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SMALL FARM PLANNING UNDER RISK : AN APPLICATION OF PARAMETRIC LINEAR PROGRAMMING

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ABSTRACT

The present study was undertaken at the farming systems research area of Jessore district to evolve risk efficient plans. Results of risk programming demonstrate that higher gross margin, labour employment and tractor/power tiller utilization were associated with higher risk. Land utilization increased along with the gross margin-risk frontier. Capital borrowing increased the risk bearing ability of the plans. Capital investment gradually increased with the increase in gross margin and risk. The results showed direction of resource use for minimizing risk at various levels of gross margins. Thus, the results would help in suggesting suitable production plan for the small farms. The farmers can choose the plans according to their personal attitude to risk. This knowledge regarding alternative opportunities corresponding to risk can be of immense help in farm decision making under risky situations.

I. INTRODUCTION

Linear programming is a mathematical model with a linear objective function, a set of linear constraints, and nonnegative variables (Anderson, Sweeney and Williams, 1985). There is substantial body of literature on the application of linear programming to examine the potentialities for improving income and employment under conditions of certainty. There is little evidence of any effort to inquire into the possibilities of maximizing income under conditions of uncertainty. The world is really marked by risk and uncertainty due to variability in yields and prices. Maximizing farm returns under these conditions by suggesting an efficient enterprise system is considered as one of the important ways to improve the growth prospects of the farm-firms (Singh and Jain, 1983). The present study was, therefore, undertaken to workout risk efficient plans in a farming systems research area of Jessore district.

The paper has been organized in four sections. The data and the model are discussed in section II. Some results pertaining to the optimum plans with miniized risk are

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presented in section III. The conclusions and policy implications of the paper are provided in the final section.

II. THE DATA AND THE MODEL

Sources of the data

Both primary and secondary data were used for the study. Primary data were collected through farm survey from a sample of 150 small farms at the Bagherpara Farming Systems Research (FSR) site, Jessore. The FSR site consists of eight villages, namely Dadpur, Debinagar, Rustompur, Bolarampur, Syed Mamudpur, Darajhat, Budhpur, and Parkul. At first, all farmers in the study area were listed according to their land holdings so as to identify the small farmers. In all, there were 301 small farmers in the study area. The list of the small farmers was arranged in order of possession of land area from 0.51 to 2.49 acres. Then, 150 small farmers were selected from the list by systematic sampling method. Each farmer was personally interviewed with the help of pre–tested interview schedule designed for the study. Data pertaining to one agricultural year 1989–90 were collected from the sample farmers. This period covered three rice crop seasons namely *Aus, Aman* and *Boro,* and a truncated picture of other farm enterprises falling within this period. The sample farms were classified into pure owner and owner–cum–tenant farms. Pure owner farms were those cultivating their owned land and owner–cum–tenant farms were those cultivating rented–in land along with whole or part of their owned land.

Secondary data of yields of different crops for 17 years from 1973–74 to 1989–90 of Jessore district were used for the study. Yields of different crops were collected from various published sources (BBS 1985, 1987, 1989 and 1993; and Hamid, 1991).

The model

The optimum plans that could be obtained with the help of deterministic linear programming technique do not take into consideration the stochastic nature of the enterprises. Parametric linear programming similar to MOTAD (minimization of total absolute deviations) can incorporate the risk element associated with the enterprise gross margins. The E–V (expected income–variance) frontier of quadratic programming was replaced by E–A (expected income–mean absolute deviation) frontier in the MOTAD model which also takes note of the utility function of the farmers. Therefore, parametric linear programming similar to MOTAD has been applied in this study. The mean absolute deviation of the activity gross margins was considered to represent the risk attached with these enterprise gross margins.

Mean absolute deviation was defined as:

$$A = S^{-1} \sum_{h=1}^{S} \left| \sum_{j=1}^{n} (C_{hj} - g_j)\, x_j \right| \qquad \text{............ (1)}$$

where,

A = estimated mean absolute deviation

S = number of gross margin deviations

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

g_j = sample mean of gross margins of j^{th} activity

x_j = level of j^{th} activity.

Since 'S' in equation (1) is constant, Hazell (1971) suggested minimization of SA – the total absolute deviation. Now, equation (1) takes the form :

$$SA = \sum_{h=1}^{S} \left| \sum_{j=1}^{n} (C_{hj} - g_j)\, x_j \right| \qquad \text{......... (2)}$$

However, in the present study, since the trend component was predominant in gross margin series, following Hazell, a slight modification was made in the original model. In place of g_j, the present study used g_{hj} to mean the trend of gross margins of the j^{th} activity in h^{th} year.

Thus, the model took the form:

$$SA = \sum_{h=1}^{S} \left| \sum_{j=1}^{n} (C_{hj} - g_{hj})\, x_j \right| \qquad \text{......... (3)}$$

Where, SA means the sum of the absolute trend deviations of the gross margins.

Objective function

The objective in the parametric linear programming was to minimize the absolute trend deviations of gross margins subject to the constraints. The objective function used was of the following form :

$$\text{Minimize } Zo = \sum_{h=1}^{17} Y_h^-$$

where,

Zo = absolute total trend deviations

Y_h^- = absolute negative trend deviations for the h^{th} year.

Resource Constraints or Resource Supplies

Six restrictions were incorporated in the model. These were land, human labour, bullock labour, tractor/power tiller, capital and minimum cereal requirement constraints. A datailed discussion on the formulation of these constraints can be seen in Alam (1994). In addition to the usual constraints of the linear programming model, the MOTAD formulation involves two more constraints, namely gross margin deviation constraint and expected gross margin constraint.

Gross margin deviation

The MOTAD model requires time series of gross margins for the activities in question. Gross returns were calculated for various crops based upon 17 years time series data on yields and constant harvest prices prevailed in 1989–90. Gross margins were obtained by deducting the constant costs of production based on constant input prices for 1989–90 from the gross returns. The assumption of constant cost over the years was indispensable since costs for different years were difficult to obtain. This constant cost assumption has been made by many researchers in their studies. Data on *mukhikachu* cultivated by farmers were available for 13 years. The data for rest of the years of the series were generated by linear extrapolation.

The gross margins of the crops so obtained were then tested for the presence of trend using the equation Y = a + bt. In the present study, the gross margins of the crops were later subject to test for normality. Numerous methods are available for testing the normality of a sample. Two commonly tests are Shapiro–Wilk and Lilliefor. The Lilliefor test is based on a modification of the Kolmogorov–Smirnov test for the situation when means and variances are not known but must be estimated from the data. The Shapiro–Wilk test has been found to have good power in many situations when compared to other tests of normality (Conover, 1980). For this study, Shapiro–Wilk and Lilliefor tests were used for testing as to whether the gross margins were normally distributed. It should be mentioned here that only yield risk was considered for calculating the gross margins.

The gross margin deviation constraint used in the model was specified as below :

$$\sum_{j=1}^{n} (C_{hj} - g_{hj})\, x_j + Y_h^- \geq 0 \qquad \text{(for all h;} \qquad h = 1, 2, \ldots\ldots, 17)$$

where,

C_{hj} = gross margins of j^{th} crop activity in h^{th} year

g_{hj} = trend of gross margins for j^{th} crop activity in h^{th} year

Y_h^- = absolute values of negative trend deviations for the h^{th} year

Expected gross margin

The trend of gross margins for crop activities was used as the expected gross margin. Cost of hired human and bullock labour, hired tractor/power tiller and borrowed capital were deducted from this expected gross margin as in linear programming model and accordingly, the gross margin constraint took the following form:

$$\sum_{j=1} f_j\, x_j - \sum_{t=1}^{8} W_h L_t - \sum_{t=1}^{5} W_b K_t - \sum_{t=1}^{2} W_d P_t - \sum_{t=1}^{4} r M_t = \lambda$$

where,

f_j = expected (trend) gross margin for j^{th} crop activity

$\sum_{t=1}^{8} W_h L_t$ = cost of hired human labour in t^{th} period

$\sum_{t=1}^{5} W_b K_t$ = cost of hired bullock labour in t^{th} period

$\sum_{t=1}^{2} W_d P_t$ = cost of hired tractor/power tiller in t^{th} period

r = rate of interest for six months

$\sum_{t=1}^{4} rM_t$ = cost of borrowed capital in t^{th} peroid

λ = a scalar.

'λ' ranged from 0 to some maximum value defined specifically for each tenurial group of the small farms separately. For each of these defined levels of gross margins, the sum of absolute negative trend deviations were minimized subject to the constraints dicussed so far.

To have a clear perception about the income mean deviations, standard deviation and coefficient of variation were calculated. Standard deviation = $d\ [\ \pi\ s/2(s-1)]^{1/2}$ where,

d = the estimated mean absolute deviation

π = 22/7

S = number of observations in the sample.

Coefficient of variation of gross margins which is the ratio between the minimized risk (standard deviation) and the expected gross margin was also calculated.

Considering the objective function, linear programming constraints, gross margin deviation and expected gross margin constraints, the parametric linear programming model similar to MOTAD–II was specified as follows:

$$\text{Minimize } Zo = \sum_{h=1}^{17} Y_h^-$$

Subject to

1. $\sum_j l_{js}\, x_j \leq L_S$ (Land)

   $(s = 1, 2, \ldots\ldots, 72)$

2. $\sum_j h_{jt}\, x_j - L_t \leq H_t$ (Human labour)

   $(t = 1, 2, 3, 4, 5, 6, 7, 8)$

3. $\sum_j b_{jt}\, x_j - K_t \leq B_t$ (Bullock labour)

   $(t = 1, 2, 3, 4, 5)$

4. $\sum_{j} d_{jt} x_j - P_t \leq D_t$ (Tractor/power tiller)

(t = 1, 2)

5. $\sum_{j} C_{jt} x_j - M_t \leq C_t$ (Capital)

(t = 1, 2, 3, 4)

6. $\sum_{k} f_k x_k \geq F^{(Min)}$ (Minimum cereal requirement)

7. $\sum_{j=1} (C_{hj} - g_{hj}) x_j + Y_{\bar{h}} \geq 0$ (gross mar. deviations of crop activities ; h=1, 2, ... , 17)

8. $\sum_{j=1} f_j x_j - \sum_{t=1}^{8} W_h L_t - \sum_{t=1}^{5} W_b K_t - \sum_{t=1}^{2} W_d P_t - \sum_{t=1}^{4} r M_t = \lambda$ (Expected gross margin)

and

$x_j, Y_{\bar{h}}, L_t, K_t, P_t, M_t, \geq 0$ (For all j, h and s)

The model could be solved on conventional linear programming (LP) codes and this would generate a set of farm plans which were efficient for expected income with minimum absolute income deviation.

III. ANALYSIS OF RESULTS

The available farm resources were allocated optimally among different crops under conditions of risk on two tenurial groups of small farms at two levels of capital availability (i. e. existing and borrowed). The dual objectives of minimization of risk, and attainment of the expected level of income defining the utility function of the farmers were kept in mind while deriving these optimum plans. With the help of gross margins equation, the gross margins were parameterized by increasing them by a constant increment of Tk. 300.00. The results of the analysis are presented in Tables 1, 2, 3 and 4.

Risk and gross margin

In this study, the farmers were classified as risk averters, average risk bearers and risk preferers based on their attitude towards risk. Risk averters are likely to choose those plans with less risk and are content with lower returns. Average risk bearers are prepared to bear certain amount of risk with certain high income. Risk preferers are more enterprising and they prefer those plans which contain highly risky outcomes.

On the pure owner farms under existing capital situation, gross margin increased from Tk. 3400 to Tk. 4340.81 in the efficient plans (Table 1). As the gross margin increased, risk, as measured by standard deviation, also increased (Figures 1, 2, 3 and 4). It is evident from Tables 1 and 2 that coefficient of variation also increased along the gross margin-risk frontier. The final plan in each case carried the largest gross margin with the largest coefficient of variation. Due to relaxation of capital supply, gross= margin increased from Tk. 4300 to Tk. 6610.25 in the efficient plans (Table 2). The pr)cess of optimization under risk generated a maximum income of Tk. 6610.25 which was less than the income that could be generated under conditions of certainty. As the gross margin increased from Tk. 4300 to 6610.25, the minimized risk increased from Tk. 261.45 to Tk. 716.33. As a result, the coefficient of variation increased from 6.08 to 10.84%. This indicates that risk increased at a faster rate than gross margin. It is to be noted that in the beginning plans smaller incomes (gross margins) were expected with greater concern for risk, but as larger incomes were expected in the later plans, concern for risk decreased. Therefore, in the beginning plans less risky crops occupied more area while more risky but remunerative crops started appearing with larger area in the later plans. This phenomenon indicated the forward gross margin-risk movement over the efficient plans. Hence, the beginning plans were suggested to the risk averters, the intermediate plans to the risk bearers and the last few plans to the risk preferers.

On the owner-cum-tenant farms under limited capital situation, an expected income of Tk. 4300 could be obtained with a standard deviation (risk) of Tk. 275.15 which resulted in the coefficient of variation of around 6%. Comparison of this with Plan-4 in the case of the pure owner farms indicated that the same income of Tk. 4300 was attained with a higher level of risk of Tk. 528.68. The coefficient of variation was around 12%. In the last plan, gross margin was Tk. 7005.98 with a standard deviation of Tk. 987.62. Coefficient of variation increased over the efficient plans thereby indicating a faster movement in risk than gross margin (Table 3). Due to the relaxation of capital, an expected income of Tk. 7600 was associated with a risk of Tk. 623.86 resulting in a coefficient of variation of around 8%. As the gross margin increased from Tk. 7600 to 10213.47, the standard deviation increased from Tk. 623.86 to Tk. 1403.65 (Table 4). This resulted in an increasing coefficient of variation. The maximum gross margin could be attained by the owner-cum-tenant farms was Tk. 10213.47 as against Tk. 6610.25 in the case of the pure owner farms. The coefficients of variation were around 11% and 14% for pure owner and owner-cum-tenant farms respectively (Tables 2 and 4).

Inter-tenurial group comparison of the results indicated that the efficient plans of the owner-cum-tenant farms carried lower coefficients of variation than those of the pure owner farms. This indicates that there existed greater scope for stabilizing income on the owner-cum-tenant farms which was neither too resource intensive nor too resource scarce.

Risk, land utilization and cropping pattern

On the pure owner farms under existing capital situation, the process of resource optimization with risk minimization resulted in five efficient farm plans, each one representing a different combination of gross margin and risk. Total cropped area gradually increased from 64.35 decimals in Plan-1 to 90.69 decimals in Plan-4. In PlanS, it decreased slightly. In Plan-1 the cropping intensity was 86%, while in Plan-4 it was 121% (Table 1). In high land under non-irrigated situation, the efficient plans represented allocation of land in broadcast *aus (MV),* transplanted *aman (MV),* mustard, *mukhikachu* and sweetgourd. In this land type, broadcast *aus* (MV) was the dominant crop which occupied about 19% to 25% of total cropped area. The next dominant crop was mustard which occupied about 12% to 21% of total cropped area. It was expected that the acreage under broadcast *aus* (MV) and mustard would increase gradually with the increase in risk from Plan-1 to Plan-5. But no such relationship was found. In Plan-1 and 2, whole of the land was not utilized, while in other plans, land was utilized fully (Table 1). In high land under irrigated situation, broadcast *aus (MV),* brinjal (summer), brinjal (winter) and bittergourd entered into the efficient plans. Brinjal (summer) in the first plan, broadcast *aus* (MV) in the first two plans and bittergourd in the last three plans totally disappeared. In this land type, brinjal (winter) occupied about 4% to 7% of total cropped area. Bittergourd was found less risky crop and broadcast *aus* (MV) was found more risky crop in this land type. It is noted that the whole area of this land type was utilized in all the plans. In medium high land under non-irrigated situation, the efficient plans allocated only transplanted *aman (MV).* This crop occupied about 38% of total cropped area in Plan-1 and its area gradually decreased and in Plan-5, about 19% of total cropped area was utilized. Transplanted *aman* (MV) occupied a major portion of total cropped area. It is noted that in Plan-4 and Plan-5, total area of this land type was not utilized. The opposite result was found in medium high land under irrigated situation. In this land type, the whole area was utilized in Plan-4 and Plan-5. The efficient plans suggested for the allocation of transplanted *aman (MV), boro (MV),* wheat' (MV) and potato (MV). Transplanted *aman* (MV) and potato (MV) were found to be dominant crops in this land type. Transplanted *aman* (MV) was found to be the most risky crop in this land type because in the first three plans, no area was covered by this crop. In medium low land under non-irrigated situation, broadcast *aman* occupied about 1% of total ciopped area in Plan-1 and then it totally disappeared. In medium low land under irrigated situation, *boro* (MV) covered the whole area of this land type in the first two plans and then totally disappeared.

On the owner-cum-tenant farms under existing capital situation, 10 efficient plans appeared with various combinations of gross margin and risk. Total cropped area gradually increased from 82.53 decimals in Plan-1 to 154.75 decimals in Plan-10. In the

Table 1. Optimum Plans with Minimized Risk (Efficient Plans) for Pure Owner Farms Under Limited (Existing) Capital Situation

Sl.	Particulars	Unit	Efficient Plans				
No.			1	2	3	4	5
1.	Gross margin	Taka	3400	3700	4000	4300	4340.81
2.	Minimized risk (Standard deviation)	Taka	268.53	349.89	398.25	528.68	554.91
3.	Coefficient of variation	Percent	7.90	9.46	9.96	12.29	12.78
4.	Area under crops						
	High land (Non–irrigated)	Decimals	24.92	37.90	54.66	52.26	56.13
			(38.73)	(50.52)	(61.06)	(57.63)	(62.05)
	B. *Aus* (MV)	Decimals	12.39	18.53	18.69	17.41	18.64
			(19.26)	(24.70)	(20.88)	(19.20)	(20.61)
	T. *Aman* (MV)	Decimals	6.10	4.46	5.21	-	2.45
			(9.48)	(5.95)	(5.82)		(2.71)
	Mustard	Decimals	-	8.66	18.69	17.41	18.64
				(11.54)	(20.88)	(19.20)	(20.61)
	Mukhikachu	Decimals	6.07	3.39	2.69	6.78	6.97
			(9.43)	(4.52)	(3.00)	(7.48)	(7.70)
	Sweetgourd	Decimals	0.36	2.86	9.38	10.66	9.43
			(0.56)	(3.81)	(10.48)	(11.75)	(10.42)
	High land (Irrigated)	Decimals	6.47	6.47	6.50	8.14	7.95
			(10.06)	(8.62)	(7.25)	(8.97)	(8.80)
	B. *Aus* (MV)	Decimals	-	-	0.03	1.67	1.48
					(0.03)	(1.84)	(1.64)
	Brinjal (Summer)	Decimals	-	1.28	0.03	1.67	1.48
				(1.71)	(0.03)	(1.84)	(1.64)
	Brinjal (Winter)	Decimals	2.32	4.82	6.44	4.80	4.99
			(3.61)	(6.42)	(7.19)	(5.29)	(5.52)
	Bittergourd	Decimals	4.15	0.37	-	-	-
			(6.45)	(0.49)			

Table 1. Contd.

Sl. No.	Particulars	Unit	Efficient Plans 1	2	3	4	5
	Medium high lands (Non–irrig.)						
	T. *Aman* (MV)	Decimals	24.61 (38.24)	24.61 (32.81)	24.61 (27.49)	21.43 (23.63)	17.50 (19.35)
	Medium high land (Irrig.)	Decimals	7.30 (11.24)	5.61 (7.48)	3.76 (4.20)	8.86 (9.77)	8.86 (9.80)
	T. *Aman* (MV)	Decimals	-	-	-	7.14 (7.87)	8.86 (9.80)
	Boro (MV)	Decimals	1.25 (1.94)	-	-	-	-
	Wheat (MV)	Decimals	1.64 (2.55)	0.65 (0.87)	-	1.72 (1.90)	-
	Potato (MV)	Decimals	4.41 (6.85)	4.96 (6.61)	3.76 (4.20)	-	-
	Medium low land (Non–irrig.)						
	B. *Aman*	Decimals	0.62 (0.96)	-	-	-	-
	Medium low land (Irrigated)						
	Boro (MV)	Decimals	0.43 (0.67)	0.43 (0.57)	-	-	-
5.	Total cropped area	Decimals	64.35 (100)	75.02 (100)	89.53 (100)	90.69 (100)	90.44 (100)
6.	Cropping intensity	Per cent	85.83	100.07	119.42	120.97	120.63
7.	Human labour	Days	39.00	39.59	41.88	43.90	43.97
8.	Bullock labour	Days	7.99	8.77	9.10	9.16	9.29
9.	Tractor/power tiller	Taka	4.14	9.92	17.31	17.63	18.76
10.	Capital	Taka	917.86	1186.74	1514.58	2050.54	2137.49

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

Table 2. Optimum Plans with Minimized Risk (Efficient Plans) for Pure Owner Farms Under Borrowed Capital Situation

Sl. No.	Particulars	Unit	Efficient Plans								
			1	2	3	4	5	6	7	8	9
1.	Gross margin	Taka	4300	4600	4900	5200	5500	5800	6100	6400	6610.25
2.	Minimized risk (Standard deviation)	Taka	261.45	284.08	316.50	347.13	387.02	450.76	538.60	653.19	716.33
3.	Coefficient of variation	Percent	6.08	6.18	6.46	6.68	7.04	7.77	8.83	10.21	10.84
4.	Area under crops										
	High land (Non–Irrigated)	Decimals	30.08	29.79	30.76	29.98	33.66	43.14	54.59	56.14	56.14
			(38.39)	(37.30)	(37.45)	(36.48)	(38.75)	(44.82)	(50.64)	(48.32)	(41.72)
	B. *Aus* (MV)	Decimals	2.97	3.58	1.80	-	-	-	-	-	-
			(3.79)	(4.48)	(2.19)	-	-	-	-	-	-
	T. *Aman* (MV)	Decimals	5.47	2.81	0.96	-	-	-	-	-	-
			(6.98)	(3.52)	(1.17)						
	Chickpea	Decimals	-	-	-	-	-	2.16	7.64	-	-
								(2.24)	(7.09)		
	Mukhikachu	Decimals	19.63	21.68	25.31	28.07	28.07	28.07	28.07	28.07	28.07
			(25.06)	(27.15)	(30.81)	(34.15)	(32.31)	(29.17)	(26.04)	(24.16)	(20.89)
	Sweetgourd	Decimals	2.01	1.72	2.69	1.91	5.59	12.91	18.88	28.07	28.07
			(2.56)	(2.15)	(3.28)	(2.33)	(6.44)	(13.41)	(17.51)	(24.16)	(20.89)
	High land (Irrigated)	Decimals	6.47	6.47	9.55	8.79	9.88	9.72	9.72	9.72	9.72
			(8.26)	(8.10)	(11.63)	(10.69)	(11.37)	(10.11)	(9.03)	(8.37)	(7.23)
	B. *Aus* (MV)	Decimals	-	-	3.08	2.32	3.41	3.24	3.24	3.24	3.24
					(3.75)	(2.82)	(3.93)	(3.37)	(3.01)	(2.79)	(2.41)
	Wheat (MV)	Decimals	-	-	3.08	0.93	-	-	-	-	-
					(3.75)	(1.13)					

Table 2. Contd.

Sl. No. Particulars	Unit	Efficient Plans								
		1	2	3	4	5	6	7	8	9
Potato (MV)	Decimals	-	-	-	0.65 (0.79)	0.35 (0.40)	-	-	-	-
Brinjal (Summer)	Decimals	-	-	-	0.74 (0.90)	3.06 (3.52)	3.24 (3.37)	3.24 (3.01)	3.24 (2.79)	3.24 (2.41)
Brinjal (Winter)	Decimals	0.91 (1.16)	-	0.19 (0.23)	0.45 (0.55)	1.11 (1.28)	1.96 (2.04)	3.24 (3.01)	3.24 (2.79)	3.24 (2.41)
Bittergourd	Decimals	5.56 (7.10)	6.47 (8.10)	3.20 (3.90)	3.70 (4.50)	1.95 (2.24)	1.28 (1.33)	-	-	-
Medium high land (Non-irrigated)	Decimals	24.61 (31.42)	24.61 (30.82)	24.61 (29.96)	24.61 (29.94)	24.61 (28.33)	24.61 (25.57)	24.61 (22.84)	30.78 (26.49)	49.22 (36.63)
T. *Aman* (LV)	Decimals	5.41 (6.91)	-	-	-	-	-	-	-	-
T. *Aman* (MV)	Decimals	19.20 (24.51)	24.61 (30.82)	24.61 (29.96)	24.61 (29.94)	24.61 (28.33)	24.61 (25.57)	24.61 (22.84)	24.61 (21.18)	24.61 (18.31)
Chickpea	Decimals	-	-	-	-	-	-	-	6.17 (5.31)	24.61 (18.32)
Medium high land (Irrigated)	Decimals	10.22 (13.05)	12.02 (15.06)	10.26 (12.49)	11.85 (14.42)	11.75 (13.53)	11.80 (12.27)	11.89 (11.03)	12.58 (10.83)	12.32 (9.18)
B. *Aus* (LV)	Decimals	1.36 (1.74)	3.16 (3.96)	0.61 (0.75)	-	-	-	-	-	-
T. *Aman* (MV)	Decimals	-	-	0.79 (0.96)	2.99 (3.64)	2.89 (3.33)	2.94 (3.06)	3.03 (2.81)	3.72 (3.20)	3.46 (2.58)

Table 2. Contd.

Sl. No.	Particulars	Unit	Efficient Plans								
			1	2	3	4	5	6	7	8	9
	Boro (MV)	Decimals	-	-	0.79 (0.96)	2.99 (3.64)	2.89 (3.33)	2.94 (3.06)	3.03 (2.81)	3.72 (3.20)	3.46 (2.58)
	Wheat (MV)	Decimals	3.23 (4.12)	2.97 (3.72)	1.94 (2.36)	-	-	-	-	-	-
	Potato (MV)	Decimals	5.63 (7.19)	5.89 (7.38)	6.13 (7.46)	5.87 (7.14)	5.97 (6.87)	5.92 (6.15)	5.83 (5.41)	5.14 (4.43)	5.40 (4.02)
Medium low land (Non–irrigated)		Decimals	6.53 (8.33)	6.53 (8.18)	6.53 (7.95)	6.53 (7.95)	6.53 (7.52)	6.53 (6.78)	6.53 (6.06)	6.53 (5.62)	6.53 (4.86)
	B. *Aman*	Decimals	4.89 (6.24)	6.53 (8.18)	5.58 (6.79)	6.53 (7.95)	6.53 (7.52)	6.53 (6.78)	6.53 (6.06)	6.53 (5.62)	6.53 (4.86)
	T. *Aman* (LV)	Decimals	1.64 (2.09)	-	0.95 (1.16)	-	-	-	-	-	-
Medium low land (Non–irrigated)	***Boro*** (MV)	Decimals	0.43 (0.55)	0.43 (0.54)	0.43 (0.52)	0.43 (0.52)	0.43 (0.50)	0.43 (0.45)	0.43 (0.40)	0.43 (0.37)	0.43 (0.32)
5.	Total cropped area	Decimals	78.34 (100)	79.85 (100)	82.14 (100)	82.19 (100)	86.86 (100)	96.23 (100)	107.77 (100)	116.18 (100)	134.36 (100)
6.	Cropping intensity	Percent	104.50	106.51	109.56	109.63	115.86	128.36	143.75	154.97	179.22
7.	Human labour	Days	56.09	57.69	60.14	64.70	67.66	70.94	74.38	76.48	80.63
8.	Bullock labour	Days	11.44	11.66	12.21	12.75	13.27	13.47	13.66	13.76	13.85
9.	Tractor/power tiller	Taka	6.98	9.48	11.74	8.25	9.67	17.26	30.16	32.20	65.40
10.	Capital	Taka	816.01	905.44	1022.17	1161.57	1389.63	1665.74	1945.23	2340.53	2659.72

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

Table 3. Optimum Plans with Minimized Risk (Efficient Plans) for Owner-cum-tenant Farms Under Limited (Existing) Capital Situation

Sl. No.	Particulars	Unit	Efficient Plans									
			1	2	3	4	5	6	7	8	9	10
1.	Gross margin	Taka	4300	4600	4900	5200	5500	5800	6100	6400	6700	7005.98
2	Minimized risk (Standard deviation)	Taka	275.15	299.52	347.80	406.06	455.27	489.12	704.58	802.19	907.90	987.62
3.	Coefficient of Variation	Percent	6.40	6.51	7.10	7.81	8.28	8.43	11.55	12.53	13.55	14.10
4.	Area under crops						**Owned land**					
	High land (Non-irrigated)	Decimals	39.29	40.88	44.83	45.62	55.02	58.69	64.37	66.33	61.08	56.52
			(47.61)	(42.32)	(46.02)	(46.00)	(53.91)	(56.29)	(58.18)	(56.32)	(48.32)	(36.53)
	B. Aus (MV)	Decimals	3.21	4.58	6.69	9.30	11.72	11.99	8.01	6.05	1.01	6.38
			(3.89)	(4.74)	(6.87)	(9.38)	(11.48)	(11.50)	(7.24)	(5.13)	(0.80)	(4.12)
	T. Aman (MV)	Decimals	11.47	12.18	9.32	1.22	2.12	-	7.19	11.50	6.94	3.58
			(13.90)	(12.61)	(9.57)	(1.23)	(2.08)		(6.50)	(9.75)	(5.49)	(2.31)
	Mukhikachu	Decimals	21.52	19.44	20.18	21.09	22.35	22.50	20.99	18.64	17.95	16.75
			(26.08)	(20.12)	(20.71)	(21.26)	(21.90)	(21.58)	(18.97)	(15.80)	(14.20)	(10.83)
	Sweetgourd	Decimals	3.09	4.68	8.64	14.01	18.83	24.20	28.18	30.14	35.18	29.81
			(3.74)	(4.85)	(8.87)	(14.13)	(18.45)	(23.21)	(25.47)	(25.55)	(27.83)	(19.27)
	High land (irrigated)	Decimals	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83
			(4.65)	(3.96)	(3.93)	(3.86)	(3.75)	(3.67)	(3.46)	(3.25)	(3.03)	(2.48)
	Wheat (MV)	Decimals	2.76	-	-	-	-	-	-	-	-	-
			(3.35)									
	Brinjal (Winter)	Decimals	1.07	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83
			(1.30)	(3.96)	(3.93)	(3.86)	(3.75)	(3.67)	(3.46)	(3.25)	(3.03)	(2.48)
	Med. high land (Non-irrigated)	Decimals	17.05	19.31	18.89	22.29	20.01	22.29	17.80	16.19	22.29	22.29
			(20.66)	(19.99)	(19.39)	(22.47)	(19.61)	(21.38)	(16.09)	(13.73)	(17.63)	(14.40)
	T. *Aman* (LV)	Deimals	4.22	8.25	3.23	-	-	-	-	-	-	-
			(5.11)	(8.54)	(3.32)							

Table 3. Contd.

Sl. No. Particulars	Unit	Efficient Plans									
		1	2	3	4	5	6	7	8	9	10
T. *Aman* (MV)	Decimals	12.83 (15.55)	11.06 (11.45)	15.66 (16.07)	22.29 (22.47)	20.01 (19.61)	22.29 (21.38)	17.80 (16.09)	16.19 (13.73)	22.29 (17.63)	22.29 (14.40)
Med. high land (Irrigated)	Decimals	6.81 (8.24)	6.81 (7.05)	6.81 (6.99)	6.81 (6.87)	6.81 (6.67)	7.37 (7.08)	6.81 (6.15)	3.38 (2.87)	1.28 (1.01)	-
T. *Aman* (MV)	Decimals	-	-	-	-	-	0.56 (0.54)	-	-	-	-
Boro (MV)	Decimals	-	-	-	-	2.66 (2.61)	3.55 (3.41)	4.00 (3.61)	0.87 (0.74)	-	-
wheat (MV)	Decimals	1.03 (1.24)	0.60 (0.62)	0.95 (0.98)	1.83 (1.85)	-	-	-	-	-	-
Potato (MV)	Decimals	5.78 (7.00)	6.21 (6.43)	5.86 (6.01)	4.98 (5.02)	4.15 (4.06)	3.26 (3.13)	2.81 (2.54)	2.51 (2.13)	1.28 (1.01)	-
Med. low land (Non–irrigated)	Decimals	5.42 (6.57)	5.42 (5.61)	5.42 (5.56)	5.42 (5.46)	5.42 (5.31)	1.63 (1.56)	1.07 (0.97)	0.04 (0.03)	0.78 (0.62)	-
B. *Aman*	Decimals	2.04 (2.47)	2.75 (2.85)	5.42 (5.56)	5.42 (5.46)	5.42 (5.31)	1.63 (1.56)	1.07 (0.97)	0.04 (0.03)	0.78 (0.62)	-
T. *Aman* (LV)	Decimals	3.38 (4.10)	2.67 (2.76)	-	-	-	-	-	-	-	-
				Rented–in land							
High land (Non–irrigated)	Decinmals	-	10.23 (10.59)	7.51 (7.71)	3.15 (3.18)	1.93 (1.89)	2.66 (2.55)	13.32 (12.04)	24.85 (21.07)	33.83 (26.76)	68.78 (44.44)
B. *Aus* (MV)	Decimals	-	-	-	-	-	2.66 (2.55)	13.32 (12.04)	24.85 (21.07)	33.83 (26.76)	34.39 (22.22)
Mustard	Decimals	-	10.23 (10.59)	7.51 (7.71)	3.15 (3.18)	1.93 (1.89)	-	-	-	-	34.39 (22.22)
Lentil	Decimals	-	-	-	-	-	-	-	-	-	(0.0008) (–)

Table 3. Contd.

Sl. No.	Particulars	Unit	Efficient Plans									
			1	2	3	4	5	6	7	8	9	10
	High land (irrigated)											
	Bittergourd	Decimals	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33
			(4.03)	(3.45)	(3.42)	(3.36)	(3.26)	(3.19)	(3.01)	(2.82)	(2.63)	(2.15)
	Med. high land (irrigated)											
	Boro (MV)	Decimals	6.11	6.11	6.11	6.11	5.71	4.46	0.11	-	-	-
			(7.40)	(6.32)	(6.27)	(6.16)	(5.60)	(4.28)	(0.10)			
		Decimals	3.16	2.73	3.83	5.23	3.10	2.73	0.11	-	-	-
			(3.83)	(2.83)	(3.93)	(5.27)	(3.04)	(2.62)	(0.10)			
	Wheat (MV)	Decimals	2.95	3.38	2.28	0.88	2.61	1.73	-	-	-	-
			(3.57)	(3.49)	(2.34)	(0.89)	(2.56)	(1.66)				
	Med. low land (Non–irrigated)											
	B. *Aman*	Decimals	-	-	-	1.93	-	-	-	-	-	-
						(1.94)						
	Med. low land (irrigated)											
	Boro (MV)	Deimals	0.69	0.69	0.69	0.69	-	-	-	-	-	-
			(0.84)	(0.71)	(0.71)	(0.70)						
5.	Total cropped area	Decimals	82.53	96.61	97.42	99.18	102.06	104.26	110.64	117.95	126.42	154.75
			(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
6.	Cropping intensity	Percent	60.08	70.33	70.92	72.20	74.30	75.90	80.55	85.87	92.04	112.66
7.	Humand labour	Days	60.00	62.77	64.20	66.38	67.37	68.47	69.13	70.20	72.35	72.48
8.	Bullock labour	Days	12.59	13.39	12.99	12.36	12.23	11.78	12.39	13.69	14.43	16.74
9.	Tractor/power tiller	Taka	6.15	6.48	11.94	19.33	23.51	30.34	36.96	41.92	49.08	44.18
10.	Capital	Taka	864.65	996.55	1174.85	1383.68	1620.56	1914.06	2269.54	2631.00	2993.36	3828.66

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

Table 4. Optimum Plans with Minimized Risk (Efficient Plans) for Owner–cum–tenant Farms Under Borrowed Capital Situation

Sl. No.	Particulars	Unit	Efficient Plans									
			1	2	3	4	5	6	7	8	9	10
1.	Gross margin	Taka	7600	7900	8200	8500	8800	9100	9400	9700	10000	10213.47
2	Minimized risk (Standard deviation)	Taka	623.86	696.17	726.20	792.94	861.47	938.69	975.18	1069.80	1186.88	1403.65
3.	Coefficient of Variation	Percent	8.21	8.81	8.86	9.33	9.79	10.31	10.37	11.03	11.87	13.74
4.	Area under crops				**Owned land**							
	High land (Non–irrigated)	Decimals	49.52	52.88	56.56	61.49	66.50	71.77	72.38	72.38	72.38	72.38
			(31.91)	(33.09)	(34.15)	(35.95)	(37.80)	(40.00)	(36.08)	(35.22)	(30.58)	(28.79)
	Mukhikachu	Decimals	36.19	36.19	36.19	36.19	36.19	36.19	36.19	36.19	36.19	36.19
			(23.32)	(22.65)	(21.85)	(21.16)	(20.57)	(20.17)	(18.04)	(17.61)	(15.29)	(14.38)
	Sweetgourd	Decimals	13.33	16.69	20.37	25.30	30.31	35.58	36.19	36.19	36.19	36.19
			(8.59)	(10.44)	(12.30)	(14.79)	(17.23)	(19.83)	(18.04)	(17.61)	(15.29)	(14.38)
	High land (irrigated)	Decimals	7.62	7.04	7.55	6.85	6.00	4.81	5.11	4.62	5.88	3.83
			(4.91)	(4.41)	(4.57)	(4.01)	(3.40)	(2.69)	(2.55)	(2.24)	(2.49)	(1.52)
	B. *Aus* (MV)	Decimals	-	1.33	3.72	3.02	2.17	0.98	1.28	0.79	2.05	-
				(0.83)	(2.25)	(1.77)	(1.23)	(0.55)	(0.64)	(0.38)	(0.87)	
	Jute	Decimals	3.79	1.88	-	-	-	-	-	-	-	-
			(2.44)	(1.18)								
	Potato	Decimals	3.79	3.83	3.72	3.02	2.17	0.98	1.28	0.79	2.05	-
			(2.44)	(2.40)	(2.25)	(1.77)	(1.23)	(0.55)	(0.64)	(0.38)	(0.87)	
	Brinjal (winter)	Decimals	0.04	-	0.11	0.81	1.66	2.85	2.55	3.04	1.78	3.83
			(0.03)		(0.07)	(0.47)	(0.94)	(1.59)	(1.27)	(1.48)	(0.75)	(1.52)
	Med. high land (Non–irrigated)	Decimals	22.29	22.29	22.29	22.29	22.29	22.29	22.29	23.31	44.58	44.58
			(14.37)	(13.95)	(13.46)	(13.03)	(12.67)	(12.42)	(11.11)	(11.35)	(18.84)	(17.72)
	T. *Aman* (MV)	Decimals	22.29	22.29	22.29	22.29	22.29	22.29	22.29	22.29	22.29	22.29
			(14.37)	(13.95)	(13.46)	(13.03)	(12.67)	(12.42)	(11.11)	(10.85)	(9.42)	(8.86)
	Chickpea	Decimals	-	-	-	-	-	-	-	1.02	22.29	22.29
										(0.50)	(9.42)	(8.86)

Table 4. Contd.

Sl. No. Particulars	Unit	Efficient Plans									
		1	2	3	4	5	6	7	8	9	10
Med. high land (Irrigated)	Decimals	6.81 (4.39)	6.81 (4.26)	6.81 (4.11)	6.81 (3.98)	6.81 (3.87)	6.81 (3.80)	6.81 (3.40)	6.81 (3.32)	6.81 (2.88)	12.93 (5.14)
T. Aman (MV)	Decimals	-	-	-	-	-	-	-	-	-	6.12 (2.43)
Boro (MV)	Decimals	-	-	-	-	-	-	-	-	-	6.12 (2.43)
Potato (MV)	Decimals	6.81 (4.39)	6.81 (4.26)	6.81 (4.11)	6.81 (3.98)	6.81 (3.87)	6.81 (3.80)	6.81 (3.40)	6.81 (3.32)	6.81 (2.88)	0.69 (0.28)
Medium low land (Non–irrigated)											
B. *Aman*	Decimals	5.42 (3.49)	5.42 (3.39)	5.42 (3.27)	5.42 (3.17)	5.42 (3.08)	4.80 (2.68)	3.44 (1.72)	-	-	5.42 (2.16)
				Rented–in land							
High land (Non–irrgated)	Decimals	34.39 (22.17)	34.39 (21.52)	34.39 (20.76)	34.40 (20.12)	34.39 (19.56)	34.39 (19.17)	56.02 (27.92)	68.39 (33.29)	67.33 (28.45)	68.78 (27.34)
B. *Aus* (MV)	Decimals	14.34 (9.24)	15.05 (9.42)	14.73 (8.89)	17.78 (10.40)	21.40 (12.17)	26.11 (14.55)	26.84 (13.38)	34.00 (16.55)	32.94 (13.92)	34.39 (13.67)
T. *Aman* (MV)	Decimals	18.01 (11.61)	19.34 (12.10	19.66 (11.87)	16.62 (9.72)	12.99 (7.39)	8.28 (4.62)	7.55 (3.76)	0.39 (0.19)	1.45 (0.61)	-
Jute	Decimals	2.04 (1.32)	-	-	-	-	-	-	-	-	-
Mustare	Decimals	-	-	-	-	-	-	(21.63 (10.78)	34.00 (16.55)	32.94 (13.92)	25.84 (10.27)
Lentil	Decimals	-	-	-	-	-	-	-	-	-	8.55 (3.40)
High land (Irrigated)											
Bittergourd	Decimals	3.33 (2.15)	3.33 (2.08)	3.33 (2.01)	3.33 (1.94)	3.33 (1.89)	3.33 (1.86)	3.33 (1.66)	3.33 (1.62)	3.33 (1.41)	3.33 (1.32)

Table 4. Contd.

Sl. No.	Particulars	Unit	Efficient Plans									
			1	2	3	4	5	6	7	8	9	10
	Med. high land (Non-irrigated)	Decimals	13.72 (8.84)	13.72 (8.59)	13.72 (8.28)	13.72 (8.02)	13.72 (7.80)	13.72 (7.65)	13.72 (6.84)	13.72 (6.68)	23.45 (9.90)	27.44 (10.90)
	T. *Aman* (MV)	Decimals	13.72 (8.84)	13.72 (8.59)	13.72 (8.28)	13.72 (8.02)	13.72 (7.80)	13.72 (7.65)	13.72 (6.84)	13.72 (6.68)	13.72 (5.79)	13.72 (5.45)
	Chickpea	Decimals	-	-	-	-	-	-	-	-	9.73 (4.11)	13.72 (5.45)
	Med. high land (Irrigated)	Decimals	6.80 (4.37)	8.63 (5.41)	10.28 (6.21)	11.14 (6.70)	12.22 (6.94)	12.22 (6.80)	12.22 (6.10)	12.22 (5.94)	12.22 (5.16)	12.22 (4.86)
	T. *Aman* (MV)	Decimals	0.69 (0.44)	2.52 (1.58)	4.17 (2.52)	5.33 (3.12)	6.11 (3.47)	6.11 (3.40)	6.11 (3.05)	6.11 (2.97)	6.11 (2.58)	6.11 (2.43)
	Boro (MV)	Decimals	0.69 (0.44)	2.52 (1.58)	4.17 (2.52)	5.33 (3.12)	6.11 (3.47)	6.11 (3.40)	6.11 (3.05)	6.11 (2.97)	6.11 (2.58)	6.11 (2.43)
	Wheat (MV)	Decimals	5.42 (3.49)	3.59 (2.25)	1.94 (1.17)	0.78 (0.46)	-	-	-	-	-	-
	Med. low land (Non-irrigated)											
	B. *Aman*	Decimals	4.58 (2.96)	4.58 (2.87)	4.58 (2.76)	4.58 (2.68)	4.58 (2.60)	4.58 (2.55)	4.58 (2.28)	-	-	-
	Med. low land (Irrigated)											
	Boro (MV)	Decimals	0.69 (0.44)	0.69 (0.43)	0.69 (0.42)	0.69 (0.40)	0.69 (0.39)	0.69 (0.38)	0.69 (0.34)	0.69 (0.34)	0.69 (0.29)	0.69 (0.28)
5.	Total cropped area	Decimals	155.17 (100)	159.78 (100)	165.62 (100)	171.02 (100)	175.95 (100)	179.41 (100)	200.59 (100)	205.47 (100)	236.67 (100)	251.60 (100)
6.	Cropping intensity	Percent	112.97	116.32	120.57	124.50	128.09	130.61	146.03	149.59	172.30	183.17
7.	Human labour	Days	103.26	106.10	109.58	111.75	113.31	113.33	115.20	110.94	118.40	127.17
8.	Bullock labour	Days	22.45	22.59	22.85	22.76	22.62	22.24	24.01	24.42	24.88	24.15
9.	Tractor/power tiller	Taka	19.16	23.63	28.67	34.75	41.00	47.44	48.39	50.81	101.57	106.14
10.	Capital	Taka	2111.83	2325.69	2543.63	2768.34	2995.01	3229.23	3523.17	3922.52	4406.24	5620.55

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

high land under non-irrigated situation, the efficient plans included broadcast *aus* (MV), transplanted *aman* (MV), *mukhikachu* and sweetgourd. Among them, *mukhikachu* and sweetgourd were the dominant crops which occupied a significant proportion of total cropped area. However, land was utilized fully in all plans (Table 3). In high land under irrigated situation, land was also utilized fully in all plans. In medium high land under non-irrigated situation, transplanted *aman* (MV) occupied about 11% to 22% of total cropped area. But no systematic trend was found. Full utilization of land of that land type was observed only in Plans-4, 6, 9 and 10. In medium high land under irrigated situation, total area of this land type was utilized by transplanted *aman (MV), boro (MV),* wheat (MV) and potato (MV) with a minor exception in Plans-6, 8, 9 and 10. Among them, potato (MV) and *boro* (MV) were found dominant crops. The allocation of potato (MV) was found systematic with a minor exception. The allocation area gradually decreased over the efficient plans. In medium low land under non-irrigated situation, land was utilized fully upto Plan-5 and then some areas remained unutilized. In Plan-10, land was unutilized fully.

As far as rented-in land is concerned, broadcast *aus* (MV) and mustard were the dominant crops in high land under non-irrigated situation., Only in Plan-10, the whole area of that land type was utilized. In high land under irrigated situation, the whole area was utilized by bittergourd and a systematic trend of percentage of land allocation was found. Due to capital scarcity, none of the crop activities entered into the plan for medium high land under non-irrigated situation. In medium high land under irrigated situation, full utilization of land was observed upto Plan-4, and from Plan-8, land was unutilized fully. In medium low land under non-irrigated situation, land was unutilized fully with a minor exception in Plan-4. *Boro* (MV) occupied the whole area of the medium low land under irrigated situation upto Plan-4 and then it totally disappeared.

Optimum plans under borrowed capital situation were worked out for two tenurial groups of small farms. Due to liberalization of capital, the cropped area increased but the crops remained unaffected with a few exceptions. In the case of the pure owner farms under high land non-irrigated situation, mustard was replaced by chickpea. Instead of broadcast *aus (MV), mukhikachu* and sweetgourd were found to be the dominant crops. In high land under irrigated situation, wheat (MV) and potato (MV) were included in addition to existing crops. In medium high land under non-irrigated situation, transplanted *aman (LV)* and chickpea were added in addition to transplanted *aman (MV)*. In medium high land under irrigated situation, only broaddcast *aus* (MV) was added (Tables I and 2). The total cropped area gradually increased from 78.34 decimals to 134.36 decimals i. e. cropping intensity increased from 105 to 179%.

An interesting feature was found in the case of the owner-cum-tenant farms under borrowed capital situation. Due to relaxation of capital, some crops disappeared and some crops entered over the efficient plans. In case of the owned land, broadcast *aus* (MV), and transplanted *aman* (MV) totally disappeared in high land under non-irrigated situation. But land allocation to *mukhikachu* and sweetgourd tremendously increased. In the case of high land under irrigated situation, opposite result was found. Here, broadcast *aus (*MV), jute and potato were incorporated with the existing crops. In medium high land under non-irrigated situation, chickpea was replaced by transplanted *aman* (LV). In medium high land under irrigated situation, wheat totally disappeared.

In the rented high land under non-irrigated situation, transplanted *aman* (MV) and jute were added to the existing crops. In medium high land under non-irrigated situation, transplanted *aman* (MV) and chickpea were added. In medium high land under irrigated situation, transplanted *aman* (MV) were added with *boro* (MV) and wheat (MV). In other cases, the same crops were found but the allocation of area tremendously increased specially in medium low land under both irrigated and non-irrigated situations. The total cropped area gradually increased from 155.17 to 251.60 decimals i. e. cropping intensity increased from 113 to 183%.

Risk and cropping pattern associated with stability

On the pure owner farms under limited capital situation, the efficient plans represented allocation of land in mustard and sweetgourd in the high land under nonirrigated situation. Mustard, the second dominant crop occupied about 12 to 21% of the total cropped area. Under borrowed capital situation, mustard was replaced by another stable crop chickpea and occupied land in the intermediate risk plans. Sweetgourd utilized more land in the high risk plans compared to that under limited capital situation. In the high land under irrigated situation, wheat (MV) entered in the intermediate risk plans. Bittergourd utilized land in the low risk plans under limited capital situation whereas that crop entered in the intermediate risk plans under borrowed capital situation. In the medium high land under irrigated situation, another stable crop chickpea entered in the high risk plans under borrowed capital situation. In the irrigated medium high land under borrowed capital situation, *boro* (MV) entered in the high risk plans, and wheat (MV) entered in the low risk plans and utilized more land compared to that under limited capital situation. In the medium low land (in the case of both pure owner and ownercum-tenant farms), the existing stable crops such as broadcast *aman* and *boro* (MV) entered in the high risk plans and utilized whole area under borrowed capital situation in the non-irrigated and irrigated conditions respectively.

On the owner-cum-tenant farms under limited capital situation, sweetgourd appeared in all plans and utilized more land under borrowed capital situation in the high land under non-irrigated situation. In the high land under irrigated situation, brinjal (winter) utilized less land under borrowed capital situation. In the medium high land, another stable crop

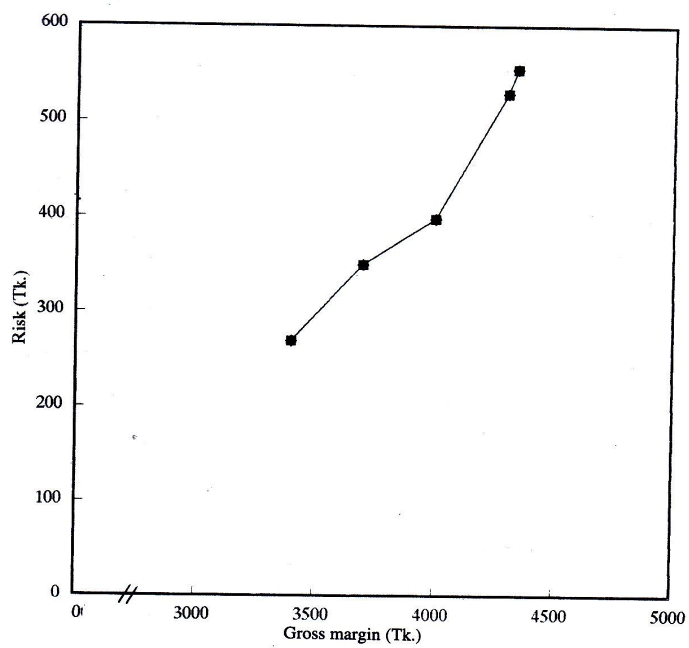

Fig. 1. Gross Margin Risk Frontier for Pure Owner Farms under Existing Capital Stituation

chickpea and the existing stable crop *boro* (MV) entered in the high risk plans under non–irrigated and irrigation situations respectively. In the rented high land under non–irrigated situation, the existing mustard and lentil entered in the high risk plans under borrowed capital situation. In the medium high land under non–irrigated situation, another stable crop chickpea entered in the high risk plans under borrowed capital condition. Due to the relaxation of capital, the existing *boro* (MV) entered in the high risk plans and occupied more land.

Based on the above discussion, it is seen that different pictures were noticed irrespective of the tenurial groups under limited and borrowed capital situations. In some cases, the existing stable crops such as mustard, broadcast *aman* and *boro* (MV) entered in the low risk plans under limited capital situation. Those crops appeared in the high risk plans under borrowed capital condition. Sweetgourd appeared in all plans under limited and borrowed capital situations but utilized more land under borowed capital situation. Brinjal (winter) also appeared in all plans but utilized less land under borrowed capital situation. In some cases, wheat (MV) and chickpea could not enter in the low risk plans under limited capital situation. Due to the relaxation of capital, those crops entered both in the low risk and high risk plans. The capital borrowing increased the risk bearing ability of the plans.

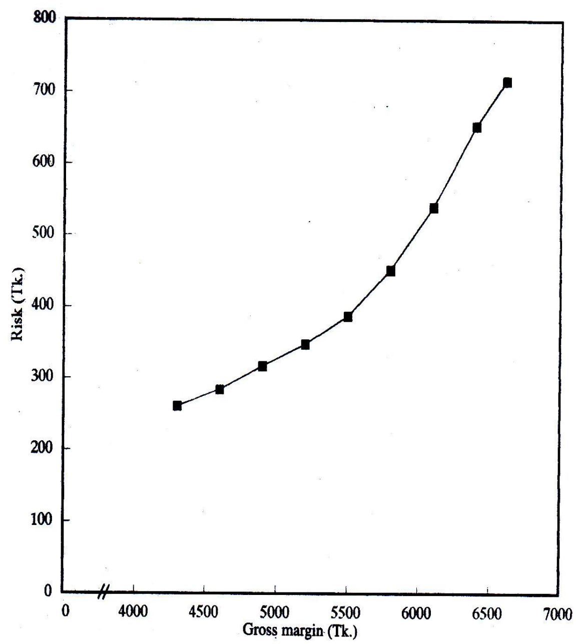

Fig. 2. Gross Margin Risk Frontier for Pure Owners Farms under Borrowed Capital Stituation

Risk and labour employment

On the pure owner farms under existing capital situation, human labour employment increased from 39 man–days in Plan–1 to 44 man–days in the last efficient plan indicating an increase of 13%. Continuous increase in human labour employment was due to increase in the cultivated area in successive plans. Further, inclusion of bullock labour at higher lavel also favoured an increase in human labour employment. Under borrowed capital situation, human labour employment also increased in successive plans. In the first plan, human labour employment was 56 man–days while it increased to 81 man–days in the last plan representing an increase in human labour employment to the extent of 45%.

On the owner–cum–tenant farms also, human labour employment increased in successive plans. The human labour employment increased from 60 man–days in Plan–1 to 72 man–days in Plan–10 indicating an increase of 20% under existing capital situation.

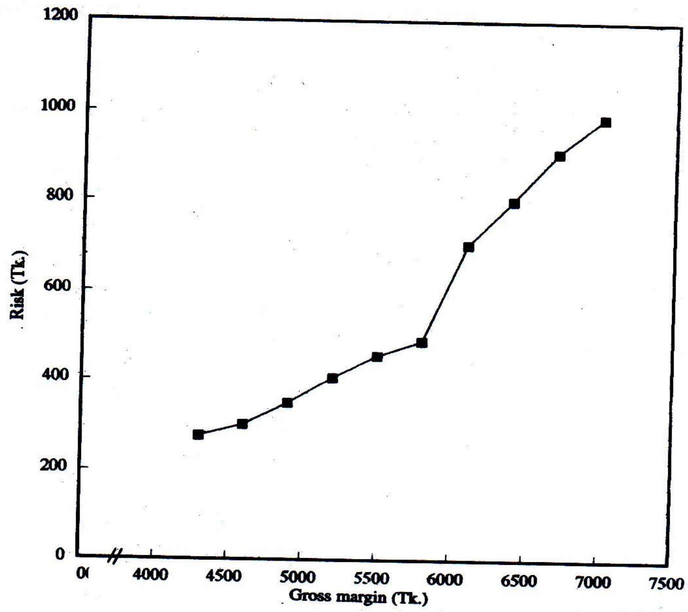

Fig. 3. Gross Margin Risk Frontier for Owner-cum-tenant Farms under Existing Capital Stituation

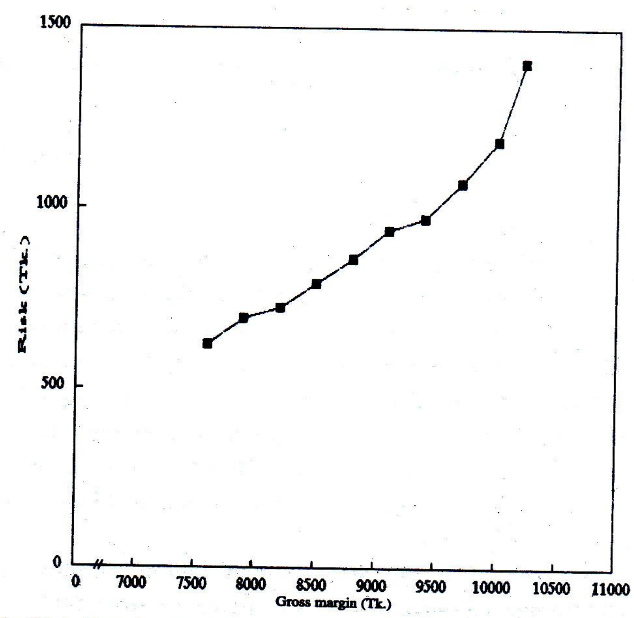

Fig. 4. Gross Margin Risk Frontier for Owner-cum-tenant Farms under Borrowed Capital Stituation

Due to relaxation of capital, human labour employment was 103 man-days in Plan-1 which increased to 127 man-days in Plan-10 indicating an increase of 23%.

As regards bullock labour employment, there appeared to be a positive relationship of bullock labour employment in the successive plans with the increase in total cropped area. On the pure owner farms, bullock labour employment increased by 16% and 21% respectively under existing and borrowed capital situations (Tables 1 and 2). The corresponding bullock labour employment increment figures for the owner-cum-tenant farms were 33% and 11% under existing and borrowed capital situations respectively (Tables 3 and 4).

Inter-tenurial group comparison of the results indicates that human labour employment was directly related to the total cropped area. Bullock labour employment was also directly related to the total cropped area with a minor exception in the case of the owner-cum-tenant farms. It is difficult to calculate bullock labour employment without considering tractor/power tiller utilization. In the case of some crops, only bullock labour was needed. But for other crops, both bullock labour and tractor/power tiller were needed. The utilization of bullock labour and tractor/power tiller thus depend on what type of crops would be allocated in the successive plans. Hence, the consideration of combined bullock labour and tractor/power tiller is justified.

Risk and tractor/power tiller utilization

The utilization of tractor/power tiller was directly related with the total cropped area. The tractor/power tiller utillization increased in successive plans with a minor exception in the case of the pure owner farms under borrowed capital situation. The utilization of tractor/power tiller increased by 353% and 837% respectively for the pure owner farms under existing and borrowed capital situations. The corresponding figures for the owner-cum-tenant farms were 618% and 454% respectively. The tremendous increase of tractor/power tiller utilization compared to bullock labour employment indicates the greater utilization of tractor/power tiller by those crops which entered into the successive plans.

Risk and capital use

In general, capital use on farms increased as gross margins increased in the successive plans. In order to generate the larger expected gross margins along the frontier, larger area was brought under cultivation and this facilitated the use of more capital on each of the farms. From Tables 1, *2, 3* and *4* it is evident that risk also increased as the capital use increased. On the pure owner farms under existing capital situation, capital use increased from Tk. *918* in Plan-1 to Tk *2137* in Plan-5. Under borrowed capital situation, capital use increased from Tk. *816* in Plan-1 to Tk. *2660* in

Plan–9. On the owner–cum–tenant farms under existing capital situation, capital use increased from Tk. 865 in Plan–1 to Tk. 3829 in Plan–10. Under borrowed capital situation, the use of capital increased from Tk. 2112 in Plan–1 to Tk. 5621 in Plan–10. In general, it can be said that risk increased with the larger use of capital which yielded larger returns in the last few plans.

IV. CONCLUSIONS AND POLICY IMPLICATIONS

The foregoing analysis reveals that higher gross margin, labour employment and tractor/power tiller utilization were associated with higher risk. Total cropped area under conditions of risk was generally lower than that under the perfect knowledge situation. Standard deviation (risk) moved much faster than the return along the gross margin–risk frontier. The study demonstrates that there existed greater scope for stabilizing income on the owner–cum-tenant farms which were neither too resource intensive nor too resource scarce. Land utilization increased along with the gross margin–risk frontier. The borrowing of capital increased the risk bearing ability of the plans. Capital investment gradually increased with the increase in gross margin and risk.

The results of the study showed direction of resource use for minimizing risk at various lavels of gross margins. The results obtained under various resource situations and tenurial groups of the small farms would provide a broad basis to the policy makers for formulating improved planning regarding farming practices in the area under study. The study results would help in suggesting suitable production plans for the small farms. It would also help in selecting appropriate plan for risk averters, average risk bearers and risk preferers, depending upon the resource availability and the goal of the farmers.

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