IMPACTS OF FERTILIZER PRICING POLICY IN BANGLADESH: A MULTICRITERIA ANALYSIS

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Abstract

Fertilizer policy has been an important policy issue during the past few years in Bangladesh, moving the political consensus in the direction of modernizing legislation as a first step towards changing the problematic situation of distribution and pricing of fertilizer. Several possibilities have been debated, especially the pricing of fertilizer. This paper aims to contribute to this policy discussion by simulating the impact that various policies based upon the price of fertilizer could have on agricultural production. Specifically, the study analyzes the economic, social and environmental implications of alternative fertilizer policies. The present research used a methodology of Weighted Goal Programming approach to estimate a utility function in the context in which farmers' behavior was not explained by the maximization of gross margin as a single objective but by a compromise between multiple objectives, such as the maximization of the total gross margin, the minimization of the variance of the total gross margin and the minimization of the labor. This methodology was applied to an agricultural region of Bangladesh. The most important criterion appeared to be the maximization of total gross margin and circumstantially the minimization of risk. The empirical results of this study show that a policy of increased price of fertilizer would have an enormous impact on farm income and employment.

Key words: Bangladesh; fertilizer policy; agricultural production planning; weighted model of multiple programming; multicriteria analysis; utility function.

INTRODUCTION

Along with other inputs of production, fertilizer appears to be the most important input in terms of value of production and employment, especially in irrigated areas of Bangladesh. The study by Khondker *et al.* (2002) found that nearly 87 percent of farmers used fertilizers, and in irrigated villages almost all farmers used fertilizer. It also showed that chemical fertilizer accounted for around 18 to 20 per cent of total expenditure on High Yielding Variety (HYV) crop production. Therefore, the pricing and distribution mechanism of chemical fertilizer is a critical determinant for the desired and sustained growth of agricultural production in the country. A well-planned fertilizer policy is, therefore, essential for gradual increase of cropping intensity as well as yield in Bangladesh.

Considering the importance of application of fertilizer for stable and expanding agricultural production, various efforts have been made to design an efficient, undistorted and non-discriminatory fertilizer distribution system in Bangladesh. Nevertheless, Bangladesh fertilizer policy is not consistent with the importance of this strategic sector. Fertilizer distribution in Bangladesh has been completely privatized since 1989/90. When the private sector was allowed to import fertilizers in 1992, subsidies were eliminated. At present, the Government is providing no subsidy on fertilizers at the farm level and is selling all fertilizers at full cost pricing. As a result fertilizer prices have been increased dramatically.

In the last quarter of 1994, the privatization program was subjected to widespread concern and criticism due to rapid, and exorbitant increase in retail prices of Urea. In fact, concerns and fears were turned into real problems with the culmination of a crisis in 1995. The crisis of 1995 was seen by many as a demonstration of the failure of the liberalization policies so far followed in fertilizer distribution. Policy-makers felt that greater government control over the market was essential to prevent a recurrence of the crisis.

However, the lessons from the 1995 fertilizer crisis compelled Government (GoB) to exercise some interventionist measures in the privatized distribution mechanism during the late nineties. After the crisis, fertilizer policy has been an important policy issue during the past few years, moving the political consensus in the direction of modernizing legislation as a first step towards changing the situation. Several possibilities have been debated, especially the pricing of fertilizer. A high powered national committee has been monitoring the changing demand and supply of Urea fertilizer in the national market for the last few years in order to avoid both over supply, excess demand and price instability.

This paper aims to contribute to this policy discussion by simulating the impact that various polices based upon the price of fertilizer could have on agricultural production. Specifically, the study analyzes the economic, social and environmental implications of alternative fertilizer policies using a multicriteria model of farmers' behavior. Considering the overwhelming importance of Urea fertilizer in total consumption of chemical fertilizer (75%), the behavior has been estimated for Urea only.

The success of fertilizer schemes depends on how producers value fertilizer and on their willingness to pay for it. The utility of fertilizers to farmers, and thus demand for it, is in terms of inputs (intermediate good) requires to produce end products demanded by consumers. The willingness to pay for fertilizer depends upon the value of the output over the cost of producing that extra output (value of the marginal product of fertilizer).

A number of approaches can be used to approximate the value of fertilizer with principal one the Linear Programming (LP) referred to one period (Manos and Kitsopanidis, 1988). If sufficient data can be obtained at a reasonable cost, LP has several advantages over other methods. However, the use of one criterion, such as the maximum total gross margin, is not enough for the explanation of farmers' behavior. It is obvious that the farmers interest itself is not only for the maximization of total gross margin, but also for other conflicting criteria, such as the minimization of the variance of the total gross margin, the minimization of labor, the minimization of variable cost, the minimization of fertilizers etc. These criteria, all or certain, can be incorporated in one and unique utility function.

An interesting body of literature emerged at the end of the seventies, beginning of the eighties showing the need to find a balance between multiple objectives and goals in agricultural planning. Among these studies at least the papers by Gomez-Limon and Berbel (2000), Berbel and Rodriguez (1998), Gomez-Limon *et al*. (2002), Arriaza *et al*. (2002), Sumpsi *et al*. (1997), and Amador *et al*. (1998) should be cited. From these papers derive the necessity to formulate decision-making models in agricultural planning, which recognize the multiplicity of objectives and goals detected by the above researchers. In other words, traditional Mathematical Programming models based on the optimization of a single objective should be replaced by multicriteria analysis. There are two main types of multicriteria technique with Mathematical Programming: Multiobjective Programming, which tries to optimize simultaneously several objectives (often with many of them in conflict), and Goal Programming, which tries to satisfy as far as possible a set of goals compatible with the preferences exhibited by farmers. In the present study, we used utility functions where the ability to simulate real decision-makers' preferences is based on the estimation of relative weightings. These utility functions are a good approximation to the farmers' hypothetical utility functions. The relative methodology was developed by Sumpsi *et a1*. (1997) and extended by Amador *et a1*. (1998). It is based upon Weighted Goal Programming (WGP) model (Romero and Rehman (1989)) and has previously been used by Berbel and Rodriguez (1998), Gomez-Limon and Berbel (2000) and Gomez-Limon and Arriaza (2000). This model combines the simplicity and the flexibility of LP with the completed environment of MCDM models.

MATERIALS AND METHODS

The Farm Region and Data Used

This model is applied to a region of Bangladesh that occupies a fertile plain area of 4182 hectares. The land is suitable for production of rice, wheat, maize, jute, and winter crops (Figure 1). Agriculture is the main occupation and source of livelihood of the most people in the region. We selected this region because it is representative of northern Bangladesh, relatively homogenous and has good data availability.

The analysis was based on the primary data collected through a comprehensive field survey. The technical and economic coefficients of crops were gathered from a sample of 97 farms of the region using a suitable questionnaire. The survey was conducted to one agricultural year 2002-2003 and the data are referred to a period of 12 years (1990-'91 to 2001-'02) and they were collected from the villages and municipalities of the study region. Secondary data were collected from the various issues of BBS.

The Utility Function

In this paper a surrogate utility function is estimated with the use of WGP model, which is used to estimate the fertilizer demand for crop production. The following steps were followed:

1. Establishment of a set of objectives $f_1(x)\ldots f_i(x)\ldots f_n(x)$ that may be supposed to be the most important for farmers and represent the real objectives of the farmers (e.g. profit maximization, risk minimization etc.).

2. Calculation of the pay-off matrix for the above objectives, which has the following formulation:

Objective attributes	$f_1(x)$	$f_2(x)\ldots$	$\ldots f_i(x)\ldots$	$\ldots f_q(x)$
$f_1(x)$	f_1^*	f_{12}	f_{1i}	f_{1q}
$f_2(x)$	f_{21}	f_2^*	f_{2i}	f_{2q}
$\ldots f_i(x)$	f_{i1}	f_{i2}	f_i^*	f_{iq}
$\ldots f_q(x)$	f_{q1}	f_{q2}	f_{qi}	f_q^*

(1)

The elements of the matrix need to be calculated by optimizing one objective in each row. Thus, f_{ij} is the

value of the *i* attribute when the *j*-th objective is optimized.

3. Estimation of a set of weights that optimally reflect farmers' preferences. Once the pay-off matrix has been obtained, the following system of *q* (number of objectives) equations is solved:

$$\sum_{j=1}^{q} w_j f_{ij} = f_i \qquad i = 1, 2, \ldots, q; \text{ and} \qquad (2)$$

$$\sum_{j=1}^{q} w_j = 1$$

where, q is the number of relevant objectives that was fixed previously, w_j are the weights attached to each objective (the solution), f_{ij} are the elements of the pay-off matrix and f_i are the real values that show the observed behavior of farmers in the existing situation.

4. Since the above system does not result in a set of w_j (weights of each objective that reproduce the actual behavior of the farmer), it is necessary to search for the best possible solution by minimizing the sum of deviational variables that finds the closer set of weights. For this purpose (Romero, 1991) the following model of Linear Programming (Model (3)) has been solved:

$$? \text{ in } \sum_{i=1}^{q} \frac{n_i + p_i}{f_i} \qquad (3)$$

(3)

subject to:

$$\sum_{j=1}^{q} w_j f_{ij} + n_i - p_i = f_i \text{ ; } i = 1, 2, \ldots q; \text{ and } \sum_{j=1}^{q} w_j = 1$$

where, p_i is the positive deviational variable that measures the difference between real value and optimum solution for the *i*-th objective, and n_i is the negative deviational variable.

Multicriteria Model Specification

- **Decision variables**

Each farmer of the region has a set of variables X_i (crops). These are the decision variables that may take any value belonging to the feasible set.

- **Objectives**

Three objectives were selected that can be considered as belonging to the farmers' decision-making process.

Maximization of gross margin (GM): Farmers wish to maximize their profits and gross margin (GM) is a good estimator of profit. The objective function that is included in the model is determined as bellow:

$$GM = \sum_{i=1}^{q} GM_i \times X_i \qquad (4)$$

Minimization of risk: The fluctuations of prices and yields play a very important role in the agricultural production, and risk is therefore always present in any agricultural system. In this case, the risk is measured as the variance of the total GM. Thus the risk is calculated

by the type:

$$\text{Total risk} = \bar{x}_i' \, [\text{cov}] \, \bar{x}_i \qquad (5)$$

where, [cov] is the variance/covariance of gross margin during the period of 12 years, and X_i is the vector of area of each crop in hectare.

Minimization of labor: Labor is calculated as the sum of labor for all farm activities (TL), therefore the objective function wil1 be:

$$\sum_{i=1}^{q} TL_i \times X_i = TL \qquad (6)$$

- **Resource constraints**

For the study region, the following restrictions were incorporated in the model.

Land constraint: The sum of all crops must be equal to 100. This constraint is only introduced in order to obtain the outcome of the model (decision variables X_i) as percentages.

Crop production policy: Although the intensification of food grain production, especially rice-based production system is apparently profitable from the farmers' point of view, this approach has appeared to be harmful in protecting the land productivity. At present, rice covers about 75 percent of the cultivated land in Bangladesh. The production system dominated by a single crop (i.e. rice) is neither scientific nor acceptable from the economic point of view. It is, therefore, necessary to increase the cultivation and production of other crops. For this reason, we applied a constraint for all rice (aus, aman and boro) that they must be less than their historical quota of 52.26% of the total available area.

Marketing constraints: Given the potential for expanding wheat acreage, efforts should be continued to encourage farmers to grow more wheat. For this reason, wheat is constrained to be greater than the historical quota assigned to each farmer (upper limit in the period of 1990-'91 to 2001-'02). Maize has also gained popularity as human food side by side with the poultry feed. Public sector procurement of maize has been introduced like rice and wheat in order to encourage farmers in maize cultivation. For this circumstances, "a greater than" constraint for maize has been included in the model. We have fixed this upper limit on the basis of the maximum historical cultivation during the period 1990-'91 to 2001-'02. Although vegetables are riskier than other crops, these possess higher gross margins. Thus, the program for increasing area and production of vegetables needs to be extended in order to obtain higher farm income. For this case, "a greater than" constraint is included in the model. We have placed this maximum limit according to the historical maximum in the period 1990-'91 to 2001-'02.

Rotational considerations: In this study, three rotational constraints have been taken. Rotation 1 implies that the area planted to potato cannot exceed the area planted to boro rice. In rotation 2, we considered that the aus rice supplies land for the production purposes to jute. In rotation 3, we supposed that the mustard supplies land for the production purposes to radish seed.

All this information has been included in the model that forms the basis for the MCDM simulation.

- **Attributes**

Some attributes of great interest for the analyst have been also included that are not taken into consideration by the farmers at the process of decision-making, but that are to be analyzed later in the study. The attributes that are analyzed are:

Fertilizer consumption: The projected fertilizer consumption is measured in kg/ha and it is the variable that the policy makers wish to control as a consequence of changes in fertilizer management policy.

Economic impact: The economic impact on the change of policy is measured by calculating agricultural income from the fertilizer pricing, measured in Taka/ha (1 Euro equal to 80.00 Taka).

Social impact: Since fertilizer-intensive agriculture is one of the main sources of employment in the study region, any change in the policy will influence considerably the social structure of rural areas. This attribute is measured in hours per ha.

Environmental impact: An increase in the use of fertilizers and chemicals are the main sources of pollution in the agriculture. The demand for fertilizers is used as an indicator of the environmental impact of the agriculture in the study area, measured in kilograms of Urea that are added per ha (kg/ha).

- **Weighted Goal Programming Process**

The above-mentioned algorithm is applied to our model as follows:

In the first step, three objectives $f_i(x)$, $i = 1, 2, 3$ were selected that were described above with their respective mathematical functions (maximum gross margin (GM), minimum variance (VAR) and minimum labor (TL)).

In the second step, the pay-off matrix was obtained by solving each time the program (single objective max./min.). The pay-off matrix for the study region is presented in Table 1. The last column shows the real situation (existing farm plan) in the study region. These values show the actual crop distribution in the region (for 100 hectares) and the relation among different crops and the objectives considered [GM, VAR and TL]. Thus we can see how far the existing situation (2001-2002) is from each separate optimum (column). This prompts us to try a combination of the three objectives for better simulation of farmers' behavior.

In step 3, the set of weights was obtained that best reflects farmers' preferences and minimize deviations from present real values. More specifically, from the solution of model (3) the following weights were resulted:

W_1 (maximize GM) = 0.8617

W_2 (minimize risk VAR) = - 0.1383
W_3 (minimize labor TL) = 0

From these weights we may deduce that the farmers in the region behave according to an additive utility function, in which the objectives considered are the maximization of gross margin with a weight of 0.8617 and the minimization of risk (measured as variance) with a weight of 0.1383. It is important to note that although we proposed labor minimization as an objective taken into account by farmers, the results have shown us that this hypothesis was wrong and actually total labor is not considered as a relevant criterion in this particular agricultural system where rice is the prominent crop. The calculation of these weights was based on the existing situation, where the fertilizer price is 6.00 Taka/kg. With the basis of these weights the utility function is as follows :

$$U = 86.17\% GM - 13.83\% VAR. \quad (7)$$

(7)

In order to obtain non-dimensional utility function, the factor of each objective is divided by the range between the best and the worst value in the pay-off matrix. We thus result to the following utility function:

$$U = 4.58361 \times 10^{-07} GM - 1.92686 \times 10^{-12} VAR$$

(8)

which is same with the function

$$U = 458361 GM - 1.923 VAR. \quad (9)$$

This expression that the model attempts to maximize is employed in the subsequent simulation.

- **Real Values Vs Simulated (Validation)**

The estimated utility function (equation 9) for the study region was used as the objective function of MCDA Quadratic Programming model (the equation 9 is quadratic because the variance is entered) in order to obtain the optimum production plan of the total region.

In table 2 the existing production plan, the optimum plan that was achieved by the application of MCDM model as well as the plan achieved by traditional Linear Programming model that had single objective of maximization of gross margin (LP model) are presented. At the present fertilizer price level of 6.00 Taka/kg, the MCDM model achieves a production plan with fewer crops than existing situation but more crops than the suggested LP model. The crop sectors that are suggested to be produced by MCDM are aus rice (19.31%), aman rice (19.83%), aman* rice (3.97%), boro rice (3.07%), wheat (9.49%), maize (7.31%), tomato (3.91%), brinjal (7.22%), mustard (1.62%), cabbage (3.71%), cauliflower (2.13%), radish seed (2.45%), potato (4.95%), red amaranth (3.62%), jute (2.53%) and lady's finger (4.88%). The mentioned three objectives i.e. the maximization of gross margin, the minimization of risk and the minimization of labor present better result in MCDM model than the existing plan as well as the model suggested by LP. The MCDM model trying to combine the two objectives, profit maximization and risk minimization, gives a farm plan that achieves 31.61% more gross margin, 5.24% more variance of gross margin and 3.69% more total labor than the existing plan. The MCDM model also provides 8.82% less gross margin than the gross margin achieved by LP model that has as objective function the maximization of gross margin. As regards the variance, the MCDM model achieves an important reduction of 27.11% in comparison with the LP model. Regarding the total labor, it shows 2.85% decrease comparing the traditional LP model.

- **Elicitation of Fertilizer Demand Functions**

The estimated utility function (equation 9) is used to estimate the value of fertilizer demand for the production of fertilizer-used crops using the described MCDM model with the following adaptations:

1. Function to be maximized is above function (9)
2. Gross margin includes the additional cost of fertilizer and
3. Three new crops are introduced that require various levels of fertilizer in order to allow the system to be adapted to the increasing cost of fertilizer.

The result of this procedure is shown in table. 3, where we can see that each of these 3 new crops (e.g. potato) is represented by two different decision variables or activities. Each crop variable is followed by a number, which represents the amount of fertilizer in kg employed per hectare. Of course, for each fertilizer supply, the crops will have different productivities, e.g. "potato* 494" (X_{16}) means crop requiring 494 kg fertilizer yielding 13457 kg/ha, "potato 469" (X_{15}) means crop requiring 469 kg fertilizer yielding 13893 kg/ha. Similarly, "Aman* 161" (X_3) means the yield of Aman* is 2726 kg/ha, which requires 161 kg fertilizer per ha while "Aman 136" (X_2) indicates 2691 kg/ha yield, requiring 136 kg fertilizer per ha. Finally, "Lady's finger* 358" (X_{20}) means it requires 358 kg/ha fertilizer for 7835 kg/ha yield and "Lady's finger 333" (X_{19}) means crop requiring 333 kg fertilizer per ha for 6927 kg/ha yield.

As a result, decision variables in our model consist of 20 crops, each combined with a fertilizer supply level. Each of these modified fertilizer-used crops includes technical and economic coefficient such as, labor and the remaining inputs data.

RESULTS AND DISCUSSION

The multicriteria (weighted goal) model was used in order to examine the effect of a policy of increased fertilizer prices on production plans and hence, on the fertilizer consumption, the farmers' income, the employment and the environment. In particular, the simulations of farmers' responses to fertilizer price increases were done using the utility function 9. This function was modified proportionally in each increased price of fertilizer, since the crops' gross margin was decreased because of additional variable cost of fertilization. The initial price of fertilizer was taken as 6.00 Taka/kg that corresponded to the existing situation. The differences between the classical LP model and the MCDM model are also focused. Table 4 shows crop distributions for MCDM model as a response to change in the prices of fertilizer.

- **Fertilizer Consumption**

Figure 2 summarizes the fertilizer demand for the study region in response to its price changes from 6.00 Taka/kg to the level of 18.5 Taka/kg, by solving MCDM and LP model. The figure shows two formal declining demand curves that represent how farmers react to the increasing costs of fertilizer. The different slopes of the demand curves are due to changes in the crop plans, as an adaptation to the rising cost of fertilizer resources: the low prices of fertilizer imply the crops with high consumption of fertilizer, but when the fertilizer price increases, more fertilizer consumed crops (tomato, cabbage, cau liflower, potato, and lady's finger) either decrease or remain constant. Consequently, the continuous increase of fertilizer price from 6.00 to 18.5 Taka/kg has the result of corresponding reduction of gross margin of farm enterprises and the achievement of different farm plans (Table 4). These plans present continuous increase of the area of aus rice, aman rice, aman* rice, wheat, maize and mustard at the reduction of the area of brinjal, cabbage, cauliflower, potato and lady's finger. The interesting fact is that the area of maize increases until price level 15.5 Taka/kg, after this price, the area starts to decrease. The probable reason for such type of behavior is that although maize is a high fertilizer-intensive crop, considering its profitability and low risk, farmers keep continuation to increase the area of maize in response of fertilizer price increases. But at the levels of very high fertilizer prices, farmers decrease the area under maize.

On the basis of these estimates, we can conclude that an agricultural policy based upon fertilizer price changes will have an impact on fertilizer demand. When the fertilizer price is increased, demand for fertilizer is decreased. It is interesting to observe the similarities and differences between the two curves. The demand of fertilizer in the MCDM model begins from 184.00 kg/ha for the price of 6.00 Taka/kg and is decreased progressively until 12.01% in the price of 18.5 Taka/kg. While, in LP model the demand of fertilizer begins from 228.00 kg/ha and is decreased progressively up to 16.89% in the price of 18.5 Taka/kg (Figure 2).

It is observed from Figure 2 that evolution is smoother in MCDM model. The smoother curve of the multicriteria demand function in comparison with classical profit maximization is exp lained by crop plans that are formed by the smaller number of crops grown when profit is the only objective, and only the most profitable crops are included. On the other hand, when risk minimization is taken into account, such as in the utility function (equation 9), the farmer tries to diversify his activities by bringing a wider variety of crops into the cultivation plan. This behavior is more realistic and in our case, the best result is defined as the optimum of the multicriteria objective function.

- **Economic Impact: Farm Income**

In this study, the impacts on income are measured with the total gross margin. It is obvious that fertilizer pricing would have an enormous impact on farm income. Farm income decreases gradually as a result of continuous increase of fertilizer prices (Figure 3). In response of continuous increase in fertilizer prices, farmers change their production plans and try to decrease the consumption of fertilizer, introducing less profitable crops as substitutes for the more costly crops that require more fertilizer. This process decreases the farm income considerably.

Figure 3 shows that at the beginning of the simulation the farm income is 22220 and 24368 Taka/ha for MCDM and profit maximization model respectively, as fertilizer prices increase, these values decrease, accompanying the general trend of fertilizer demand. Fertilizer price of 18.5 Taka shows a loss of income of 6.79% (1508 Taka/ha) and 8.74% (2129 Taka/ha) for MCDM and profit maximization model respectively comparing their initial prices. The figure indicates that the rate of decrease of farm income is higher in case of LP model than the MCDM model.

It is important to note that the economic viability of the most fertilizer-intensive crops in the region is threatened by the implementation of fertilizer price policy. As a result of fertilizer prices rise, the levels of agriculture conflict the socio-economic sustainability.

- **Social Impact: Farm Employment**

The impacts on employment are measured with the used labor. Figure 4 shows how farmers' behavior varies when demand is based on multiattribute utility against profit maximizing model. As fertilizer price increases, a reduction in farm labor input is caused as a result of the responses to price increases, by reducing fertilizer consumption through changes in farm plans and introducing less profitable crops as substitutes for higher-value/higher labor or fertilizer-intensive crops. This implies that fertilizer-intensive crops will be replaced by less labor demanding and more mechanized crops.

Figure 4 shows that in LP model, until the fertilizer price level of 10.00 Taka/kg, labor demand decreases in a certain range, from 11.00 to 12.50 Taka/kg price level, labor demand decreases at a higher rate than the previous prices and from the fertilizer price level 14.00 Taka/kg and above, labor demand decreases dramatically from their initial prices as a result of significant crop plans change. On the other hand, in MCDM model, at fertilizer price of 7.00 Taka/kg, the labor demand shows a reduction (0.69%) than the initial price of 6.00 Taka/kg, from price level 8.00 Taka/kg to the level of 11.00 Taka/kg, fertilizer price is characterized by a relatively certain farm plan without significant diversification in labor demand. The fertilizer prices from 12.50 to 14.00 Taka/kg show a smooth reduction of labor demand curve. On the other hand, over this level, crop plans change, inducing relatively a large reduction in labor demand.

Thus we may conclude that the solution for the above region is a challenge for the future agricultural policies. Considering all the points that have been said, it is very necessary to find a compromise solution, from the political/social point of view, that equates all these dimensions in the best interest of future fertilizer-intensive agriculture, of the reinforcement of its competitiveness, without ceasing to consider the possible implication for the human and socio-economic environment of study region where agriculture is often the unique social activity propelling development.

- **Environmental Impact: Fertilizer Use**

As discussed before, Figure 2 and Table 4 show that the increasing cost of fertilizer leads to a significant reduction in fertilizer use as a result of changes in the production plans and inclusion of less productive crops. This constitutes very important conclusion if we intend to adopt fertilizer pricing as an instrument for environmental policy. This behavior will obviously have a positive impact in the reduction of non-point chemical pollution by agriculture. However, efficient fertilization is more dependent on the use of sound fertilizing techniques than on the total amount of fertilizer used. The findings of the research are that the price of fertilizer would have to be increased to as much as 17.00 Taka/kg in MCDM model and 14.00 Taka/kg in LP model if it is to have a significant impact on fertilizer consumption (9.81% reduction in MCDM model and 12.49% reduction in LP model). However, the reduction in fertilizer consumption will be accompanied by corresponding reduction of farm income (6.06% in MCDM model and 6.65% in LP model) (Figure 3). We would recommend that priorities be put upon volume control (and reducing distribution losses) that will lead to similar saving without the social cost of a policy of pricing.

CONCLUSIONS

This paper provides a utility function introducing a Weighted Goal Programming approach that is used as an instrument capable of reproducing the behavior of the farmer in a region of Bangladesh. This function incorporates three objectives, such as the maximization of gross margin, the minimization of variance of gross margin and the minimization of labor.

From the result, it seems that there is no single objective capable of explaining the behavior followed by farmers in the region. In fact, two (GM maximization and risk minimization) of the mentioned objectives have significant weights values. It is observed that the weight or importance attached to the farms to the maximization of GM is significantly higher than the other objective, i.e., farmers seem to have an interest towards GM maximization. This conclusion is corroborated by reality. Thus, the objective to maximize GM, which is the traditional dominant objective in most of the decision-making models in agricultural planning, is consistent with the real preferences revealed by farmers. Risk is also proved as a significant objective for the study region. This conclusion can be explained by the fact that farmers perceive risk through an index measuring the variability of total gross margins such as the variance or the mean absolute deviation.

The estimated utility function was used to take alternative farm plans that achieve different levels of income, labor and environmental impacts. The received farm plans achieve smaller farm income up to 6.79% (MCDM) and 8.74% (LP) as the fertilizer price increases from 6.00 to 18.5 Taka/kg. The impact of this reduction on the rural areas that depend upon fertilizer-intensive agriculture will be catastrophic. When fertilizer consumption decreases as a result of the substitution of higher labor or fertilizer-intensive crops with less profitable crops, there is a significant loss of employment, both directly on farms and indirectly on processing facilities. In response of fertilizer pricing, there is an important reduction in its consumption; hence it has a positive impact on environment. But the environmental impact of fertilizer use could also be reduced significantly by improved agricultural practices.

The above conclusions are drawn from the analysis of a representative fertilizer-intensive farming community in Bangladesh, but we believe that they are capable in contributing to the policy debate on normative innovations on the fertilizing sector of Bangladesh agriculture. From the empirical point of view we wish to remark that our results show how farmers' behavior is better simulated by a utility function involving several criteria, which differs from the traditional profit-maximization assumption. This is of special interest when results are to be considered for policy making, as is the case with fertilizer in Bangladesh in the present study. The analytical tools outlined in this paper treated as a valid methodology and could also be used in other regions for producing more realistic policy-impact simulations and other agricultural policies.

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Tab. 1. : Pay-off matrix for the selected region (100 ha)

Values	Optimum			Real (existing)
	GM	VAR	LAB	
GM	1942879	102405501359	62918	1688298
VAR	1708442	71776569271	58944	61608269304
LAB	1592190	65293091317	54219	58836

Tab. 2. : Model validation for the selected region (100 ha)

Items	Observed values (existing farm plan)	LP model		MCDM model	
		Values	% deviation	Values	% deviation
Farm plans:					
Aus	26.10	0.00	-100.00	19.31	-26.02
Aman	22.21	0.00	-100.00	19.83	-10.73
Aman*	0.00	45.56	100.00	3.97	100.00
Boro	3.96	1.33	-66.31	3.07	-22.38
Wheat	9.49	9.70	2.21	9.49	0.00
Maize	7.84	14.27	81.98	7.31	-6.77
Tomato	1.62	2.33	43.83	3.91	141.48
Brinjal	3.26	3.30	1.12	7.22	121.47
Sweet gourd	2.17	3.66	68.46	0.00	-100.00
Radish	1.53	0.00	-100.00	0.00	-100.00
Mustard	1.64	0.00	-100.00	1.62	-1.15
Cabbage	2.41	2.41	0.00	3.71	54.02
Cauliflower	3.72	3.73	0.00	2.13	-42.64
Radish seed	2.46	0.51	-79.20	2.45	0.00
Potato	2.77	0.79	-71.56	4.95	78.76
Potato*	0.00	4.92	100.00	0.00	0.00
Red amaranth	3.64	3.61	-0.69	3.62	0.00
Jute	2.49	1.17	-52.94	2.53	1.76
Lady's finger	2.71	0.00	-100.00	4.88	80.28
Lady's finger*	0.00	2.71	100.00	0.00	0.00
Total	**100.00**	**100.00**		**100.00**	
Objectives:					
GM	1688298	2436817	44.34	2221974	31.61
VAR (million)	61608.27	88949.75	44.38	64836.55	5.24
LAB	58836	62799	6.74	61010	3.69

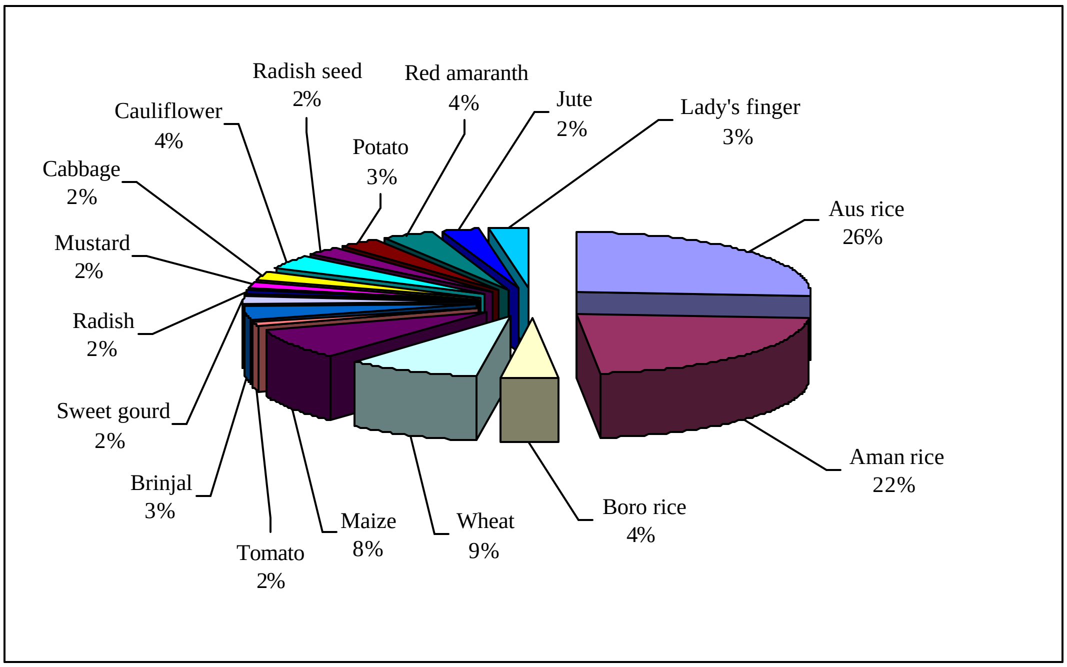
Tab. 3. : Crop variables with different levels of fertilizer (average of period 1990-'91 to 2001-'02)

Crops	Variables	Yield (kg/ha)	Total labor (hours/ha)
Aus 86	X1	3689	585
Aman 136	X2	2691	528
Aman* 161	X3	2726	600
Boro 124	X4	5573	659
Wheat 136	X5	4462	464
Maize 432	X6	6684	654
Tomato 371	X7	11063	1046
Brinjal 136	X8	18713	925
Sweet gourd 56	X9	16464	358
Radish 86	X10	11181	449
Mustard 47	X11	1707	330
Cabbage 371	X12	27599	901
Cauliflower 333	X13	18438	778
Radish seed 135	X14	569	377
Potato 469	X15	13893	831
Potato* 494	X16	13457	868
Red amaranth 37	X17	5326	346
Jute 162	X18	2978	874
Lady's finger 333	X19	6927	469
Lady's finger* 358	X20	7835	500

Tab. 4 . : Alternative farm plans of MCDM model in r esponse to changes in fertilizer price

Simulated crops (100 ha)	Variables	Fertilizer price (?aka/kg)										
		6.00	*7.00*	*8.00*	*9.00*	*10.00*	*11.00*	*12.50*	*14.00*	*15.50*	*17.00*	*18.50*
Aus	X1	19.31	19.48	19.93	20.32	20.62	21.03	21.72	22.19	22.20	22.04	21.77
Aman	X2	19.83	19.87	19.91	19.95	19.99	20.04	20.10	20.15	20.22	20.27	20.32
Aman*	X3	3.97	4.10	4.23	4.37	4.53	4.62	4.95	5.12	5.57	5.93	6.34
Boro	X4	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
Wheat	X5	9.49	9.49	9.49	9.49	9.49	9.49	9.49	9.49	9.82	11.03	12.28
Maize	X6	7.31	7.36	7.42	7.48	7.53	7.53	7.66	7.65	7.81	7.66	6.91
Tomato	X7	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91
Brinjal	X8	7.22	6.25	6.20	6.16	6.13	6.09	6.08	6.06	6.04	6.02	6.00
Sweet gourd	X9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Radish	X10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mustard	X11	1.62	2.57	2.63	2.65	2.65	2.71	2.65	2.72	2.73	2.77	2.81
Cabbage	X12	3.71	3.61	3.47	3.39	3.39	3.39	2.97	2.65	2.12	2.12	2.12
Cauliflower	X13	2.13	2.13	2.13	2.13	2.13	2.07	1.98	1.94	1.79	1.20	0.94
Radish seed	X14	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45
Potato	X15	4.95	4.82	4.66	4.54	4.42	4.31	4.10	3.95	3.61	2.86	2.40
Potato*	X16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red amaranth	X17	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62
Jute	X18	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53
Lady's finger	X19	4.88	4.73	4.32	3.92	3.52	3.12	2.72	2.50	2.50	2.50	2.50
Lady's finger*	X20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Fig. 1. : Crop distribution of the selected region (1990-'91 to 2001-'02)



Source: Various issues of BBS, Bangladesh

Fig. 2 : Fertilizer use of MCDM against profit maximization in response of fertilizer price changes

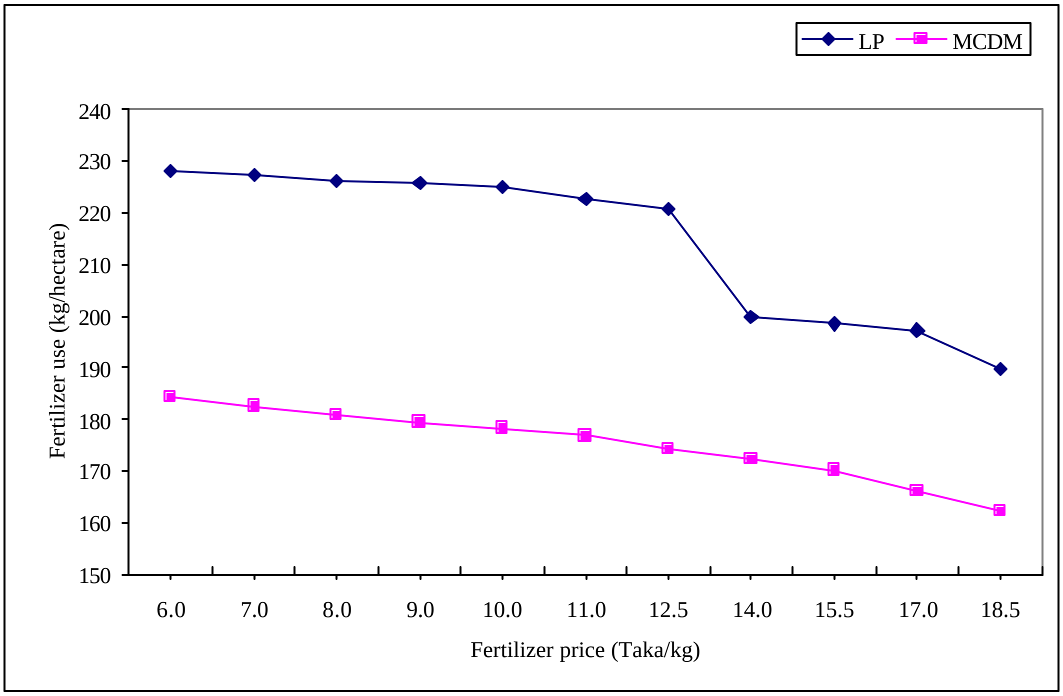


Fig. 3. : Farm income of MCDM and profit maximization in response to changes in fertilizer price

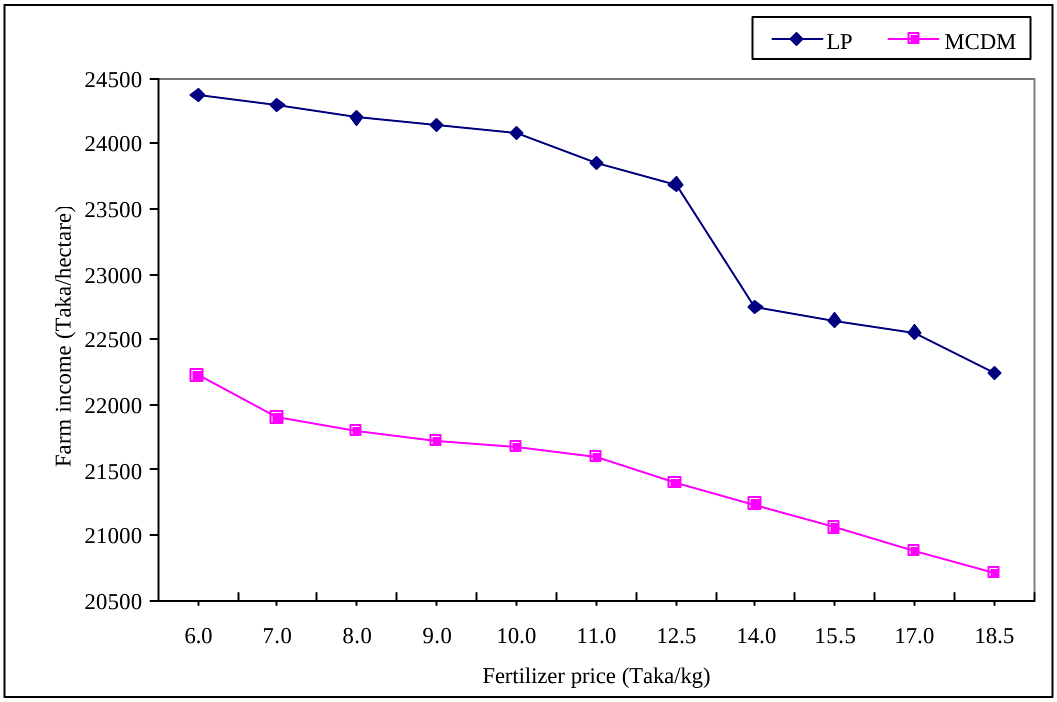


Fig. 4. : Farm employment of MCDM against profit maximization in response of fertilizer price changes