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An Empirical Test of Multiple Objective Vs Single Objective Decision Making in Agricultural Production

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ABSTRACT: This study was conducted to determine the allocative efficiency of resources of subsistence farmers in the Hanguranketa and Walapane divisions of Nuwara Eliya District, Sri Lanka. The unit of analysis was a representative farm constructed from a sample of 50 farms. Linear programming, Minimization of Total Absolute Deviation (MOTAD), and goal programming models were run. The results show that the farmers efficiently allocate their limited resources among alternative farm enterprises and they possess multiple objectives such as maximizing profit, minimizing risk, and subsistence production. The results further indicate that the goal programming model can predict the farmer behaviour more accurately than the linear programming model and MOTAD.

INTRODUCTION

There is ample literature which have tested the economic rationality of farm producers based on the behavioral assumption of profit maximization (Sirohi & Gangwan, 1968). Most of these studies assume that even the small farmers maximize profits within their technological, institutional, and resource constraints. As a result most of these studies conclude that there are inefficiencies in the allocation of factors of production in small farm traditional agriculture.

On the contrary, Shultz (1964) asserts that small farmers though poor are efficient. Therefore, researchers searched for new techniques to predict the individual producer's behaviour. This new method hypothesized that inadequate treatment of risk was a major factor accounting for the differences between actual and predicted individual behaviour (Anderson, 1977). As a result risk minimization was considered as an additional objective of the individual producers. Programming techniques such as quadratic programming, sequential programming, and MOTAD were used for analysis.

Although the behaviour is usually assessed by a single criterion objective function, small farmers possess multiple objectives rather than single objective such as profit maximization. Several techniques have been developed to analyze situations having multiple objectives. These techniques however, have not been adequately applied to farm planning and prediction of farmer behaviour.

The objective of this paper is to assess individual producer behaviour using a multiple objective decision making model. This is achieved by comparing the actual farm plan with those predicted by general linear programming, MOTAD, and goal programming models.

METHODS

Goal programming

Goal Programming (GP) is an optimization technique for solving problems involving multiple goals. It was developed for multiple objective decision making by Charnes and Cooper (1961), (Cited in Bernett, Blake and McCarl, 1982). Unlike linear programming, GP contains a composite objective function. The idea is to minimize deviation from specified levels of two or more goals. The composite objective function can be stated in one of two ways. The first one is lexicographic goal programming which assumes that goal satisfaction occurs in a sequential order. The second one is Weighted Goal Programming (WGP) which assumes that goal satisfaction may be traded off using relative cost weights on deviation from target levels.

Mathematically WGP problem can be expressed as follows:

$$\text{Minimize } \Sigma_i \ (w_i^+ * d_i^+ \ + \ w_i^- * d_i^-)$$

$$\text{Subject to } \Sigma_i \ Gi_j \ X_j \ - \ d_i^+ \ + \ d_i^- \ = g_i, \quad \text{For all i}$$

$$\Sigma_j \ a_{kj} \ X_j \ <= b_k, \text{ For all k}$$

$$X_j \ , \ d_i^+ \ , \ d_i^- \ >= 0, \text{ For all i and j}$$

Where:

d_i^+ = Amount of positive deviation or over production

d_i^- = Amount of negative deviation or shortage

w_i^+ = Weight or relative importance – Return to over satisfaction

w_i^- = Weight or relative importance – Return to under satisfaction

G_{ij} = Coefficient of objective achievements

X_j = Decision variables

a_{kj} = Amount of resource k required to produce a unit of output j.

b_k = Endowment of the k th resource.

Subscript i refers to goals

j refers to decision variables or activities

k refers to constraints

For a given goal d_i^+ or d_i^- must always be zero in the solution, because it is not physically possible to have both under achievement and over achievement at the same time.

Empirical model

For the analysis data were collected by a survey of 50 farmers in Hanguranketa and Walapane divisions of the Nuwara Eliya district. A representative farm was constructed using this information. The characteristics of the representative farm are as follows.

paddy land = 0.8 ac.; non paddy land = 0.8 ac.; Cash borrowings Rs. 4500.00 and Rs. 2620.00 in *Maha* and *Yala* seasons respectively; non constraint on hired labour; cultivate four to five crops in a year; crops are paddy, beans, cabbage and brinjal.

Linear programming formulation of the problem

The LP model was constructed to maximize an objective function in gross margin; with land, labour and capital as constraints. The gross margin was calculated by subtracting total variable cost excluding family labour from total net revenue. Twelve constraints were used for family labour and another twelve constraints were used for hired labour. Two constraints were taken for *Yala* working capital and *Maha* working capital. A capital transfer activity from *Yala* to *Maha* season and capital borrowing activities for the two seasons at the current rate of interest of 14% per annum were also included. Eight crop production activities were considered.

MOTAD formulation of the problem

The MOTAD formulation considered price risk as the main criteria. Prices of six seasons were taken from published sources and were deflated using Colombo Consumers Price Indices. These deflated prices were used to compute the gross margins, the expected values and the deviations of each crop. The constraints of the MOTAD were the same as those of the LP formulation. However, the objective function was shifted from profit maximization to minimization of deviation.

Goal programming formulation of the problem

Hazell's (1971) approach on MOTAD defines efficiency in terms of expected income and risk in the form of mean absolute deviation. Therefore, the MOTAD approach can be considered as a multiple objective programming model with two objectives. Besides the structure of the model facilities its use as a GP model (Romero and Rehman, 1985). The GP model was formulated by incorporating the additional objectives into the MOTAD.

The following section summarizes the formulation of the objective function.

1. Maximizing expected gross margin (EXP) goal can be formulated as follows:

$$\Sigma_j \, EXP_j \, X_j + d_1^- - d_1^+ = Z_1$$

where, d_1^+ = Over achievement of the gross margin goal, and
d_1^- = Under achievement of the gross margin goal.

The goal of avoiding over achievement is:

$$\text{Min } Z = w_1 * d_1^-$$

2. Subsistence requirement of paddy (SUB) goal can be formulated as follows.

$$\Sigma_j \; SUB_j \; X_j \; + \; d_2^- \; - \; d_2^+ \; = \; Z_2$$

where, d_2^+ = Over achievement of the paddy consumption goal, and

d_2^- = Under achievement of the paddy consumption goal.

The goal of avoiding under achievement is:

$$\text{Min } Z = w_1 * d_1^- + w_2 * d_2^-$$

3. Risk minimizing (MOTAD) goal can be formulated as follows.

$$\Sigma_j \; MOT_j \; X_j \; + \; d_3^- \; - \; d_3^+ \; = \; Z_3$$

where, d_3^+ = Over achievement of the risk goal, and

d_3^- = Under achievement of the risk goal.

The goal of avoiding over achievement is:

$$\text{Min } Z = w_1 * d_1^- + w_2 * d_2^- + w_3 * d_3^+$$

This composite objective function and goal equalities were included in the MOTAD formulation. The GP objective function is given in Table 1.

RESULTS AND DISCUSSION

The deviation of the following variables in the actual farm plan was considered as the verification criteria. a) Crop mix, b) Gross margin generated, and c) Land extent cultivated. Table 2 shows the levels of

Table 1. Goal Programming Formulation of the problem.

No.	d1+	d1−	d2+	d2−	d3+	d3−	Type	b
Z		100		12	0.02			
Mot			− 1	1			E	0
Sub	− 1	1					E	75
Exp					1	− 1	E	75,000

Table 2: Comparison of LP, GP and MOTAD models with actual behaviour (land, area in acres).

Item	Actual	LP	MOTAD	GP
X1 (Maha paddy)	0.800	–	0.800	0.8000
X2 (Yala paddy)	0.800	0.800	–	0.7057
X3 (Maha beans)	0.260	1.600	–	0.6113
X4 (Yala beans)	0.320	–	–	–
X5 (Maha cabbage)	0.112	–	0.620	0.1887
X6 (Yala cabbage)	0.174	–	0.800	0.0943
X7 (Maha brinjal)	0.078	–	–	–
X8 (Yala brinjal)	0.075	–	–	–
Gross Margin (Rs.)	6123	8106	6857 – 8433	6625 – 7855

each of these variables in the farm plan of the representative farm, and the resulting farm plan given by LP, MOTAD and GP models.

Crop mix

It is clear that the LP and MOTAD models are unable to explain the actual behaviour as far as crop mix is concerned. According to LP model farmers grow only bean in *Maha* and paddy in *Yala* season, and according to MOTAD model they grow paddy in *Maha* and cabbage in both seasons whereas farmers grow all the crops: paddy, beans, cabbage and brinjal in *Yala* and *Maha* season in the actual situation. Only GP model shows a consistency according to this criteria, showing the cultivation of paddy in *Maha* and *Yala*, beans in *Maha* and cabbage in *Yala* and *Maha*. However, none of the models include the cultivation of brinjal which is of less significance when compares to the other crops.

Land allocation

Only the results of the GP are plausible and similar when land allocation to the different crops is concerned. It includes paddy in both seasons at maximum availability of paddy lands; beans in *Maha* and cabbage in both seasons. However, according to the GP model farmers grow beans only in the *Maha*. The actual practice is not exactly the same and it may be due to the inadequate formulation of the GP model.

Although the MOTAD results exhibit a little superiority over LP formulation it does not show the cultivation of beans which is the most common crop in this area. Practically almost all the farmers grow beans wherever possible.

Gross margin generated

All the models generated gross margins that were higher than the actual gross margins received by the farmers. LP model shows the highest which is Rs. 8106.58. Gross margins generated by MOTAD and GP formulations are within the range of Rs. 6857 – 8433 and Rs. 6625 – 7855 respectively. The average gross margin gained by a typical farmer is Rs. 6123. GP model has a value closer to the actual than the other two models.

Sensitivity of the farm plan

The chosen programming model, goal programming model was taken to find out the sensitivity of capital, land and labour resources of the farm plan.

Capital: Available capital do not constrain the solution.
Farm plan is also insensitive to the changes in the interest rate up to the tested level of 20%.

Land: As shown by the solution, land constraints the solution. The current farm plan is insensitive land sizes between 0.7 and 1.1557 acres for *Yala* low land, between 0.7 and 0.9423 acres for *Maha* low land and between 1.5431 and 1.8641 acres for *Maha* total land.

CONCLUSION

The objective of this study was to determine how closely farmers behaviour can be predicted using LP, MOTAD and GP models. Results show that farmers efficiently allocate their resources. As far as the different models are concerned, the GP model performed better than LP and MOTAD generating results consistent with the actual behaviour. The multi objective model does exhibit superiority over comparable profit maximizing and risk minimizing models.

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