

Farm planning under risk and uncertainty of a rural area in Bangladesh

MOSSAMMAT ANJUMAN ARA BEGUM,
MOHAMMED KAMRUZZAMAN, BASIL MANOS*

JEL classification: O180, Q120

1. Introduction

Bangladesh economy, since its independence, has undergone intermittent economic turbulence, shock and disequilibrium. Large current account deficits, fiscal imbalance, high inflation rates, low saving/investment rates, were the major characteristics of the economy, leading to low growth rate during most of the period. Adopting inappropriate macroeconomic policies by the government mainly created these economic problems. To overcome this economic crisis, Bangladesh, under the pressure of the World Bank, initiated free market economic policies commonly known as structural adjustment policies since the mid 1980's.

Agriculture is the dominant sector of the Bangladesh economy and growth and the stability of Bangladesh depends largely on the growth of agriculture. It is the main occupation of the people employing 68.5 percent of the labor force. This sector directly contributes around 25 percent to the gross domestic product and above 80 percent of the total population directly or indirectly depends on agriculture. Agricultural production is typically a risky business. Farmers face a variety of

Abstract

Bangladesh agriculture achieved an impressive growth following green revolution but risk in agriculture has also increased during the period. Risk in agriculture affects farmers' decisions and often results in technically and allocatively inefficient level of resources use.

The present study is undertaken to work out risk efficient sets of production plans of a rural area in Bangladesh, the district of Rangpur. The specific objectives of the study were to develop production plans to minimize risk and to study the effect of changes in gross return, existing resources, and its availability on risk efficient production plans. An E-V model of Quadratic Programming has been used to consider the impact on land among crops and livestock to farm plan based on macro technical and economic data of a period of 11 years. This results in an E-V frontier that shows the trade-off between the expected income and the variance of the income. The efficiency frontier corresponds to a number of alternative policies, each of them reflecting a different risk aversion level of the policy makers.

Résumé

L'agriculture du Bangladesh s'est développée énormément par suite de la révolution verte mais le risque en agriculture a aussi augmenté au cours de cette période. Ce risque influence les décisions des agriculteurs et aboutit souvent à un niveau technique et d'allocation inefficaces de l'utilisation des ressources.

La présente étude est entreprise pour élaborer des séries de plans de production à risque efficace d'une zone rurale au Bangladesh, dans le district de Rangpur. Les objectifs spécifiques de cette étude consistaient à développer des plans de production visant à minimiser le risque et étudier l'effet des changements du profit brut, des ressources existantes, et de sa disponibilité sur les plans de production à risque efficace. On a utilisé un modèle E-V de Programmation Quadratique pour tenir compte de l'impact des plans d'exploitation sur la terre, les cultures et le bétail, se basant sur les données macro techniques et économiques d'une période de 11 ans. Ceci aboutit à une frontière E-V qui illustre le compromis entre le revenu attendu et la variance du revenu. La frontière d'efficacité correspond à un certain nombre de politiques alternatives, chacune desquelles réfléchissant un différent niveau d'aversion au risque des décideurs.

price, yield and resources risks that make their incomes unstable from year to year.

Farm resources (land, labor and capital) may be allocated to various crop and livestock enterprises through production plans, each of which achieves different economic results.

A Quadratic Programming model is used in this study to program the agricultural production of a rural area in Bangladesh. The main resources considered by the plan are stochastic in time. The results of the model are useful both to the farmers and to the authorities responsible for planning in this area.

The specific objectives of the study were to develop optimal production plans to minimize risk and to study the effect of changes in gross margin, existing resource

use and its availability on risk efficient production plans. Furthermore, the following hypotheses were tested: a) It is possible to minimize risk in farm income through optimum enterprise-mix, and b) The effect of changes in gross margin, existing resource use, and its availability has an influence on risk.

2. Farm Planning Under Risk and Uncertainty

Agricultural productive activity has always been considered to be rather risky. It is because agriculture is spe-

* Mossammat Anjuman Ara Begum and Mohammed Kamruzzaman are postgraduate research scholars and Basil Manos is professor, Department of Agricultural Economics, Aristotle University of Thessaloniki, Greece.

cific in the sense that it comprises many factors, which are usually out of the producers' control. Therefore, the farmers are exposed to numerous natural and economic resources of uncertainty: price and demand uncertainty, factor input uncertainty, uncertainty due to weather, climate etc. A number of studies suggest that these risks can have important consequences for farmers' decisions, especially among small holding farms in developing countries (Dillon and Anderson, 1971; Wiens, 1976; Herath et al., 1982).

Two are usually the main goals in farm planning: the maximization of total gross margin and the minimization of risk. These two optimizations are generally conflicting to each other. More remunerative enterprises may be more risky. Optimistic and enterprising farmers prefer the maximization of gross return and are ready to take risk. But the risk averting farmers are satisfied with lower income. Risk averters prefer low but stable total gross margin rather than uncertain high gross margin. Decision makers plan to maximize the expected total gross margin by manipulating decision variables in response to a given set of parameter values. They also plan to minimize the variation of the total gross margin of the production plan. This variation is due to the variability of yields, prices, labor required, and capital needed and is connected with the optimum farm plans according to the economic results expected.

This kind of risk and uncertainty led to the development of various programming models. The problem of random variation in the Linear Programming (LP) model is partially solved by using the Mean Absolute Deviation Criterion (MOTAD model) introduced by Hazell (1971) and applied from many researchers (e.g. Sekar and Palanisami, 2000). This problem is solved more completely by using Quadratic Programming. It has been suggested as the most useful tool for incorporating risk in farm planning. Quadratic Programming can also be used in the dual form for variations in quantities of available resources when these are treated as random variables with known probability distributions (Tinter and Sengupta, 1972).

3. The E-V Model in Quadratic Programming

The E-V model is the Quadratic Programming approach to incorporating a mean-variance criterion in the objective function. The earliest work in capital budgeting using the Quadratic Programming/mean-variance criterion was done by Farrer (1962). The E-V model is so named because the optimum production plan is selected on the basis of the expected gross margin E and its variance V .

In this case, the gross margin of each farm enterprise is considered a random variable, and the variance of the expected total gross margin for the whole region is a function of the variances and covariances of the gross margins

of the farm enterprises studied (Manos and Kitsopanidis, 1986).

The E-V model is expressed by

$$(1) \quad \min \quad V = x'Dx$$

subject to constraints:

$$\begin{aligned} Ax &\geq Ib \\ cx &= \lambda, \quad 0 \leq \lambda \leq E_{\max} \\ x &\geq 0 \end{aligned}$$

Where,

x = n-vector of levels X_j of activities $j = 1, 2, \dots, n$

x' = transpose of x

b = m-vector of levels of available resources $i = 1, 2, \dots, m$

A = m x n matrix of technical and economic coefficients a_{ij} of resource i and activity j

c = n-vector of the mean gross margin c_j of activities $j = 1, 2, \dots, n$

D = n x n matrix of covariance's \hat{U}_{ij} of gross margin c_i and c_j

E_{\max} = maximum total gross margin of the linear programming approach

λ = parameter that takes values in the interval $(0, E_{\max})$

3.1 Study Area and Collection and Analysis of Data

The area of the present study is Sadar Upazila in the district of Rangpur in Bangladesh. It occupies a fertile plain area of 330 sq. km. The land is suitable for production of rice, jute, tobacco and winter crops. The temperature in this area varies from 9.4oC to 33.1o C. The average annual rainfall is about 2026 mm with the lowest in January and the highest in July. Agriculture is the main occupation and source of livelihood of most people in the area. About 70% of the land of the study area is devoted to agriculture directly or indirectly.

The analysis was based on the primary data collected through a comprehensive field survey. A sample of 120 farms was chosen. The survey was conducted in one agricultural year 1999-2000 and the data pertained to the years from 1988-89 to 1998-99. Secondary data were collected from various sources.

3.2. Matrix Formulation

Typical farm situation was considered for the construction of programming matrix. Typical farm with farm size of 4.8 acre was selected for applying the Quadratic Programming model. Besides 14 crops and 3 livestock activities were considered. Risky returns would occur in the context of crop and livestock response processes because either yields or prices or both were uncertain (Dillon, 1977).

3.3. Resources Constraints

In the context of Bangladesh farming, the most limiting resources in farm production are land and capital. In addition, human labor and bullock labor also become restrictive in the whole 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. Having taken all these considerations into account, four restrictions were incorporated in the model. These were land, human labor, bullock labor, and capital constraints considering one agricultural year as 3 different seasons such as rabi (which is occupied during the months of October to March), kahrif-I (which is considered during the months of April to June) and kharif-II (consist of the months of July to September).

Land

For the present study, three types of land restrictions e.g. land I (rabi season), land II (kharif-I season) and land III (kharif-II season) were introduced. The unit of process of crop activity was taken as one acre of land (1 hectare = 2.47 acre), for cow and goat as one animal and for broiler as 100 birds. Thus 4.8 acres land availability was considered as constraint for each season in the model.

Human labor

For setting up human labor restriction, three seasonal operation wise requirements of labor for different crops and livestock were determined in consultation with the respondent farms. The human labor availability in the rabi, kharif-I and kahrif-II seasons was entered separately as three constraints and were considered at most 350, 300, and 200 man-days per year respectively.

Bullock labor

Hiring bullock labor as an activity has been included in the matrix table because bullock labor hiring was a com-

mon practice in the study area. Bullock labor availability in the rabi season at most 150, kahrif-I season at most 100 and kahrif-II season at most 50 pair-days per year were considered as constraint.

Capital

For this study, capital has been defined as working capital requirement to meeting day-to-day farm or production costs both in cash and kind. Capital availability in terms of taka was considered for 3 seasons in a year (1 Taka = 0.0179 Euro about).

The initial matrix is given in Table 1.

4. The Suggested Plans and Expected Results

The farm plans and the corresponding economic results suggested by the E-V model are shown in Table 2. The cropping intensity is 300% in all farm plans i.e. one unit land is used 3 times in one cropping year in each plan suggested by Quadratic Programming.

We observe that as the gross margin increased from taka 39125.5 in plan I to taka 41481.8 in plan VI, the farm plan changed in order to yield the highest possible variance for each level of gross margin. The changes in farm plans from I-VI mainly involved a decrease in land devoted to potatoes, aus rice, and gram and an increase for lentil, mashkalai and cows. Plan VI included aman rice but excluded boro rice, mustard, jute and mung. The decrease of some crops and the corresponding increase of others depend on the variance of each crop and the covariance of some of them.

Table 2 also shows the rapid increase of the variance as the gross margin moves continuously to higher levels. In fact, the standard deviation of gross margin increases from 7368.85 to 11930.63 taka from plan I to plan VI. The expected gross margin is increased by 6.02% and the varia-

Table 1. Initial matrix of activities and constraints

Activities	Rice			Wheat	Maize	Gram	Lentil	Mung	Mashkhalai	Mustard	Jute	Tobacco	Tomato	Potato	Livestock			Sign	b _i
	Aus X ₁	Aman X ₂	Boro X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁	X ₁₂	X ₁₃	X ₁₄	Cow X ₁₅	Goat X ₁₆	Broiler X ₁₇		
Objective function	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=	min
Expected gross margin	1944	2413.14	5560.47	2091.88	448.49	2917.85	2869.89	2507.23	2042.80	1064.00	1375.02	2024.30	2391.10	4703.61	2323.45	1035	1651.5		
Land I	0	0	1	1	1	0	1	0	0	1	0	0	1	1	0.003	0	0.01	≤	4.8
Land II	1	0	1	0	0	0	0	0	1	0	1	1	0	0	0.003	0	0.01	≤	4.8
Land III	0	1	0	0	0	1	0	1	0	0	0	0	1	0	0.003	0	0.01	≤	4.8
Human labor I	0	0	32.73	30.34	25.74	0	29.36	0	0	20.20	0	0	49.97	39.51	47.47	21.51	60.12	≤	350
Human labor II	22.85	0	29.84	0	0	0	0	0	25.59	0	49.28	40.64	0	0	30.12	13.84	45.01	≤	300
Human labor III	0	28.48	0	0	0	22.18	0	23.36	0	0	0	0	41.32	0	23.10	9.12	33.07	≤	200
Hiring bullock labor I	0	0	14.67	12.28	8.42	0	14.26	0	0	8.71	0	0	14.37	15.37	0	0	0	≤	150
Hiring bullock labor II	10.36	0	11.75	0	0	0	0	0	13.29	0	13.17	14.52	0	0	0	0	0	≤	100
Hiring bullock labor III	0	8.32	0	0	0	8.34	0	11.78	0	0	0	0	10.47	0	0	0	0	≤	50
Capital I	0	0	2404.71	1589.46	904.27	0	1395.68	0	0	480.75	0	0	535.23	3351.10	841.12	664.00	1972.30	≤	8850
Capital II	1503.58	0	1621.12	0	0	0	0	0	1023.53	0	1450.67	1846.24	0	0	555.23	451.12	1456.38	≤	7685
Capital III	0	984.62	0	0	0	1230.24	0	1156.49	0	0	0	0	473.55	0	495.76	339.90	1327.38	≤	6320

Land I – rabi season (October to March), Land II – Kharif-I season (April to June), Land III – Kharif-II season (July to September).
 Unit: Crop activities – per acre; Cow and goat – per animal; Broiler – per 100 birds.
 bi: Land – acre; Human labor – man-days/year; Bullock labor – pair-days/year; Capital I – Taka/year
 Gross margin and capital: Crop activities – Taka/acre; cow and goat – Taka/animal; and broiler – Taka/100 birds
 1 Taka = 0.0179 Euro (about)

Table 2. Crop and livestock activities in farm plans suggested by Quadratic programming

Farm enterprises and economic results	Plans					
	I	II	III	IV	V	VI
I. Crops (acre):						
a. Land I (Rabi season)						
Boro	1.02	0.87	0.79	-	-	-
Wheat	-	-	-	-	-	-
Maize	-	-	-	-	-	-
Lentil	2.73	3.11	3.28	4.30	4.43	4.69
Mustard	0.57	0.36	0.27	-	-	-
Tomatoes	-	-	-	-	-	-
Potatoes	0.48	0.46	0.46	0.50	0.37	0.11
Sub-total	4.80	4.80	4.80	4.80	4.80	4.80
b. Land II (Kharif-I season)						
Aus	2.26	2.58	2.73	2.89	2.44	1.52
Boro	1.02	0.87	0.79	-	-	-
Mashkalai	0.50	0.50	0.50	1.91	2.36	3.28
Jute	1.02	0.85	0.78	-	-	-
Tobacco	-	-	-	-	-	-
Sub-total	4.80	4.80	4.80	4.80	4.80	4.80
c. Land III (Kharif-II season)						
Aman	-	-	-	1.14	1.74	2.99
Gram	4.79	4.80	4.80	3.66	3.06	1.81
Mung	0.01	-	-	-	-	-
Tomatoes	-	-	-	-	-	-
Sub-total	4.80	4.80	4.80	4.80	4.80	4.80
II. Livestock (number):						
Cows	0.84	0.84	0.84	1.41	1.71	2.33
Goats	-	-	-	-	-	-
Broilers	-	-	-	-	-	-
III. Economic results (taka):						
1. Expected gross margin (E)	39125.5	39455.8 (0.84%)	39603.5 (1.22%)	40880.8 (4.49%)	41078.3 (4.99%)	41481.8 (6.02%)
2. Variance (million taka)	54.30	61.51	64.94	105.93	116.24	142.34
3. Standard deviation (σ)	7368.85	7842.83 (6.43%)	8058.54 (9.36%)	10292.23 (39.67%)	10781.47 (46.31%)	11930.63 (61.91%)
4. Coefficient of variation (CV)	18.83%	19.88%	20.35%	25.18%	26.25%	28.76%
5. Pr (E \pm 2 σ) = 95.45%	53863.21 24387.79	55141.46 23770.14	55720.57 23486.43	61465.26 20296.34	62641.23 19515.37	65343.07 17620.53
IV. Cropping intensity	300%	300%	300%	300%	300%	300%
Note: Figures in parentheses are the percentage increases comparing with plan I						

tion is increased by 61.91% from plan I to plan VI. This means that the rate of increase of the variance is greater compared with the rate of increase of its expected gross margin.

From Table 2 it results that the variance and coefficient of variation are minimum in plan I. This means if the farmers produce this combination of crops their risk would be minimum. Although other plans show higher expected gross margin than plan I, their variances and coefficient of variations, i.e. risks, are also high. Only the farmers who are less concerned about risk will choose the plans that are near to the highest expected gross margin. Since our objective was to develop optimum production

plans to minimize risk and plan I gives the minimum value of variance and coefficient of variation i.e. risk is minimum in plan I, we consider it as the best plan. The crop activities included in this plan are 1.02 acres boro rice (rabi and kharif-I season), 2.73 acres lentil, 0.57 acres mustard, 0.48 acre potatoes, 2.26 acres aus rice, 0.50 acres mashkalai, 1.02 acres jute, 4.79 acres gram and 0.01 acres mung. The livestock activity included in the optimum plan is 0.84 numbers of cows.

We conclude for the same plan I, if we take as a base the 95.45% confidence intervals of expected gross margin (two standard deviations). The minimum gross margin expected for plan I is taka 24387.79 and it is taka 23770.14, taka 23486.43, taka 20246.34, taka 19515.37 and taka 17620.53 for plan II, III, IV, V and VI respectively. The most profitable plan must

be chosen on the basis of the highest minimum total gross margin expected. The highest minimum gross margin expected is taka 24387.79 for plan I. Farm plan I is expected to give a level of gross margin equal to taka 39125.5 with a degree of uncertainty 95.45%, which means that the gross margin will not be less than taka 24387.79.

. A Comparison among the Existent, LP and E-V Farm Plans

In the study area, most of the farms are traditionally allocated to wheat (1.00 acres), maize (0.95 acres), lentil (0.63 acres), mustard (0.29 acres), tomatoes (0.60 acres)

Table 3. Comparison among the existent, linear programming and E-V farm plans

Farm enterprises and economic results	Existent plan	Linear programming	E-V plan
I. Crops (acre):			
a. Land I (Rabi season)			
Boro	-	-	1.02
Wheat	1.00	-	-
Maize	0.95	-	-
Lentil	0.63	4.80	2.73
Mustard	0.29	-	0.57
Tomatoes	0.60	-	-
Potatoes	1.17	-	0.48
Sub-total	4.64	4.80	4.80
b. Land II (Kharif-I season)			
Aus	-	-	2.26
Boro	0.65	-	1.02
Mashkalai	-	4.80	0.50
Jute	1.00	-	1.02
Tobacco	2.95	-	-
Sub-total	4.60	4.80	4.80
c. Land III (Kharif-II season)			
Aman	2.55	3.47	-
Gram	0.70	1.33	4.79
Mung	-	-	0.01
Tomatoes	1.00	-	-
Sub-total	4.25	4.80	4.80
II. Livestock (number):			
Cows	1.00	2.57	0.84
Goats	1.00	-	-
Broilers	-	-	-
III. Economic results (taka):			
1. Expected gross margin (E)	36478.98	41751.06	39125.5
		(+14.45%)	(+7.25%)
2. Variance (million taka)	84.33	164.36	54.30
3. Standard deviation (σ)	9183.14	12820.30	7368.85
		(+94.9%)	(-35.61%)
4. Coefficient of variation (CV)	25.17%	30.71%	18.83%
5. Pr ($E \pm 2\sigma$) = 95.45%	54845.25	67391.65	53863.21
	18112.71	16110.47	24387.79
IV. Cropping intensity	281.04%	300%	300%
Notes: Figures in parentheses are percentage increases (+) or decreases (-) comparing with existent plan			

and potatoes (1.17 acres) in the rabi season; boro (0.65 acres), jute (1.00 acres) and tobacco (2.95 acres) in kharif-I season and aman (2.55 acres), gram (0.70 acres) and tomatoes (1.00 acres) in kharif-II season (Table 3). Rice is the major crop, followed by tobacco, tomatoes, potatoes, wheat, and others. The expected total gross margin is taka 36,478. The cropping intensity is 281.04%, which means that one unit land is used 2.81 times in one cropping year.

In Table 3 the existent average farm plan of the area is compared with the farm plans suggested by LP and E-V models. The farm plan suggested by LP and E-V models are different from the existent plan in the land area covered by the crops. LP suggests only one crop in rabi sea-

son and specifically lentil (4.80 acres). E-V model suggests for the same rabi season a production plan with 4 crops, boro rice (1.02 acres), lentil (2.73 acres), mustard (0.57 acres) and potatoes 0.48 acres. LP suggests only one crop (4.80 acres of mashkalai) also in kharif-I season. On the other hand, E-V model suggests for the same season a multi-crops plan with aus rice (2.26 acres), boro rice (1.02 acres), mashkalai (0.50 acres), and jute (1.02 acres). In kharif-II season, LP suggests a production plan with two crops (aman 3.47 acres and gram 1.33 acres) and E-V model also suggests a plan with two crops, gram (4.79 acres) and mung (0.01 acres). The number of cows is 2.57 and 0.84 in the plans suggested by LP and E-V model respectively. Wheat, maize, tomatoes, tobacco, and goats were excluded from the plans suggested by the aforementioned models. Also, the area grown by mustard, potatoes and jute showed a fluctuation among farm plans suggested by the two models, namely these are present in the farm plan suggested by E-V model and are excluded from the farm plan suggested by the model of LP. The opposite is true for the area grown with aman rice which existed and covered a larger area in farm plan suggested by LP model but excluded from the farm plan suggested by the E-V model. The number of cows is increased in LP plan but is decreased in the plan suggested by E-V model. These differences explain the variation noted in the utilization of the farm resources available, the economic results expected and their variability among the various models.

As regards the economic results, the existent plan achieves total gross margin taka 36,478.98, the suggested plan by LP model taka 41,751.06 and by E-V model taka 39,125.5. This means that the plan suggested by LP presents an important increase to total gross margin equal to 14.45%. This increase is 7.25% for the plan suggested by E-V model. In this respect, the farm plan resulting from LP model is more efficient compared with the plan of E-V model. But planning agricultural production in this area is based on parameters that are average for the period 1988-89 to 1998-99. So, the plan of LP cannot give guarantee that the economic results expected are achieved. At the same time the plan suggested by LP model presents almost double risk than the existent plan (39.61% increase in variability of total gross margin), whereas the plan suggested by E-V model shows half risk than the existent plan (19.76% decrease). The coefficient of variation is less (18.83%) in E-V farm plan and greater (30.71%) in LP farm plan than the existent plan. On the other hand the plan of LP model can guaranty with probability 95.45% the best highest level of total gross margin (taka 67,391.65), whereas the plan of E-V model can guarantee with the same probability the better lowest level of gross

margin (taka 24,387.79).

The above results show that if the purpose of farm planning in the study region is the maximum gross margin, then it is better to prefer LP model. In conditions of risk and uncertainty it is better to prefer the E-V model that can achieve the highest gross margin with the lowest variability.

6. Conclusions

The results of the study show that farm plans suggested by LP and E-V models must be preferred in relation to existent farm plan of the region, because they both achieve greater gross margins. In addition, under conditions of risk and uncertainty in yields, prices, labor required, and capital needed, it is better to prefer the E-V model, because it can achieve the highest gross margin with the lowest variability, namely the highest minimum gross margin.

Comparing the two models, we conclude that it is better to prefer the LP model when the physical and economic data used are known and certain, because it achieves the maximum gross margin. On the contrary, when the physical and economic data used are uncertain then it is better to prefer the E-V model, because it achieves the highest minimum gross margin. It is stabler from both the technical and the economic point of view because it took into account the variances and co-variances of gross margins for the various crops in the period 1988-89 to 1998-99.

Risk analysis showed that there is scope in the study region to minimize risk at farm level by enterprise-mix.

On the other hand, the results suggest that farms must diversify their sources of income beyond rice at their own initiatives where state support is little. If the farms adopt the suggested crop diversification, the domestic production will be increased and farms will be more economically benefited with low risk. Moreover, the resources allocation becomes more efficient and the production increases with obvious benefits for the farmers concerned and for the nation as a whole. The increased production will not only meet the minimum requirements of the demand but will also fulfill the nutritional requirements of the population in the country.

From the policy point of view, the results show that the financial institutes in Bangladesh should provide the needed capital to the farms in order to raise the income in crops and livestock activities efficiently. The policy implementations include advising farmers in the region to

follow the production plans accommodating boro rice (rabi season), aus rice, and mashkalai, providing more credit facilities to improve the input use, so as to enable farmers to realize higher productivity and thereby income in crop activities and emphasizing the need for fixing appropriate price policy for aus rice, boro rice (rabi season), jute, and potatoes in the region.

It is expected that a policy that utilizes the results of the study will lead the country towards a stable food self-sufficiency and will help build up a self-reliant rural economy in future. In the short term, there may well be unpleasant side effects of developing such a system. However, in the long term, this is probably the only way to achieve a financially healthy sustainable agricultural sector in Bangladesh. This outline may be considered as a broad guideline rather than a blueprint to frame development policies for the agricultural sector. The actual nature and extent of policies will depend on political decisions of the government.

References

- Dillon J.L., Anderson J.R., 1971. Allocative Efficiency of Traditional Agriculture and Risk, *American Journal of Agricultural Economics*, Vol. 53, No. 1, pp. 26-32.
- Dillon J.L., Anderson J.R., 1990. *The Analysis of Response in Crop and Livestock Production*, Pergamon Press, Oxford, pp. 116-146.
- Farrer D.F., 1962. *The Investment Decision Under Uncertainty*, Prentice Hall, Englewood California, New Jersey, pp. 101-144.
- Hazell P.B.R., 1971. A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty, *American Journal of Agricultural Economics*, Vol. 53, No. 1, pp. 53-62.
- Herath H.M.G., Hardaker B., Anderson J.K., 1982. Choice of Varieties by Srilanka Rice Farmers: Comparing Alternative Decision Models, *American Journal of Agricultural Economics*, Vol. 64, No. 3, pp. 87-93.
- Manos B., Kitsopanis G., 1986. A Quadratic Programming Model for Farm Planning of a Region in Central Macedonia, *Interfaces*, Vol. 16, No. 4, pp. 2-12.
- Markowitz H.M., 1959. *Portfolio Selection: Efficient Diversification of Investments*, New York, Wiley, pp. 330-332.
- Sekar I., Palanisami K., 2000. Farm Planning under Risk in Dry Farms of Palladam Block of Coimbatore District in Tamil Nadu, *Indian Journal of Agricultural Economics*, vol. 55, No. 4, pp. 660-670.
- Tinter G., Sengupta J., 1972. *Stochastic Economics; Stochastic Process, Control, and Programming*, Academic Press, New York, pp. 203-268.
- Wiens T.B., 1976. Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment", *American Journal of Agricultural Economics*, Vol. 58, No. 4, pp. 629-635.