EFFICIENT FARMING SYSTEMS MODELING : AN APPLICATION OF COMPROMISE PROGRAMMING

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Abstract

The study was undertaken to assess the potential for increasing farm income and employment through an efficient farming system. The study was conducted in Bangalore rural district of Karnataka. An efficient farming system is one with the minimum income variability commensurate with high incomes. The data was analyzed using linear programming and its complements Minimization of Total Absolute Deviation, multi-objective and compromise programming techniques. An efficient farm plan has the potential to increase farm income by 124% for crop + poultry system of small farms and 85% for crop + dairy + sericulture system of large farms. The efficient farm plan generated the highest employment for crop + sericulture system in both categories of farms.

Traditional linear programming (LP) approach to the modeling of agricultural decisions rests on certain basic assumptions about the situation being modeled and the decision maker seeks to optimize a well-defined single objective. In reality this is not the case, as the decision maker is usually seeking an efficient compromise amongst several objectives, many of which can be in conflict, or trying to achieve satisfying levels of his goals.

Despite, the recognition given to the existence of multiple objectives in agricultural decision-making, agricultural economists have done not much work to develop and use methodologies with respect to farming situations realistically. This is particularly intriguing when one notices the amount of effort that has been devoted to the development and use of multiple criteria decision-making techniques in various disciplines such as management science, water resources research and forest planning (Romero and Rehman, 1989). The modeling involving multiple objectives is useful in farming systems research and extension. Compromise programming technique is used in the study to bring about compromise solutions among different conflicting objectives of the farmers.

The study

The present study on Farming System Modeling is to know the pattern of resource use with existing farming system and to assess the potentialities for increasing farm income and employment through an efficient farming system. In addition, the efficient farming system that will minimise income variability was considered.

The study was carried out in Bangalore rural district of Karnataka, India, with a sample of 180 farms. The information collected related to the agricultural year 1993-94 from primary and secondary sources. The data was analysed using a combination of techniques like linear programming and its complements Minimization of Total Absolute Deviation (MOTAD), *Hazell*, 1971, Multi-objective programming (MOP) and compromise programming (CP) in that sequence to make the results as close to reality as possible (Romero and Rehman, 1989). Further four objectives; some of them conflicting were optimised simultaneously in the MOP model. Gross margin and meeting the consumption requirement objectives are maximised, minimisation of income variability and hired labour use by the decision maker. The main purpose of the present study is to demonstrate the use of MOP and CP in the context of Farming Systems Modeling under Indian conditions. It is encouraging the farm management experts to make use of this technique for suggesting farming system models in the future (Nagaraja, 1995).

The Mathematical Model

The mathematical form of linear programming can be written as:

$$\text{Maximize} \quad Z = \sum_{j=1}^{n} c_j x_j \qquad \ldots\ldots \qquad \ldots\ldots (1)$$

Subject to the constraints,

$$\sum_{j=1}^{n} a_{ij} x_j > b_i \ (i = 1 \ldots n) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$x_j \geq 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (3)$$

where,

Z = objective function to be maximised,
c_j = value of the j^{th} activity,
x_j = level of the j^{th} activity,
a_{ij} = co-efficient that reflects either an absorption of ($a > 0$) or a contribution to ($a < 0$) a constraint resource and
b_i = available quantity of i^{th} resource or the requirement to be met.

Objective function

The objective function for the basic model is to maximize the "annual net farm return" from various enterprises subject to the resource constraints specified in the model. The general economic objective of a farmer is maximization of welfare.

MOTAD

Though farmers try to maximise their annual net farm return (gross margin) they also worry about the risk in farming. Farmers combine different activities by considering the risk-return trade-off among different farm enterprises. They try to choose the combination based on their past experience, asset position, entrepreneurship etc. Farmers often like to stabilise their farm income or minimise the income variability. Thus, introduction of risk in the programming is essential to make the results more relevant and useful.

In the present study it was considered appropriate to use MOTAD model (parametric risk programming technique) developed by Hazell in order to obtain risk efficient farm plans. MOTAD model uses the expected income and the mean absolute deviations assumed to represent risk.

The mean absolute income deviation (denoted by A) was defined as:

$$A = 1/S \sum_{h=1}^{s} \left| \sum_{j=1}^{n} (c_{hj} - g_j)\, x_j \right| \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where,

S = number of gross margin deviations, 1, 2, ….. S (in the present study it is six years).

c_{hj} = gross margin of the j^{th} activity in h^{th} year

g_j = sample mean of gross margin of j^{th} acivity

x_j = level of the j^{th} acivity (j = 1, 2, ….. n)

Multi-objective Programming

Multi objective programming or vector optimisation technique tackles simultaneous optimisation of several objectives subject to a set of constraints usually linear, as an optimisation solution cannot be defined for several objectives, MOP used in obtaining the set of feasible solution which are efficient (Pareto optimal) solutions rather than to locate the single optimum solution. The elements of this efficient set are feasible solution such that there are no other feasible solutions that can achieve the same or better performance for all the objectives and strictly better for at least one objective (Romero and Rehman, 1984).

Thus to generate the efficient set of MOP model could be formulated as:

$$\text{Eff. } Z(\underline{X}) = [z_1(\underline{X}) \ldots\ldots z_q(\underline{X})] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Subject to ……

$$\underline{X} \in \underline{F} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where

Eff. means the search for the efficient solutions (in a minimising and maximising sense)

$\underline{F}$ represents the feasible set, and

$\underline{X}$ indicates the vector of the decision variables.

Compromise Programming

Compromise programming was used to choose the optimum element from a set of efficient solutions as proposed by Zeleny (1973). CP starts by establishing the ideal point whose co-ordinates are given by the optimum values of the various objectives of the decision maker. The ideal point is usually infeasible. If it is feasible then there is no conflict among objectives. When the ideal point is infeasible the optimum element or compromise solutions is given by the efficient solution that is closer to the ideal point. Thus, the degree of closeness as relative deviation d_l between the j^{th} objective and its ideal value is defined by:

$$d_j = \frac{Z^*_j - Z_j(X)}{Z^*_j - Z_{*j}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where Z^*_j and Z_{*j} were the ideal and anti-ideal values for the jth objective. Relative rather than absolute deviations had to be used, as the units of measurement of the different objectives were not the same.

$\underline{X}$ is a vector of the decision variables and $Z_j(\underline{x})$ is the j^{th} objective function ought to be optimised.

In order to measure the distances between each solution and the ideal point the following distance function was used.

$$L_P(\delta, K) = \left(\sum_{j=1}^{K} \{\delta_j , d_j) ^{1/p} \right) \qquad \ldots\ldots\ldots\ldots\ldots(8)$$

Where, P was taken as 1 (L_1) and ∞ (L_∞) representing 'longest' and 'shortest' distances in the geometric sense. The parameter P in the above expression weights the deviations according to their magnitudes. Greater weight is given to the longest deviations as the magnitude of P increases. Thus, with P = ∞ the maximum of the individual deviation is minimised δ_j represents the weights to d_j signifying the importance of the discrepancy between the j^{th} objective and its ideal value. In the study four sets of δ_j were considered to obtain the different compromise solutions under the assumptions of varying weights for the discrepancies. The magnitude of K in the present case was also four i.e., the number of objectives considered for optimisation. L1 representing the longest distance geometrically was minimised by using the following linear programming problem for obtaining the best compromise farm plan.

$$\text{Min } L_1 = \frac{\delta_1 (Z^*_j - Zj(\underline{X})}{Z^*_j - Z_{*j}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$$\underline{X} \in \underline{F} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

Where

F is the set of all feasible farm plans and

$\underline{X}$ is a vector of the decision variables.

$\underline{X} \in \underline{F}$ thus denotes the linear constraints and non-negatively restrictions component of the standard LP problem.

For L = ∞ where the maximum of the individual deviations is minimised, the best compromise farm plan was obtained by solving the linear problems.

Results and Discussion

The compromise programming technique used is able to bring about compromise solutions among the different conflicting objectives by minimising the absolute deviation between each solution and its ideal point is minimum.

a) Efficient set for various farming systems

The compromise efficient farm plan under various farming systems of small farms is furnished in table 1. The result recommended only 7 crop enterprises as compared to 15 crops presently cultivated by the farms. The recommendation in crop + sericulture farming system was 0.10 hectare (ha) of *Lycopersicum esculentim* and 0.07 ha *Morus alba* for all three seasons of the year. The crop included in rabi season (October - January) was 0.17 ha of *Solanum tuberosum* and 0.17 ha of *Solanum melongena* in summer for crop + dairy, and crop + poultry systems. In crop + sericulture farming system, it was suggested to have 0.10 ha of *Solanum melongena*. This might be due to the economic rationale of the farmers to mix subsistence enterprises with commercial enterprise even while selecting commercial enterprise the plan took in to consideration the risk – return trade-off. The other enterprises included 1.50 cross-bred dairy cow and 500 poultry birds for crop + dairy and crop + poultry systems. This might be due to the fact that the by products of one enterprises could serve as the input of the other enterprise.
The details of compromise efficient plan under various farming system for large farms is given in table 2 shows substantial increases in farm incomes through reorganisation of resources. It could be seen from the table that the increase in the farm income by 85 percent in the crop + dairy + sericulture system, 80 percent in the crop + dairy system and 79 percent in the crop + fisheries farming system. The increase in income might be due to the fuller utilization of land under tubewell irrigation. The result also revealed that based on the weightage given to each objective includes seven crop enterprises consisting of a combination of subsistence crops (*Elusine coracana* and *Oryza sativa*) to meet domestic consumption requirements and commercial crops like *Lycopersicum esculentum*, *Brassica oleracea var. botrytis*, *Solanum tuberosum* and *Morus alba*.

b) Labour employment

The details of employment in compromise efficient plan are presented in table 3. It could be seen from the table that plan would generate 31, 24 and 55 mandays, 12, 38 and 18 women days and 12,9 and 15 bullock days of additional labour in crop + dairy crop + poultry and crop + sericulture farming system, respectively in small farms over the existing level of employment. For large farms, compromise plan for crop + sericulture, crop + dairy and crop + dairy + sericulture system would increase employment by 55, 44 and 41 man days, 67, 34 and 38 woman days and 16, 12 and 18 bullock days, respectively.

Conclusions

The efficient farming systems developed through compromise programming exhibited the potential on farms in realising higher income and employment. This is the best compromise solution among conflicting goals/ objectives. Labour availability in the farms (particularly family labour) encouraged the crop + sericulture farming system in all categories of farms. The findings are as per expectations. There is a further role that the farming systems specialists should play an important role in training the extension workers with respect to integrated farming system approach.
Finally, the CP approach furnishes the decision maker the most efficient farming system, which is closer to reality than the one obtained by optimising a single objective as is normally done by a majority of farm management experts at present.

Table3: Labour employment in compromise farm plan

Sl. No	Farm system	Small farms			Large farm		
		Men	Women	Bullock	Men	Women	Bullock
1.	Crop + dairy farming system	528 (31)	498 (12)	88 (12)	741 (44)	389 (34)	232 (12)
2.	Crop + poultry farming system	522 (24)	546 (38)	86 (9)	744 (32)	397 (25)	239 (11)
3.	Crop + sericulture farming system	572 (55)	547 (18)	108 (15)	802 (52)	487 (67)	250 (16)
4.	Crop + fisheries farming system	--	--	--	723 (29)	359 (37)	224 (14)
5.	Crop + dairy + poultry farming system	--	--	--	--	--	--
6.	Crop + dairy + sericulture farming system	--	--	--	742 (41)	378 (38	238 (18)

*Figures in parentheses indicate the increase in employment in days over the existing farming system

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