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Potential of Improved level technology in India; An Application of multi objective programming techniques

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Introduction

In India and abroad, the commonly used decision modeling in real life rests on the assumption that the decision maker seeks to optimize a well-defined single objective using traditional mathematical programming approach. Usually taking farming as a business enterprise, a centrist farmer will always like to allocate all the resources available at his farm in such a way that he may get maximum possible income. However in reality this is not the case as the decision maker is usually seeking an optimal compromise amongst several objectives, many of which may be in conflict. For example a farmer may be interested in maximizing his cash income, with certain emphasis on risk minimization. On the other at county level especially in a developing country a planner may aspire for a plan while maximizes food grains production and also to some extent considers employment maximization etc as the goals. So in the real world the decision makers are engaged in pursuit of several objectives and the traditional paradigm is in fact inadequate for dealing with such situations.

The application of multiple objective planning techniques in farm planning will undoubtedly lend realism to the exercise in farm planning because of the great potential of multiple objective programming in handling farm planning problems more comprehensively and its acceptability for developing the optimum farm plan is being increasingly recognized . The traditional mathematical programming approach to the modeling of agricultural decisions rests on certain basic assumptions about the situation being modeled and the decision maker himself. One fundamental assumption is that the decision maker (DM) seeks to optimize a well defined single objective. In reality this is not the case, as the DM is usually seeking an optimal compromise amongst several objectives, many of which can be in conflict, or trying to achieve satisfying levels of his goals. For instance, a subsistence farmer may be interested in securing adequate food supplies for the family, maximizing cash income, increasing leisure, avoiding risk etc. but not necessarily in that order. Similarly a commercial farmer

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may wish to maximize gross margin, minimize his indebtedness, acquire more land, reduce fixed costs etc. Two main types of decision-making situations are identified. The first situation deals with problems involving a single decision criterion or objective, while the second one involves several conflicting objectives. It is argued that decision makers are in reality engaged in the pursuit of several objectives and the traditional paradigm is inadequate for dealing with such situations. The present study is undertaken to analyze the food grain production and resource use and to suggest optimum production plans at existing technology for Punjab and Haryana. More specifically the objective of the study is to develop the optimum production plans

Review of Literature

Pant and Pandey (1999) made attempt to delineate the major environmental protection objectives for the hill agriculture, and to develop a multi-objective farm planning model for minimisation of environmental problems while maintaining the present level of foodgrain production and farm income. For the purpose, a representative hill district of Dhanding in Nepal was selected for obtaining the requisite data and other information. In all optimal plans, negative deviations from the economic goal levels (i.e. Targets for food grains production, milk production and cash farm income) and positive deviations from environmental goal levels (i.e. targets for soil erosion, cattle grazing, forest fodder and use of nitrogen, phosphorus and pesticides) are minimized. The optimum plan also suggests the substitutions of buffaloes for cows for milk production compared to the cows, the buffaloes have higher milk productivity, with more percentage of fat in milk. Provided, yet they did not seem to be adequately utilized by the villagers.

Malhan (1996) generated the compromise farm plans for different farm size categories for different zones in the Punjab state considering different objectives i.e. maximization of cash income and labour employment, minimization of working capital borrowing and labour use variability and also minimization of risk by using multi-objective programming techniques. he suggested different compromise farm plans on different farm situations which were preferred than the existing plan of each objective.

Domingo and Rehman (1988) presented an approach synthesizing MOTAD methods with in a compromise programming model to generate ‘best compromise’ solution which come closest to an ideal point. This approach can be regarded as compromise risk

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programming method (CRP). The objectives considered were minimizing the sum of absolute values of the total gross margin deviation and maximizing the expected gross margins.

Research Methodology

The present study has considered four objectives namely maximization of gross returns, maximization of labor use, maximization of food grain production and minimization of risk and worked out various compromise farm plans for the different farm situations using 5 sets of weights to the objectives as shown in table 1. First set provides equal weight-age to all the four objectives showing the same priority to each objective.

Table 1 Sets of weights for the various objectives

OBJECTIVES				
Sets of weights	Maximization of gross return	Maximization of food grain production	Maximization of human labor use	Minimization of risk
1	0.25	0.25	0.25	0.25
2	0.85	0.05	0.05	0.05
3	0.05	0.85	0.05	0.05
4	0.05	0.05	0.85	0.05
5	0.60	0.05	0.05	0.30

The second set gives highest weight to the objectives of gross returns i.e. to represent the general tendency of the farmers of maximizing profits keeping aside the rest of the objectives with lower weights. The third set gives highest weight to the food grain production because the aim of any nation is to fulfill the food requirement of its people. The fourth set of weights provide highest weights to the objective of human labor employment as this is in the interest of the nation to increase the level of employment in crop production, fifth set of weights is for those risk averter farmers who give high priority to the objective of maximization of gross returns along with the objective of minimization of risk and equal low level priority to maximizing food grain production and labor employment. This plan seems to be more realistic, close to farmers' choice

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Technique of Analysis

The objective functions are optimized simultaneously in the multiple objective programming farm planning models. First, the pay-off matrix has been constructed using 'ideal points' which represent the optimum values of the objectives under consideration within the given resource constraints. In fact, these ideal points are not feasible because the objectives are in conflict; we select the efficient farm plans closest to it by using compromise programming techniques. The worst element from each column of the pay off matrix will be the 'anti-ideal point'. The anti-ideal point shows a minimum value for the objectives, which are to be minimized. Among the different techniques to generate the efficient set, a variant of the weighting method has been chosen known as non-inferior set estimation (NISE) method, as the most suitable multiple objective programming technique for generating the efficient set (Cohan, Church and Steer, 1979). To obtain compromise solution from the efficient sets, the degree of closeness, dj between the jth objective and its ideal value has been calculated and it was made unit free by taking relative deviation as under:

$$d_j = \frac{z_j^* - z_j(x)|}{| z_j^* - z_j^+ |}$$

Where, $z_j(x)$ = the j^{th} objective function to be maximized/minimized z_j^* = the ideal value of the j^{th} objective function

z_j^+= the anti-ideal values of the j^{th} objective function

The distance between each solution and its ideal point is obtained by following distance function:

$$L_P (\delta, K) = (\Sigma \mid \delta_j . d_j |^p)^{1/p}$$

Where, p = weights of the deviations according to their magnitudes

K = no. of objective functions

δj = weights the importance of the deviations of j^{th} objective from its ideal value;

dj = degree of closeness between the j^{th} objective and

Its ideal value

j = 1, 2, 3…………………K

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For some value of δ and different values of p different compromise solution for distant function L_P are obtained and the farmer/nation can choose any one solution for given preferences of the different objectives out of the various compromise solutions. However the distance function L_P is usually used for p=1 and p= α which shows the 'A longest' and the Chebysew distance in the geometric sense respectively (greater weight is given to the largest deviation). Therefore, maximum of the individual deviations is minimized at p = α. For different values of p and δj we can generate different compromise solutions. The alternate with the lowest value for the distance function will be the best compromise solution with respect to the ideal point. For L1 metric (p=1), the best compromise solution to the ideal point can be obtained by solving the following linear programming problems i.e.

$$\text{Min } L_1 = \Sigma\, \delta_j \quad \frac{z_j^* - z_j(x)}{z_j^* - z_j^+} \quad \text{Subject to } (X)\ \varepsilon\ F$$

Where, (x) is a vector of the decision variables and

F = the set of all feasible farm plans

For Lα matrix (p=α), minimum of the individual deviation is minimized by solving the following linear programming model.

Min Lα = d

Such that

$$\delta_1 = \frac{z_j^* - z_j(x)}{z_j^* - z_j^+} \leq d$$

$$\delta_2 = \frac{z_j^* - z_j(x)}{z_j^* - z_j^+} \leq d$$

: : : :
: : : :
: : : :

$$\delta_k = \frac{z_j^* - z_j(x)}{z_j^* - z_j^+} \leq d \quad \text{Subject to } (X)\ \varepsilon\ F$$

Where d = the largest deviation and

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k = number of objective functions

L1 and Lα metric define a subset of the compromise sets. The other best compromise solution falls between the solutions corresponding to L1 to Lα. For different sets of values of the weights δj the structure of the compromise sets can be modified. The compromise programming approach find the optimum point for all the objectives and the compromise solutions for L_1 and Lα formulate the bounds of the compromise set. Different set of the solution can be obtained by varying the weights given to the different objectives. Farmers/policymakers can choose any one solution for given preference of the different objectives out of the various compromise solutions.

Result and Discussion

In table 2 the elements of the first four rows and columns form the pay off matrix for India at improved level of technology. Here the ideal production plan respectively maximum possible returns of 1591.47 billion Rs, maximum possible grain production 346.58 million tons, maximum of man power employment 5987.9 million man days and the minimum possible risk in return (mean absolute deviation) 126.12 billion Rs. under the improved level resource constraints was possible employing resources optimally. The table also shows the anti-ideal point for gross return 1154.63 billion Rs. under the ideal plan for risk. Similarly anti-ideal 254.75 million tons of grain production and 4245.6 million mandays. The anti-ideal point for risk was 288.912 billion Rs. under the maximization of labour use plan.

In table 3 by optimizing gross returns or by giving 100 percent weight to this objective we get the elements of first row of pay off matrix. Here the optimum farm plan I shows the increase in gross returns by 88.31 percent, in grain production 91.36 percent, in labour use 13.90 percent and risk by 15.58 percent as compare to existing level by following the increase in paddy, jowar, bajra, maize and tur area by 9.81 percent, 74.76 percent, 57.02 percent, 43.58 percent and 647.95 percent in kharif season. In rabi season wheat shows the increment in area by 4.33 percent and gram by 142.44 percent, where as the area under barley was declined by 48.44 percent on irrigated land. Under unirrigated land the increase in tur, paddy and maize was 99.35 percent, 40.45 percent and 6.94 percent while the area under jowar and bajra were declined by 6.18 percent and 18.68 percent in kharif season. Wheat was the most profitable rabi crop grown on unirrigated land and shows the increment by 240.22 percent, while barley and gram registered declining trend as compare to existing level. The

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row 2nd of pay off matrix indicating the maximum grain production 346.58 million tons (95 percent increment in grain production as compare to existing level by following the same kharif plan as plan I on irrigated land which indicating that the kharif crops whose yield level is higher are also most remunerative crops on irrigated

India (Selected States)

TABLE 2 PAY OFF MATRIX AND CROPPING PATTERN AT IMPROVED LEVEL OF TECHNOLOGY FOR SELECTED STATES IN INDIA

THE OBJECTIVES & CORRESPONDING VALUES					AREA UNDER FOOD GRAINS (000 HECTARE)							
					IRRIGATED							
Variables	Gross Returns (billion Rs.)	Production (Million Tons)	Human labour (Million days)	Risk (Billion Rs.)	Paddy	Wheat	Jowar	Bajra	Maize	Barley	Tur	Gram
Existing	802.62	177.73	5096.4	149.85	14561	23495	626	101	1200	481	98	1503
Gross Returns (billion Rs.)	1591.87 (98.33)	340.12 (91.36)	5804.9 (13.90)	173.21 (15.58)	15990 (9.81)	24514 (4.33)	1094 (74.76)	677 (570.2)	1723 (43.58)	248 (-48.44)	733 (647.95)	3644 (142.44)
Production (Million Tons)	1511.47 (88.31)	346.58 (95.00)	55910.9 (15.98)	177.97 (18.76)	15990 (9.81)	24357 (3.66)	1094 (74.76)	677 (570.2)	1723 (43.58)	1567 (225.77)	733 (647.95)	2482 (65.13)
Human labour (Million days)	1468.17 (82.92)	338.50 (90.45)	5987.9 (17.49)	288.91 (92.79)	15944 (9.49)	24481 (4.19)	1094 (74.76)	677 (570.2)	1766 (47.16)	313 (-34.92)	733 (647.95)	2482 (65.13)
Risk Billion Rs.	1154.63 (43.85)	254.75 (43.33)	4245.6 (-16.69)	126.12 (-15.8)	13344 (-8.35)	19512 (-16.95)	1094 (74.76)	677 (570.2)	1439 (19.91)	248 (-48.44)	733 (647.95)	2482 (65.13)

Note : Figure in parentheses represents percentage change over existing level

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TABLE 2: PAY OFF MATRIX AND CROPPING PATTERN AT IMPROVED LEVEL OF TECHNOLOGY FOR SELECTED STATES IN INDIA

THE OBJECTIVES & CORRESPONDING VALUES					AREA UNDER FOOD GRAINS (000 HECTARE)									
Variables	Gross Returns (billion Rs.)	Production (Million Tons)	Human labour (Million days)	Risk Billion Rs.	UNIRRIGATED									
					Paddy	Wheat	Jowar	Bajra	Maize	Barley	Tur	Gram	Moong	Mash
Existing	802.62	177.73	5096.4	149.85	14375	3722	9471	8270	3817	336	2638	5837	1898	2540
Gross Returns (billion Rs.)	1591.87 (98.33)	340.12 (91.36)	5804.9 (13.90)	173.21 (15.58)	20191 (40.45)	12663 (240.22)	8885 (-6.18)	6725 (-18.68)	4082 (6.94)	41 (-87.79)	5259 (99.35)	4269 (-26.86)	1600 (-15.70)	1400 (-44.88)
Production (Million Tons)	1511.47 (88.31)	346.58 (95.00)	55910.9 (15.98)	177.97 (18.76)	19720 (37.18)	13634 (266.30)	12309 (29.96)	6725 (-18.68)	4595 (20.38)	267 (-20.53)	1792 (-32.06)	3072 (-47.39)	1600 (-15.70)	1400 (-44.88)
Human labour (Million days)	1468.17 (82.92)	338.50 (90.45)	5987.9 (17.49)	288.91 (92.79)	17983 (25.09)	13634 (266.30)	12122 (27.99)	6912 (-16.42)	4452 (16.63)	32 (-90.47)	3772 (42.98)	3307 (-43.34)	1600 (-15.70)	1400 (-44.88)
Risk Billion Rs.	1154.63 (43.85)	254.75 (43.33)	4245.6 (-16.69)	126.12 (-15.8)	11191 (-22.14)	6601 (77.35)	11922 (25.87)	6725 (-18.68)	1575 (-58.73)	32 (-90.47)	3670 (39.12)	3081 (-47.21)	1600 (-15.70)	1400 (-44.88)

Note : Figure in parentheses represents percentage change over existing level

TABLE ;3 RESOURCE USE PATTERN IN PAY OF MATRIX AT IMPROVED LEVEL OF TECHNOLOGY FOR SELECTED STATES IN INDIA, 2014-15

PARTICULARS	EXISTING USE	PLANS			
		1	2	3	4
Kharif fertilizer (000 tons)	3187.62	5218.05 (63.69)	5220.40 (63.77)	5105.67 (60.17)	4164.62 (30.64)
Rabi fertilizer (000 tons)	3486.01	4907.88 (40.78)	4951.40 (42.03)	4981.03 (42.88)	2390.1 (-31.43)
Kharif Capital (billion Rs.)	223.85	343.97 (53.66)	343.60 (53.49)	339.49 (51.65)	368.15 (19.78)
Rabi capital	232.21	320.88	323.86	333.88	197.38

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(billion Rs.)		(38.18)	(39.46)	(43.78)	(-14.49)
Total human labour (million man days)	5096.4	5804.9 (13.90)	5910.9 (15.98)	5987.9 (17.49)	4245.6 (-16.69)

Note : Figure in parentheses represents percentage change over existing level

land. In rabi season wheat, barley and gram and shows the increment by 3.60 percent, 225.77 percent and 65.13 percent respectively. On unirrigated land, the area under paddy, wheat, jowar and maize was increased by 37.18 percent, 266.30 percent, 29.06 percent and 20.38 percent respectively while bajra, barley, tur and gram showed decline in area by 18.68 percent, 20.53 percent, 32.06 percent and 47.39 percent respectively. Moong and mash entered in the plan at their minimum level.

The optimum plan 3rd suggest that a maximum of 5987.9 million man days of human labour employment can be achieved showing the 17.49 percent increase in employment as compare to existing labour use by following the increase in paddy by 9.49 percent and maize by 47.16 percent in kharif season under irrigated condition. On rabi season the area under wheat was increased by 4.19 percent while the area under barley was decreased by 34.92 percent as compare to existing cropping pattern which indicate that wheat was the more labour consuming crop as compare to other rabi crops. On unirrigated land the area under paddy, jowar, maize and tur was increased by 25.09 percent, 27.99 percent, 16.63 percent and 42.98 percent respectively in kharif season. The fourth plan of the table shows the plan under least possible risk it entailed a minimum risk of Rs. 126.128 billion in growing rabi and kharif crops at their minimum level for example under irrigated conditions, paddy, wheat, jowar, bajra, maize, barley, tur and gran entering at their minimum level 13334, 19512, 1094, 677, 1439, 248, 733 and 2482 thousand hectare level and under unirrigated conditions paddy, wheat, jowar, bajra, maize, barley, tur and gram entering at 11191, 6601, 11922, 6725, 1575, 32, 3670 and 3081 thousand hectare level. The resource use patterns in pay off matrix shows (table .3) that consumption of kharif fertilizer would be increased by 63.99 percent, 63.77, 60.17 and 30.64 percent in plan I, II, III, IV respectively where as the consumption of rabi fertilizer would be increased by 40.78 percent, 42.03, 42.88 and declined by 31.43 percent in

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plan I, II, III, IV. The kharif capital shows an increment by 53.66 percent 53.49, 51.65 and 19.78 in plan I, II, III and IV whereas the use of rabi capital shows the increment by 38.18 percent, 39.46, 43.78 in plan I, II and III and decline of 14.49 percent in plan IV. The labour requirement increased by 13.90 percent, 15.98 percent, 17.49 percent in farm plan I, II and III respectively and decline of 16.69 percent in farm plan IV.

Comparison existing level of technology and at improved level of technology:

Table 2 shows at improved level of technology. It was found that by following the recommendation of scientist the grain production increased from 208.48 million tons to 346.58 million tons with the increase in gross returns from 931.90 billion Rs. To 1591.87 billion Rs. where as the increase in labour use was from 5919.1 million man days to 5987.9 million man days and risk from 125.80 billion Rs. to 126.12 billion Rs. by following the optimum production plan at improved level of technology. The crops whose area shows decline in area as compare to existing level in table 1 shows the increment in area for example area under coarse cereals and pulses like maize, jowar, bajra and gram on irrigated land by following the improved level technology. It can be mentioned that these crop can be competed with fine cereals like wheat and paddy in the time coming at higher technology. On unirrigated land wheat and paddy area still dominant even at improved level of technology. It was revealed that at improved level of technology gross returns and grain production increased by 88.31 percent and 95.00 percent while the labour use increased only 17.49 percent as compare to existing level. This shows that food grain crops are not much labour intensive crops even at higher technology. The efficient plan for risk shows the decline in risk by 15.83 percent even at the higher production and returns by 43.33 percent, 43.85 percent respectively as compare to existing level.

In resource use pattern kharif fertilizer and kharif capital shows the significant increase in their use at improved technology as compare to existing level. The consumption of rabi fertilizer and rabi capital which was very less in optimum plans of existing level of technology as compare to existing use are also shows increment in use at higher technology. While labour requirement shows no significant improvement in labour use even at higher level of technology.

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