AN APPLICATION OF MULTI OBJECTIVE COMPROMISE PROGRAMMING TECHNIQUES: A CASE STUDY OF NORTH WEST OF INDIA (PUNJAB, HARYANA, RAJASTHAN)

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I.INTRODUCTION

In India and abroad, the commonly used decision modelling 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 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

II.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 minimization 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 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.

III.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.

IV.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:

$z_j^* - z_j(x)|$

$d_j = \dfrac{}{|z_j^* - z_j^+|}$

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:

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

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

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.

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

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

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

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

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

Where d = the largest deviation and

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.

V.RESULT AND DISCUSSION

HARYANA

the farmers/ policy makers of Haryana should choose any of the four optimum farm plans by optimizing each one objective at a time which has been discussed earlier or one is free to select a compromise farm plan giving different weights to different objectives among five set of production plan (two farm plans respectively L_1 and L from each set of weights). When equal weights were allotted to each of the four objective (Table 2) taken in the study then compromise plan L_1 shows the same results as the optimum plan for maximization of gross margin, while the farm plan II shows the increment in gross returns, grain production, labour use and in risk by 6.74 percent, 2.89 percent, 5.44 percent and 0.06 percent respectively.So any one choosing the form plan in between

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these two compromise plans. In second set when maximum weight 0.85 given to the objective of gross returns the farm plan III came as form Plan I and farm plan IV shows some decline in gross returns, production labour use and in risk compare to form plan-I or III. In IIIrd set 0.85 weight was given to grain production and the farm plan V shows the same plan as plan I and III while farm plan VI shows similar results as farms plan IV shows. In fourth set 85 percent weight was given to maximize labour use and farm plan VII shows the same plan as optimizing plan for maximizing labour use was showing. While plan VIII shows the increase in returns, production, labour use and in risk by 11.85 percent, 11.94 percent and 14.48 percent respectively as compare to existing level, In fifth set when 60 percent weight was given to maximizing gross returns, 30 percent weights were assigned to minimization of risk and equal weight to labour and risk than plan IX increase in gross return 9.17 percent with the increase in risk 3.74 percent. The compromise farm plan X shows the marginal increase in risk 0.29 percent, with the increase in returns by 7.72 percent as compare to existing level.

TABLE 2; EFFICIENT COMPROMISE SETS OF PRODUCTION PLAN FOR HARYANA

THE OBJECTIVES & THEIR CORRESPONDING VALUES					**AREA UNDER FOOD GRAINS (000 HECTARE)**											
					Irrigated					**Unirrigated**						
Sets Megnitude No. of δj wts	**Gross Returns (billion Rs.)**	**Production (Million Tons)**	**Human labour (Million days)**	**Risk (Billion Rs.)**	**Paddy**	**Wheat**	**Barley**	**Jowar**	**Tur**	**Maize**	**Jowar**	**Bajra**	**Gram**	**Tur**	**Wheat**	**Barley**
Existing pattern	57.023	12.3036	172.5	7.241	**831**	**2022**	**32**	**73**	**28**	**24**	**60**	**584**	**305**	**8**	**42**	**7**
I. 1. L_1 δj = (0.25, 0.25, 0.25, 0.25)	64.820 (13.67)	14.1848 (15.28)	195.0 (13.04)	8.545 (18.00)	**1123**	**2172**	**28**	**50**	**17**	**37**	**40**	**509**	**262**	**4**	**126**	**7**
2. L_∞	60.867 (6.74)	12.6596 (2.89)	181.9 (5.44)	7.246 (0.06)	**681**	**2154**	**28**	**50**	**458**	**24**	**40**	**522**	**262**	**4**	**35**	**98**

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II. 3. L_1 δj = (0.85, 0.05, 0.05, 0.05)	64.820 (13.67)	14.1848 (15.28)	195.0 (13.04)	8.545 (18.00)	**1123**	**2172**	**28**	**50**	**17**	**37**	**40**	**509**	**262**	**4**	**126**	**7**
4. L∝	64.048 (12.31)	13.8175 (12.30)	191.3 (10.89)	8.218 (13.49)	**1014**	**2172**	**28**	**50**	**125**	**24**	**53**	**509**	**262**	**4**	**126**	**7**
III. 5. L_1 δj = (0.05, 0.85, 0.05, 0.05)	64.820 (13.67)	14.1848 (15.28)	195.0 (13.04)	8.545 (18.00)	**1123**	**2172**	**28**	**50**	**17**	**37**	**40**	**509**	**262**	**4**	**126**	**7**
6. L∝	64.387 (12.91)	13.9965 (13.75)	193.0 (11.88)	8.353 (15.35)	**1067**	**2172**	**28**	**50**	**72**	**24**	**40**	**522**	**262**	**4**	**126**	**7**
IV. 7. L_1 δj = (0.05, 0.05, 0.85, 0.05)	64.457 (13.03)	14.0641 (14.30	195.5 (13.33)	8.555 (18.14)	**1123**	**2172**	**28**	**50**	**17**	**37**	**40**	**509**	**353**	**4**	**35**	**7**
8. L∝	63.785 (11.85)	13.7625 (11.85)	193.1 (11.94)	8.290 (14.48)	**1028**	**2172**	**28**	**50**	**111**	**37**	**40**	**509**	**353**	**4**	**35**	**7**

V. 9. L_1 δj = (0.60, 0.05, 0.05, 0.30)	62.253 (9.17)	13.0396 (5.98)	185.2 (7.36	7.512 (3.74)	**766**	**2172**	**28**	**50**	**373**	**24**	**40**	**522**	**262**	**4**	**126**	**7**
10. L∝	61.427 (7.72)	12.6673 (2.95)	181.9 (5.44)	7.262 (0.29)	**661**	**2165**	**28**	**50**	**479**	**24**	**53**	**509**	**262**	**4**	**126**	**7**

Note : : Figure in parentheses represents percentage change over existing level

VI.PUNJAB

Punjab should choose any of the four optimum farm plan by optimizing each one objective at a time which has been discussed earlier on one is free to select a compromise farm plan giving different weights to different objectives among five set of production plan (two farm plan representing L1 and L from each set of weights). When equal weights were allotted to each of the four objective (table 3) taken in the study, then compromise solution L1 shows the increment in gross returns, grain production, labour use and risk by 11.06 percent, 11.25 percent, 13.35 percent and 9.12 percent respectively. While compromise plan II shows the increment only by 3.08 percent, 2.31 percent, 7.96 percent and a decline of risk by 0.85 percent respectively as compare to existing level. So any one choosing the farm plan in between these two compromise plans was likely to give preferences to the objectives as per plan I. In second set when maximum weight 0.85 given to the objective of maximization of gross returns the farm plan III shows marginal changes as compare to farm plan I. While compromise plan IV shows, marginal decline in four parameters as compare to farm plan I. In IIIrd set 0.85 weight was given to grain production and the farm plan V shows the same plan as plan IInd of pay off matrix while plan VI shows the similar results of farm plan IV. In fourth set 85 percent weight was given to maximize labour use and farm plan VII shows the same plan as farm plan V. In fifth set when 60 percent weight was given to maximizing gross returns and 30 percent weights were assigned to minimization of risk and equal weight to labour and risk then farm plan IX shows the same results of farm plan V, VII while farm plan X shows the last increase in risk as compared to existing plan showing only 2.43 percent increment in risk while increase in return was 5.73 percent.

TABLE 3 : EFFICIENT COMPROMISE SETS OF PRODUCTION PLAN FOR PUNJAB

THE OBJECTIVES & THEIR CORRESPONDING VALUES					AREA UNDER FOOD GRAINS (000 HECTARE)												
Sets Megnitude No. of δj wts	Gross Returns (billion Rs.)	Production (Million Tons)	Human labour (Million days)	Risk Billion Rs.	Irrigated						Unirrigated						
					Wheat	Paddy	Barley	Maize	Gram	Moong	Mash	Maize	Gram	Bajra	Mash	Tur	Massar
Existing pattern	115.910	26.0056	25.92	10.479	**3102**	**228**	**37**	**96**	**7**	**30**	**20**	**69**	**6**	**8**	**6**	**11**	**5**
I. 1. L_1 δj = (0.25, 0.25, 0.25, 0.25)	128.733 (11.06)	28.9315 (11.25)	294.6 (13.35)	11.435 (9.12)	**3331**	**2759**	**31**	**93**	**7**	**30**	**20**	**61**	**35**	**8**	**6**	**25**	**5**
2. L∝	119.481 (3.08)	26.6075 (2.314)	280.6 (7.96)	10.339 (-0.85)	**2812**	**2487**	**31**	**93**	**526**	**176**	**20**	**61**	**35**	**8**	**6**	**25**	**5**
II. 3. L_1 δj = (0.85, 0.05, 0.05, 0.05)	128.788 (11.11)	28.9534 (11.33)	294.5 (13.31)	11.568 (10.39)	**3331**	**2759**	**31**	**93**	**7**	**30**	**20**	**78**	**6**	**8**	**6**	**8**	**34**
4. L∝	127.741 (10.20)	28.6910 (10.32)	293.2 (12.81)	11.322 (8.04)	**3262**	**2759**	**31**	**93**	**75**	**30**	**20**	**61**	**35**	**8**	**6**	**25**	**5**

III. 5. L_1 δj = (0.05, 0.85, 0.05, 0.05)	128.737 (11.06)	28.946 (11.30)	294.8 (13.42)	11.484 (9.59)	**3331**	**2759**	**31**	**93**	**7**	**30**	**20**	**78**	**35**	**8**	**6**	**8**	**5**
6. L∝	127.723 (10.19)	28.6868 (10.31)	293.2 (12.81)	11.320 (8.02)	**3261**	**2759**	**31**	**93**	**76**	**30**	**20**	**61**	**35**	**8**	**6**	**25**	**5**
IV. 7. L_1 δj = (0.05, 0.05, 0.85, 0.05)	128.737 (11.06)	28.9461 (11.30)	294.8 (13.42)	11.484 (9.59)	**3331**	**2759**	**31**	**93**	**7**	**30**	**20**	**78**	**35**	**8**	**6**	**25**	**5**
8. L∝	127.288 (9.81)	28.5812 (9.90)	292.6 (12.58)	11.271 (7.55)	**3231**	**2759**	**31**	**93**	**106**	**30**	**20**	**61**	**35**	**8**	**6**	**25**	**5**
V. 9. L_1 δj = (0.60, 0.05, 0.05, 0.30)	128.733 (11.06)	28.9312 (11.25)	294.6 (13.35)	11.435 (9.12)	**3331**	**2759**	**31**	**93**	**7**	**30**	**7**	**61**	**35**	**8**	**6**	**25**	**5**
10. L∝	122.555 (5.73)	27.4344 (5.49)	286.1 (10.08)	10.734 (2.43)	**2904**	**2759**	**31**	**93**	**433**	**30**	**20**	**61**	**35**	**8**	**6**	**25**	**5**

Note : : Figure in parentheses represents percentage change over existing level.

VII.RAJASTHAN

Rajasthan should choose any of the four optimum farm plan by optimizing each one objectives at a time which has been discussed earlier on one is free to select a compromise farm plan giving different weights to different objectives among five set of production plan (two farms plan respectively L1 and L from each set of weights) when equal weights were allotted to each of the four objective (table 4.) taken in the study, then compromise plan L shows the increment in gross return, grain production, labour use and decline in risk by 2.48 percent,

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8.64 percent, 11.02 percent and 7.22 percent respectively while the compromise plan II shows the decline in gross returns, production, labour use and in risk by 16.10 percent, 7.97 percent, 6.33 percent and 14.10 percent respectively as compare to existing level. In second set when maximum weight 0.85 given to the objective of gross returns the farm plan III shows the same plan as optimum plan for gross returns was showing and plan IV shows only 3.87 percent increment in gross returns. In IIIrd set 0.85 weight was given to grain production and then farm plan V shows the same plan as optimum plan for grain production of pay off matrix, while plan VI shows the 8.62 percent increment in grain production. In fourth set 85 percent weight was given to maximize labour use and farm plan VII shows the same plan as optimum plan for maximizing labour use and plan VIII shows 12.5 percent increment in labour use. In fifth set when 60 percent weight was given to maximizing gross returns, 30 percent weights were assigned to minimization of risk and equal weight to labour and risk then plan IX shows the maximum increment in grain production by 8.91 percent while decline in risk by 10.92 percent. While compromise farm plan X shows the decline in risk by 13.41 percent with the marginal decline in gross returns by 1.72 percent as compare to existing level.

TABLE 4: EFFICIENT COMPROMISE SETS OF PRODUCTION PLAN FOR RAJASTHAN

THE OBJECTIVES & THEIR CORRESPONDING VALUES					**AREA UNDER FOOD GRAINS (000 HECTARE)**															
					Irrigated						**Unirrigated**									
Sets Megnitude No. of δj wts	**Gross Returns (billion Rs.)**	**Production (Million Tons)**	**Human labour (Million days)**	**Risk (Billion Rs.)**	**Paddy**	**Wheat**	**Barley**	**Gram**	**Tur**	**Maize**	**Paddy**	**Wheat**	**Jowar**	**Bajra**	**Maize**	**Gram**	**Tur**	**Mash**	**Moong**	**Barley**
Existing pattern	59.71	12.57	558.8	14.15	68	2518	192	287	7	28	96	160	561	4702	945	1926	39	208	631	71
I. 1. L_1 δj = (0.25, 0.25, 0.25, 0.25)	61.19 (2.48)	13.66 (8.64)	620.4 (11.02)	13.13 (-7.2)	154	1978	911	147	33	28	154	724	1161	4272	883	1375	360	147	343	258
2. L_∞	50.09 (-16.1)	11.57 (-7.9)	523.4 (-6.3)	12.15 (-14.1)	154	1946	942	134	3	58	154	92	699	4272	883	895	16	147	343	48
II. 3. L_1	62.98 (5.47)	13.24 (5.32)	589.8 (5.54)	14.97 (5.82	154	1978	552	493	33	28	70	724	561	4272	883	1375	360	831	343	258

δj = (0.85, 0.05, 0.05, 0.05)	62.03 (3.87)	13.47 (7.17)	606.3 (8.50)	) 13.91 (-1.7)	154	1978	736	308	33	28	154	724	878	4272	883	1375	360	429	343	258
4. L∝																				
III. 5. L1	61.66 (3.25)	13.82 (9.96)	624.2 (11.70)	14.77 (4.36)	154	1978	911	134	3	58	154	724	561	4472	1283	1375	360	147	343	258
δj = (0.05, 0.85, 0.05, 0.05) 6. L∝	61.18 (2.46)	13.65 (8.62)	620.3 (11.0)	13.12 (-7.2)	154	1978	911	134	33	28	154	724	1161	4272	883	1375	360	147	343	252
IV. 7. L1	59.88 (0.29)	13.69 (8.82)	634.8 (13.60)	14.60 (3.17)	49	1978	911	134	3	163	70	724	1189	4272	1283	1375	16	147	343	258
δj = (0.05, 0.05, 0.85, 0.05) 8. L∝	58.74 (-1.6)	13.48 (7.26)	628.7 (12.5)	13.36 (-5.56)	49	1872	1016	134	3	163	70	724	1589	4272	883	1375	16	147	343	258
V. 9. L1	60.29 (0.97)	13.35 (6.16)	608.6 (8.91)	12.60 (-10.9)	136	1978	911	134	50	28	154	724	1161	4272	883	1375	360	147	343	48
δj = (0.60, 0.05, 0.05, 0.30) 10. L∝	58.68 (-1.72)	12.82 (2.02)	595.0 (6.47)	12.25 (-13.4)	49	1978	725	134	138	28	70	724	1245	4272	883	1300	360	147	343	48

Note : Figure in parentheses represents percentage change over existing level

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