zero right hand side coefficient with at least one constraint.
9. The activities are supposed to be additive.
10. Producers have only choice to produce crops.

The model: With the help of linear programming model formulation of the equilibrium solution of any specific area is possible. Linear programming provides numerical solution of the problem and provides the results in linear form. For the crops this technique provides planning and programming to get

1. Maximum utility
2. Maximum profit
3. Minimum cost

The objective of this study was to maximize the profit of the farmer's community. Main objective function is given below;

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

Whereas:

C_{ij} = Gross margin from J-th activity in the i-th zone; X_{IJ} = Level of J-th activity in the i-th region; i = 1, Tehsil Faisalabad; i = 2, Tehsil Samundari; i = 3 Tehsil Jaranwala; i= 4 Tehsil Tandlianwala; i = 5 Tehsil ChakJhumra; j = 1 Cotton; j = 2 Rice; j = 3 Sugarcane; j = 4 Maize; j = 5 Wheat; j = 6 Kharif fodder; j = 7 Rabi fodder

There are many agronomic, physiological, management and socio-economic factors which are responsible for low yield in Pakistan. Following constraints of linear programming model, it is used as the analytical tool for optimizing the cropping pattern in the given region.

Kharif land availability constrain

$$\sum_{j=1}^{n} (a_{ij} X_{ij}) \leq KL_i Max_i \text{ For all i}$$

Whereas:

a_{ij} = Amount of land needed per unit of J-th activity in the i-th region; X_{IJ} = Level of J-th activity in the i-th region; KL_i = Amount of land available during the kharif season in the i-th region; Max_i = Maximum level of i-th activity.

Rabi and availability constrain

$$\sum_{j=1}^{n} (a_{ij} X_{ij}) \leq RL_i \quad Max_i \text{ For all i}$$

Whereas:

a_{ij} = Amount of land needed per unit of J-th activity in the i-th region; X_{IJ} = Level of J-th activity in the i-th region; RL_i = Amount of land available during the rabi season in the i-th region; Max_i = Maximum level of i-th activity

Water availability constrain

$$\sum_{j=1}^{n} (w_{ij} X_{ij}) \leq TW_i \text{ For all i}$$

Whereas:

w_{ij} = Quantity of water required per unit of j-th activities in the i-th region; X_{IJ} = Level of J-th activity in the i-th region; TW_i =Total amount of water available in the i-th zone during the g-th month

Capital availability constrain

$$\sum_{j=1}^{n} (K_{ij} X_{ij}) \leq K_i \text{ For all i}$$

Whereas:

K_{ij} =Amount of capital required for the J-th activity in the i-th region; X_{IJ} = Level of J-th activity in the i-th region; K_i =Total amount of capital available in the i-th region.

Maximum acreage constrains

$$\sum_{j=1}^{n} (a_{ij} X_{ij}) \leq Max_i \text{ For all i and j}$$

Whereas:

a_{ij} = Amount of land needed per unit of J-th activity in the i-th region; X_{IJ} = Level of J-th activity in the i-th region; Max_i = Maximum level of i-th activity

Minimum acreage constrains

$$\sum_{j=1}^{n} (a_{ij} X_{ij}) \geq Min_i \text{ For all i and j}$$

Whereas:

a_{ij} = Amount of land needed per unit of J-th activity in the i-th region; X_{IJ} = Level of J-th activity in the i-th region; Min_j = Minimum level of j-th activity

Non-negativity constraints

$$X_{ij} \geq 0$$

Whereas:

X_{IJ} = Level of J-th activity in the i-th region

RESULTS AND DISCUSSION

With the help of linear programming model optimum cropping pattern for small, medium and large land holders was assessed separately.

Optimum cropping pattern for small land holders: Increment in area of wheat (4.76%), cotton (8.98% and maize (8.08%) over respective existing areas of these crops consequence into1.04% higher profit. Contrarily, decline in areas of rice (13.79%), sugarcane (3.45%), rabi (12.12%) and kharif fodder (11.11%) over existing areas manifested 1.04% upsurge in benefits for small land holders. Therefore, results elucidated that the linear programming model suggestions were worth trying (Table-1).

Cropping plan decision might be an outcome of numerous processes subjected to variations in market prices, environmental constraints, prevailing resources and priorities of farmers. Profit optimization might be consequence of managing agricultural constraints that were further partitioned into sub-problems. Thus, efficient management might have diminished costs whereas augmented benefits. Linear programming proposed modeling considered various constraints and proposed cropping consequence into more profit (Dury *et al.,* 2011). Moreover, manipulation of available resources might have optimized benefits employing prevailing resources and constraints. Thereafter, optimizing land, water, fertilizer and agro-chemicals might have declined wastage of resources while enhanced input use efficiencies. Consequently, improvement in sustainability of agro-ecosystems might have diminished cost for production of unit output and hence benefits were relatively more than prevailing cropping patterns.

Optimum cropping pattern for medium land holders: Enhancement of cropped area under wheat, cotton and maize produced 1.10% higher benefits over existing cropped areas. While, same increment in profit was manifested by the declined cropped area of rice, sugarcane, rabi and kharif fodders than existing area. Thus, incline in area of wheat, cotton and maize was 4.60, 12.60 and 12.5% respectively over existing cropped areas. Though, diminishment in area of rice, sugarcane, rabi and kharif fodders over existing areas was 14.59, 3.408.23 and 10.07% respectively (Table 2). Linear programming model was employed to estimate the optimum cropping pattern for sugarcane. Intention was to maximize sugar, ethanol and electricity generation for small farmers. They proposed that diminishment in area of sugarcane consequence in profit maximization for small land holders (Illukpitiya *et al.,* 2013).

Statistical based decisions considering prevailing resources might prove critical regarding profitability and productivity. Henceforth, establishing and modifying existing cropping plan might have paramount significance to satiate future needs of farmers. Furthermore, linear programming model might have reviewed multiple cropping problems and thereafter optimized input use in context of constraints. Ultimately, profit might enhance, and expenses decline (Sarttra *et al.,* 2013). Raise in profit can also be adjudicated to simultaneous focus of linear programming model on numerous conflicting objects *i.e.* resource utilization, sustainability, environmental protection, profit maximization while making decision. Similarly, multistage linear programming model was used for devising of optimal cropping plan for newly cultivated areas. It was recommended to boost areas of wheat, oat, barley and legumes for profit maximization under scarce resources. While, diminution in areas of input intensive crops signified more benefits for small and medium farmers (Galan-Martin *et al*., 2015).

Optimum cropping pattern for large land holders: Existing areas of wheat, cotton and maize was 11.85, 6 and 4.19 ha respectively. Whereas, proposed areas through linear programming model for wheat, cotton and maize was 13, 7.1 and 4.8 ha to gain 1.07% higher profit than existing profit. Contrarily, 16.42, 3.45, 8.57 and 15.07% diminution over existing area was suggested to obtain 1.07% higher profit than existing profit (Table-3). Optimization of benefits employing linear programming model can be attributed to the capability of model to multiple decisions over period of times. Thus, under varying circumstances different cropping plans might optimize benefits. Linear programming model considered numerous variations in soil, environment, market prices, policies, biotic and abiotic stresses. Moreover, linear programming model might consider long term variations inherent in future projections. Hence, decision system might expound the significant future uncertainties while making decision. Thus, proposed cropping patterns maximized benefits as a consequence of enhanced input efficiencies (Jin *et al.,* 2014).

Table-1: Comparison of optimal cropping pattern with the existing cropping pattern for small land holders

No.	Crops	Existing (ha)	Optimal Solutions (ha)	Percentage of Existing cropping pattern (%)	Percentage increase or decrease in area (%)
1	Wheat	2.00	2.10	105.00	4.76
2	Rice	1.65	1.45	87.88	-13.79
3	Cotton	2.23	2.45	109.86	8.98
4	Sugar cane	0.60	0.58	96.67	-3.45
5	Maize	0.80	0.87	108.75	8.04
6	Rabi Fodder	0.37	0.33	89.19	-12.12
7	Kharif Fodder	0.80	0.72	90.00	-11.11

Small land holders= 1.04%profit.

Table-2: Comparison of optimal cropping pattern with the existing cropping pattern for medium land holders

No.	Crops	Existing (ha)	Optimal Solutions (ha)	Percentage of Existing cropping pattern (%)	Percentage increase or decrease in area (%)
1	Wheat	4.56	4.78	104.82	4.60
2	Rice	2.12	1.85	87.26	-14.59
3	Cotton	2.25	2.58	114.41	12.60
4	Sugar cane	1.52	1.47	96.71	-3.40
5	Maize	1.75	2.00	114.29	12.50
6	Rabi Fodder	1.71	1.58	92.40	-8.23
7	Kharif Fodder	1.53	1.39	90.85	-10.07

Medium land holders= 1.10% profit.

Table-3: Comparison of optimal cropping pattern with the existing cropping pattern for large land holders

No.	Crops	Existing (ha)	Optimal Solutions (ha)	Percentage of Existing cropping pattern (%)	Percentage increase or decrease in area (%)
1	Wheat	11.85	13.00	109.70	8.85
2	Rice	7.80	6.70	85.90	-16.42
3	Cotton	6.00	7.10	118.33	15.49
4	Sugar cane	6.00	5.80	96.67	-3.45
5	Maize	4.19	4.80	114.56	12.71
6	Rabi Fodder	3.80	3.50	92.11	-8.57
7	Kharif Fodder	4.20	3.65	86.90	-15.07

Large land holders =1.07 % profit.

Conclusion: The sum of this investigation is that by the adoption of optimum cropping pattern there will be substantial enhancement in profit by 1.04%, 1.10% and 1.07 % for the small, medium and large land holders, respectively. Therefore, it is recommended that yield and profit may be improved by enhancing the area of wheat, cotton and maize while decline in the area of rice, sugarcane, Rabi and Kharif fodder.

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