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Research Note

OPTIMUM CROPPING PLAN FOR A SAMPLE OF FARMS IN A FARMING SYSTEM RESEARCH AREA OF BANGLADESH.

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ABSTRACT

Optimum cropping plan has been developed using data from a sample of 40 farms in a farming system research area of Mymensingh district. The results revealed a considerable divergence between the existing and optimal crop plans under both restricted and unrestricted capital situation. Among the crops incorporated in the optimal plan under restricted capital, Aman (LV) found the prime place in the Kharif-II land under non-irrigated situation, accounting for 33 per cent of the total cropped area. When capital restriction was relaxed, brinjal (summer) was the most dominant crop occupying 39 per cent of total cropped area. The optimal return with unrestricted capital was 49 per cent higher than the existing return from the crop enterprises. The results imply that serious efforts need to be directed to remove credit constraints for improving farm incomes of the typical farms studied in the area.

1. INTRODUCTION

The study of farm management involves three successive stages :(i) analysis of the present position of the farm business, (ii) interpretation of the present position for indication of possible improvements and (iii) preparation of an acceptable course of action for improvement of performance of the farm business. The first stage falls within the class of positive analysis wherein the existing level of performance is examined by arithmetic or rigorous mathematical techniques including sophisticated functional analysis. The usual approach is to examine the level of performance of a farm or group(s) of farms and compare it with the 'standard' or 'average' performance in the locality. The second and third stages identified above fall within the purview of normative analysis which seeks to determine what should be done to the farm(s) for improvement of performance.

Most farm management studies in Bangladesh have been concerned with analysis of existing performance in the arithmetic fashion, usually of groups of sample farms selected under certain criteria. Some studies attempted production function analyses revealing the

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marginality conditions of resource use with respect to production of individual or selected enterprises (Hossain 1974, Jabber 1976, Mandal 1979, Talukder 1980, Alam 1983, Ahmed 1992). Such type of analysis, in addition to being very partial in nature, addresses only the existing aspect in the organization and operation of the farm business, and fails to answer as to what would be the optimum combination of enterprises under given restraining conditions.

Performance analysis using arithmetic and functional analysis may reveal a particular enterprise to be highly profitable. However, there may be serious limits to expansion of the enterprise, imposed by physical, economic, social and environmental constraints. Thus maximization of overall profit of a farm business is governed by a number of constraints which need to be accommodated in planning a farm. Such an approach calls for programming exercise in the planning process of farm. Linear programming (LP), as applied to farm planing, represents a systematic method of determining mathematically the optimum plan for the choice and combination of farm enterprises, so as to maximize income or minimize costs within the limits of the available farm resources (Yang 1965). Although the application of LP is constrained by its assumptions, the technique has a great advantage in that it can provide an accurate solution to a large and complex problem within a very short time. Besides, LP generates other additional information such as marginal value products of scarce resources which are often useful in indicating the line along which efforts should be directed to relax operational constraints.

This study is a modest attempt to apply linear programming for determining an optimum cropping plan for a sample of farms practising Crop-Cattle-Poultry-Fish farming system in a selected area of Mymensingh district. The data and methodology are discussed in section II. Some results pertaining to the existing and optimal plans are presented in section III and some conclusions are drawn in section IV of the paper.

II DATA AND METHODOLOGY

Data for the study were collected through farm survey from a sample of 40 farms practising Crop-Cattle-Poultry-Fish farming system in the two villages-Kazirshimla and Kanhor of Mymensingh district. The sample frame for selection of the sample was obtained from the office of the Farming System and Environmental Studies (FSES) project run by a team of researchers of Bangladesh Agricultural University, Mymensingh. Data were collected for one year of operation of farms beginning from July 1993 to June 1994. This period covered three rice crop seasons namely Boro, Aus and Aman, and a truncated picture of other farm enterprises falling within this period. For the purpose of the present paper, data relating to only the crop component were utilized. Data for the sample of 40 farms were averaged and converted into input-output coefficients of a representative farm for feeding into the LP matrix.

Formulation of the LP Model

The objective function set for the study was to maximize the return over variable cost (gross margin), where the return represented the product term of average yield of an enterprise and its unit price. The variable costs referred to the costs associated with use of the variable inputs. The general deterministic linear programming model of the study was specified as :

$$\text{Maximiz} : Z = \Sigma C_j X_j - \sum_{t=1}^{8} W_h L_t - \sum_{t=1}^{4} W_b K_t - \sum_{t=1}^{2} W_p P_t - rM$$

Subject to :

1) (Land) $\sum_j l_{js} X_j \leq L_s$ (s = 1, 2, 3, 4)

2) (Human labour) $\sum_j h_{jt} X_j - Lt \leq H_t$ (t = 1, 2, 3, 4, 5, 6, 7, 8)

3) (Bullock labour) $\sum_j b_{jt} X_j - K_t \leq B_t$ (t = 1, 2, 3, 4)

4) (Tractor/power tiller) $\sum_j d_{jt} X_j - P_t \leq D_t$ (t = 1, 2)

(5) (Capital) $\sum_j C_{jt} X_j - M \leq C$

6) (Minimum cereal requirement) $\sum_j f_k X_k \geq F^{(min)}$

were,

Z = Total gross margin in Taka.
C_j = gross margin of the j^{th} crop activity.
X_j = area under j^{th} crop activity.
W_h = wage rate per unit of human labour.
L_t = number of hired human labour in t^{th} period.
W_b = wage rate per unit bullock labour.
K_t = number of hired bullock labour in t^{th} period.
W_p = hiring rate per unit of tractor/power tiller.
P_t = tractor/power tiller hired in t^{th} period.
r = rate of interest (Tk) for six months.
M = amount of capital borrowed.
l_{js} = land coefficient for j^{th} crop on s^{th} type of land
h_{jt} = labour requirement in mandays for j^{th} crop activity in t^{th} period
b_{jt} = bullock labour requirement in pair of days for j^{th} crop activity in t^{th} period.

d_{jt} = tractor/power tiller requirement or j^{th} crop activity in t^{th} period in hours.
c_{jt} = capital requirement in taka or j^{th} crop activity in t^{th} period.
f_k = . cereal production in kg of k^{th} cereal crop activity.
X_k = the level of the k^{th} cereal crop activity.
L_s = available s^{th} type of land in hectare.
H_t = human labour (mandays) available in t^{th} period.
B_t = bullock labour (pair days) available in t^{th} period.
D_t = tractor/power tiller available in t^{th} period.
C = amount of capital available.
$F^{(min)}$ = minimum cereal requirement of the farm family.

and non-negativity restrictions;

$X_j \geq 0$, $Lt \geq 0$, $Kt \geq 0$, $Pt \geq 0$, $M \geq 0$.

Thus maximization of the objective function as employed in this study represents maximization of gross margin which is the return over variable cost. As human labour hiring, bullock labour hiring, tractor/power tiller hiring and capital borrowing have been treated as separate activities, costs of these activities have not been charged in the calculation of gross margin of individual crops.

In this study individual crops have been considered as real activities. A total of 20 such activities were included in the model of which 10 were irrigated and the other 10 were non-irrigated crop activities.

Identification and specification of resource constraints is of vital importance in linear programming exercise. In the context of Bangladesh farming, the most limiting resources in farm production are land and capital. In addition, human labour and draft power also become restrictive in certain periods of the year. It also seems plausible to assume that farmers would like to ensure minimum cereal requirement of the farm family out of their operation of the farm business. This consideration can also act as a limiting condition in planning for organization and operation of the farm. Having taken all these considerations into account, six restrictions were incorporated in the model. These were land, human labour, bullock labour, power tiller, capital and minimum cereal requirement constraints.

For a typical farm considered in the present study, optimization was done on an average of 0.97 hectares of land and four types of land restrictions were considered e.g. Kharif-I, Kharif-II, Rabi irrigated and Rabi non-irrigated.

For setting up human labour restriction, seasonal operationwise requirements of labour for different crops were determined in consultation with the respondent farmers. There were certain peak operational periods when existing farm family labour was inadequate for meeting the requirements and some casual labour had to be hired for accomplishing the required farm operations within time. These peak periods of labour shortage have been used for defining labour resource constraint. Eight such labour shortage periods identified wre February, March, April, May, July, August, November and December which were incorporated in the model as different periods of labour restrictions.

Bullock power restriction was set in a similar way as for human labour. Bullock power constraint was considered for February, April, July and November when land preparation activity was intensive in the field. In addition to use of bullock power, tractor/power tiller hiring was a common practice in the study area. The availability of tractor/power tiller in terms of hours was considered as a constraint for April and December when its demand rose at peak.

One of the objectives of the present study was to find out the need for operating capital of the typical farm and to assess the farm income under unbounded capital use. However, no evidence was available as to the amount of capital a farmer would require to invest for crop production in a year. Some trial run of LP was made to determine marginality condition such that the marginal value product (MVP) of capital was equal to its marginal factor cost (MFC). It was found that if an average farm cultivating 0.97 hectares of land could invest Tk. 12000 per year as operating capital, the MVP of capital would be equal to its MFC. Therefore, capital constraint was fixed at Tk. 12000 in the study.

Family food supply, another possible constraint in farm planning, was also incorporated in the model. It was revealed from the field survey that farmers wanted to cover at least that much area by cereal crops that was needed to fulfill their home consumption requirement. For ascertaining minimum annual requirement of foodgrains for a typical family, each of the respondent farmers were asked to report the minimum foodgrain requirement of his own family. It was estimated that an average farm family would require a minimum of 1318 Kilograms of cereal (rice and wheat) per annum for home consumption. Thus minimum cereal production of 1318 kg per annum was set as a constraint and was incorporated in the model.

III. ANALYSIS OF RESULTS

The purpose of the study has been to examine the existing resource allocation pattern and to find out optimum crop plan to see how far the profitability of the farms can be improved if the resources are reallocated optimally. In other words, attempt is made here to examine whether there is any divergence between returns to the resources actually realized and those which would be realized if the given resources were reallocated optimally. Two sets of optimum plans have been tried : one with restricted capital and the other with unrestricted capital.

Land Allocation Under Existing and Optimum Plans

Existing Land Use Pattern

The existing land use pattern together with the emerging optimal allocation of land with restricted and unrestricted capital situations for the representative farms are presented in Table

1. Of all the crops in the existing plan, Aman (MV) emerged as the most predominating one occupying about 25 per cent of gross cropped area. This was followed by Boro (MV), Aman (LV) and Aus (MV). It would be evident from Table 1 that more than 80 per cent of the area was occupied by the paddy crop and the remaining 20 per cent was covered by wheat, jute and other vegetable crops. The study area was not a major wheat producing area because the available irrigation facilities were used for irrigating Boro paddy and there was little scope for ensuring irrigation for growing wheat.

Optimum Land Use Pattern with Restricted Capital

Optimization and reallocation of available resources was found to bring significant changes in the existing land use pattern. Due to optimization, Aman (LV) found the prime place in the kharif-II land under non-irrigated situation accounting for roughly 33 per cent of the total cropped area. The next dominant crop was jute which occupied about 16 per cent of the total cropped area in the kharif-I land under non-irrigated situation and Aus paddy found no place in the optimal plan. Among rabi crops, mustard covered 16 per cent of gross cropped area in the optimal plan under irrigated situation. A comparative analysis of the optimal crops under various seasons reflect that Aman (LV) is the most predominant crop for all the rotations. Jute also turned out important crop which needed an increase in area allocation. Aus (LV), Aus (MV), 'data', lentil, onion, brinjal (winter), radish, bittergourd and spinach did not find any place in the optimal plan.

Optimum Land Use Pattern with Unrestricted Capital

When capital restriction was relaxed, the optimum plan of the representative farm indicated some variation in the area allocation. Brinjal was the most dominant crop in the Aman season under non-irrigated situation which occupied 39 per cent of total cropped area. Although separate information on production of brinjal is not available in the study area, Talukder and Begum (1993) found that per hectare gross margin from all vegetable crops was the highest of all the field crops in the same study area. The next dominant crop was Boro (MV) which accounted for roughly 22 per cent of total cropped area. This was followed by Aman (MV) and cucumber which also marked a considerable increase in gross cropped area over the plan under restricted capital. The increase in area for these crops may be the result of complete elimination of the economically less paying crops from the plan. Relatively less number of crops emerged in this plan compared to the number of crops in the optimum plan under restricted capital situation. Aman (LV) which occupied substantial area in the existing plan, was completely eliminated from the optimal plan under unrestricted capital situation. When capital restriction was ignored, brinjal (summer) turned out to be the dominating crop in the plan. Except wheat, area in all other crops entering this plan needed to be increased over the optimal plan with restricted capital. These shifts occured primarily because of the relaxation of the capital constraint which permitted cultivation of the more capital intensive and remunerative crops.

A summary of the results of capital-resource variable programming is presented in Table 2. Figure 1 is the graphical representation of the data corresponding to Table 2 containing

Table 1 : Allocation of Land to different crops under existing and optimal plans

Crops	Area in hectare		
	Existing plan	optimum plans	
		with restricted capital	with unrestricted capital
1. Aus (LV)	0.06 (3.80)	-	-
2. Aus (MV)	0.18 (11.39)	-	0.26 (16.46)
3. Jute	0.01 (0.63)	0.26 (16.46	-
4. Data	0.01 (0.63)	-	-
5. Aman (MV)	0.40 (25.33)	0.05 (3.16)	0.09 (5.70)
6. Aman (LV)	0.25 (15.82)	0.52 (32.91)	-
7. Brinjal (summer)	0.05 (3.16)	0.13 (8.23)	0.61 (38.61)
8. Boro (MV)	0.39 (24.69)	0.04 (2.53)	0.34 (21.52)
9. Wheat	0.09 (5.70)	0.16 (10.13)	0.03 (1.90)
10. Lentil	0.01 (0.63)	-	-
11. Chickpea	0.02 (1.27)	0.03 (1.90)	-
12. Patato	0.01 (0.63)	0.01 (0.63)	0.04 (2.53)
13. Mustard	0.01 (0.63)	0.25 (15.82)	-
14. Onion	0.01 (0.63)	-	0.07 (4.43)
15. Cucumber	0.02 (1.27)	0.07 (4.43)	0.14 (8.86)
16. Sweetgourd	0.02 (1.27)	0.06 (3.80)	- -

Crops	Area in hectare		
	Existing plan	optimum plans	
		with restricted capital	with unrestricted capital
17. Brinjal (winter)	0.01 (0.63)	-	-
18. Radish	0.01 (0.63)	-	-
19. Bittergourd	0.01 (0.63)	-	-
20. Spinach	0.01 (0.63)	-	-
All crops	1.58 (100.00)	1.58 (100.00)	1.58 (100.00)

Note : Figures in the parentheses are percentages of total cropped area.

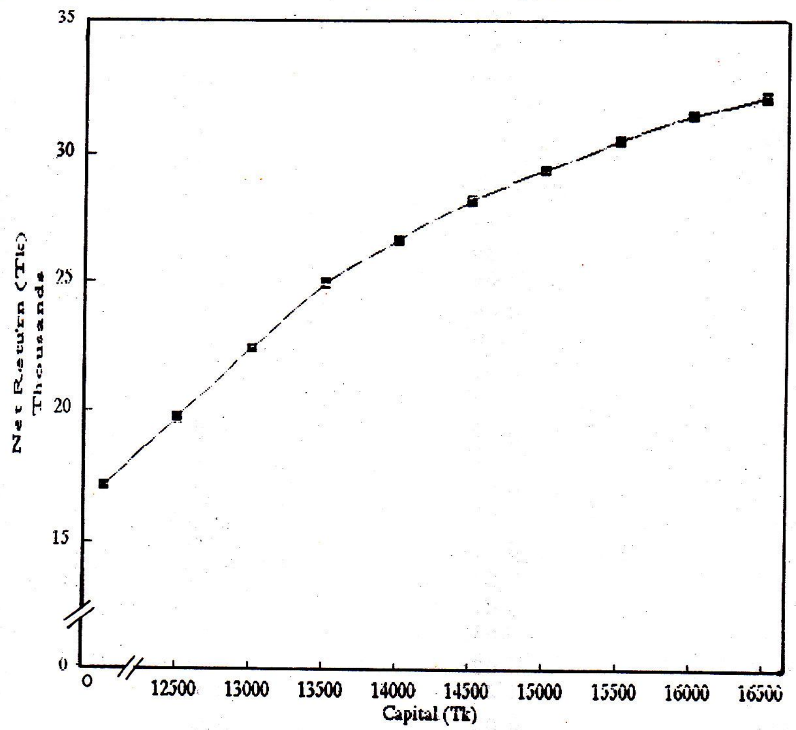

Fig. 1. Relationship Between Net Return and Capital

Table 2 : Summary of the capital-resource variable programming for the sample farms

Capital needed (Tk.)	Crops in hectare															Net return (Tk.)
	Jute	Aus (MV)	Aman (MV)	Aman (LV)	Brinjal (summer)	Boro	Wheat	Lentil	Chick-pea	Potato	Mustard	Cucum-ber	Sweet-gourd	Brinjal (winter)	Onion	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12000	0.26	-	0.05	0.52	0.13	0.04	0.16	-	0.03	0.01	0.25	0.07	0.06	-	-	17144.50
12500	0.26	-	0.17	0.34	0.19	0.04	0.14	-	0.04	0.005	0.27	0.07	0.06	-	-	19783.91
13000	0.26	-	0.30	0.16	0.24	0.04	0.12	-	0.04	0.003	0.29	0.07	0.05	-	-	22423.32
13500	0.26	-	0.40	-	0.30	0.04	0.2	-	0.04	0.003	0.30	0.07	0.05	-	-	24953.55
14000	0.26	-	0.30	-	0.40	0.04	0.26	-	0.02	0.02	0.14	0.07	0.06	-	-	26575.94
14500	0.26	-	0.22	-	0.48	0.04	0.40	0.01	-	0.03	-	0.07	0.07	-	-	28158.38
15000	0.20	0.06	0.18	-	0.52	0.04	0.41	0.004	-	0.04	-	0.09	0.05	-	-	29342.00
15500	0.16	0.10	0.14	-	0.56	0.04	0.42	-	-	0.04	-	0.10	0.01	0.01	-	30480.48
16000	0.09	0.17	0.11	-	0.59	0.03	0.40	-	-	0.04	-	0.12	-	0.07	0.02	31437.95
16500	0.01	0.25	0.09	-	0.61	0.03	0.36	-	0.01	0.03	-	0.14	-	-	0.06	32083.29

the results of resource (capital) variable programming. In the figure, the horizontal axis represents the amount of capital, while the vertical exis record different levels of the net returns. Figure 1 reveals that with the increase in the amount of capital needed, net return also increased upto certain level. When needed capital were Tk. 12000 and Tk. 16500, net returns were Tk. 17145 and Tk. 32083 respectively. If needed capital exceeds Tk. 16500, net return from different crop production diminishes. Thus there appears to be a ceiling of operating capital requirement beyond which use of operating capital brings about decreasing net returns from the crop enterprises.

Effect of Optimization on Farm Income (Gross Margin)

The returns per unit of land, which is a binding constraint, is taken as a measure of efficiency. A picture of net returns yielded by the optimal plan is presented in Table 3.

Table 3 : Net returns in the existing and optimal plans with restricted and unrestricted capital positions.

Items of information	Empirical magnitudes
1. Existing returns (Taka)	16257.75
2. Optimal returns with restricted capital (Tk.)	17144.50
3. Percentage increase in optimal return with restricted capital over existing returns	5.17
4. Optimal returns with unrestricted capital (Tk.)	31906.21
5. Percentage increase in optimal returns with unrestricted capital over existing returns	49.05
6. Additional capital (Tk.)	4707.68
7. Additional returns (Tk.)	14761.71
8. Return per additional unit of capital (Tk.)	3.14

The table as a whole portrays a favourable impact of optimum land and non-land resource allocation on the net farm returns. An improvement in income level of 5.17 per cent is observed in the case of restricted capital over existing returns. Furthermore, the relaxation of capital constraint led to an increase in the returns from Tk. 16257.75 in the existing plan to Tk. 31906.21 in the optimum plan with unrestricted capital i.e. an increase by 49.05 per cent. The additional capital was less than the additional capital required under the optimal plan. This would imply that capital acted as a severe constraint. A clear indication that may follow is that even with the limited capital resources presently available with the farms, a change in the crop plan would positively enhance the existing farm incomes. However, if additional capital is made available to these farms, it would further increase the net farm returns, even at the existing level of technology. The overall results reveal that there is scope of augmenting the net farm income in all the farms if capital constraint is relaxed.

The most profitable crops revealed from the results should be interpreted with some degree of caution. It should be noted that the actual areas devoted to the crops were very small, although their per hectare gross margins were quite high. These crops may have been profitable for that specific area and may not hold true for other areas of the country. Moreover, the sample size for the study was too small to allow for any broader generalization to be made out of the results of the study.

IV. CONCLUSIONS

The results of the LP exercise showed that resource allocation patterns in the optimum plan both with restricted and unrestricted capital were remarkably different from that in the existing plan. In general, optimum plan suggests lesser degree of diversification in crop production than is currently being practised. A good number of crops currently being produced need to be eliminated from the farm plan.

The results also showed that net returns from crop production increased with increase in the level of capital. Howeer, given the resource endowments and other constraints, there remains enough scope to improve returns from the crop components by reorganizing the enterprises and reallocating resources to the desired enterprises. The optimum plan appeared to be capital intensive and at the same time highly profitable. It implies that the provision of credit may help to expand the area under more remunerative crops, However, the results obtained from the study are based on a small sample of farms in a limited area. Moreover, area devoted to some of the crops were too small to generate any robust input-output coefficient. Thus sufficient caution should be exercised in making generalizations out of the results of the study.

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