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Fertilizer price policy, the environment and farms behavior

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Abstract

The analysis of the effects of fertilizer pricing on intensive agriculture and farms behavior ought to be an important topic of research for agricultural and environmental economists in Bangladesh. Several possibilities for fertilizer policy have been debated, in particular for the pricing of fertilizer. Following this observation, this study, contributes to that 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 using a multi-criteria model. For this purpose the weighted goal programming approach is used to estimate a utility function considering three criteria, the maximization of the total gross margin, the minimization of the variance of the total gross margin and the minimization of the labor. The model is applied to an agricultural region of Bangladesh. The empirical results show that the most important criterion in farmers' utility function is the minimization of labor and circumstantially the maximization of total gross margin and the minimization of risk. Moreover they show that a policy of increased fertilizer price would have a very important impact on farm income and employment.

JEL classification: Q0; Q1; Q2; G13

Keywords: Agricultural production planning; Weighted model of multiple programming; Multi-criteria analysis; Utility function

1. Introduction

The pricing and distribution mechanism of chemical fertilizer is a critical determinant for the desired and sustained growth of agricultural production in Bangladesh. A well-planned

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fertilizer policy is thus 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 (Kamruzzaman, Manos, & Begum, 2006). Fertilizer distribution in Bangladesh has been completely privatized since 1989/1990. 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 farm level and is selling all fertilizers at full cost pricing. As a result fertilizer prices have been increased dramatically.

The management and use of fertilizer have been the focus of fertilizer policy of Bangladesh during the past few years, moving the political consensus in the direction of modernizing legislation as a first step towards changing the problematic situation. 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. Several possibilities for fertilizer policy have been debated, in particular for the pricing of fertilizer. This study, contributes to that discussion by simulating the impact that various policies based upon the price of fertilizer could have on agricultural production.

In this paper, a multi-criteria weighted programming model is applied for the planning of agricultural production in a region of Bangladesh and the analysis of policy increase of fertilizer prices. This model combines the simplicity and the flexibility of linear programming (LP) with the completed environment of multi-criteria decision making models (MCDM) (Mullen, 2004; Rehman & Romero, 1993; Romero & Rehman, 1989). The MCDM models constitute a balance between multiple objectives and goals in agricultural planning.

2. Data

The MCDM model is applied to a region of Bangladesh that occupies a fertile plain area of 330 km^2. The land is suitable for production of rice, jute, tobacco and winter crops. 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 coefficients of crops were gathered from a sample of 120 farms of the region using a suitable questionnaire. The survey was conducted to one agricultural year 2001–2002 and the data are referred to a period of 11 years (1990–1991 to 2000–2001) and they were collected from the villages and municipalities of the study region. Secondary data were collected from the various issues of BBS.

3. Analysis of the model

3.1. Variables

Each farmer of the region has a set of decision variables X_i composed of 14 intensive crops each combined with a level of fertilizer supply (Table 2).

3.2. Objectives

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

3.2.1. Maximization of gross margin (GM)

The objective function that is included in the model is determined as bellow:

$$\mathrm{GM} = \sum_{i=1}^{q} \mathrm{GM}_i \times X_i$$

where X_i is the area of crop i in acres, GM_i is the gross margin of crop i in Taka/acre and GM is the total gross margin of the farm (1 acre = 0.405 ha and 1 Taka = 0.80 Euro).

3.2.2. Minimization of risk

The risk is measured as the variance of the total GM and is calculated by the type:

$$\text{Total risk} = \bar{x}'_i[cov]\bar{x}'_i$$

where [cov] is the variance/covariance of total gross margin during the period of 11 years, and x_i is the vector of area of each crops in hectares.

3.2.3. Minimization of labor

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

$$\sum_{i=1}^{q} \mathrm{TL}_i \times xi = \mathrm{TL}.$$

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

3.3. Constraints

3.3.1. 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.

3.3.2. Crop production policy

Rice is the staple food in the study region. For this reason, a constraint is applied for all rice that they must be greater than their historical quota of 23% of the total available area.

3.3.3. 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 1990–1991 to 2000–2001). 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 1990–1991 to 2000–2001.

3.3.4. Rotational considerations

In this study, two 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, it is considered that the crop aus supplies land for the production purposes to jute.

3.4. Attributes

Some attributes of great interest have been also included that are not taken into consideration by the farmers at the process of decision-making. These are:

- *Fertilizer consumption*. The projected fertilizer consumption is measured in kg/acre 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 farm income from the fertilizer pricing, measured in Taka/acre.
- *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 man-days per acre.
- *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 acre (kg/acre).

3.5. The utility function

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, Amador, and Romero (1993, 1997) and extended by Amador, Sumpsi, and Romero (1998). It is based upon weighted goal programming and has previously been used by Berbel and Rodriguez (1998), Berbel and Gomez-Limon (2000), Gomez-Limon and Arriaza (2000), Gomez-Limon and Berbel (2000), Arriaza, Gomez-Limon, and Upton (2002), Gomez-Limon, Arriaza, and Berbel (2002), Manos, Bournaris, and Kamruzzaman (2003), and Gomez-Limon and Riesgo (2004). With this methodology a surrogate utility function is estimated, which is used to estimate the fertilizer demand for crop production.

3.6. The weighted goal programming process

For the estimation of farmers' utility function the following steps were followed:

In the first step, three objectives $fi(x)$, $i = 1, 2, 3$ 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 acres) and the relation among different crops and the objectives considered (GM, VAR and TL). Thus we can see

Table 1
Pay-off matrix for the selected region (100 acre)

	Optimum			Real (existing farm plan)
	GM	VAR	LAB	
GM	368756.10	268306.21	181146.68	253584.51
VAR	4784007485	1043347374	2871898817	2948512271
LAB	3757.04	2696.22	2465.71	3376.01

how far the existing situation (2000–2001) 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. These weights were found following the proposed by Romero (1991) approach. The resulted weights are:

- W_1 (maximize GM) = 0.272967
- W_2 (minimize risk VAR) = −0.243542
- W_3 (minimize labor TL) = −0.483491

From these weights we may deduce that the farmers in the study region behave according to an additive utility function, in which the objectives considered are the maximization of gross margin with a weight of 0.272967, the minimization of risk (measured as variance) with a weight of 0.243542 and minimization of labor with a weight of 0.483491. 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:

$$U = 27.30\%\,\text{GM} - 24.35\%\,\text{VAR} - 48.35\%\,\text{TL}$$

The corresponding non-dimensional utility function that was used in our analysis is:

$$U = 149,246\,\text{GM} - 6.42\,\text{VAR} - 37,171,000\,\text{LAB} \quad (1)$$

4. Application of the model

The estimated utility function (Eq. (1)) for the study region was used as the objective function of MCDA quadratic programming model (Eq. (1) is quadratic because the variance is entered) in order to obtain the optimum production plan of the study region. The set of constraints remains the same.

In Table 2 the existing production plan and the optimum plan that was achieved by the application of MCDM 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. The crop sectors that are suggested to be produced are tomato (51.66%), aman rice (18.18%), potato (8.67%), lentil (6.1%), boro rice (4.82%), tobacco (4.27%), wheat (4.15%) and jute (2.15%). 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. The MCDM model trying to combine the three objectives, gives a production plan that achieves 37.09% more gross margin, 40.78% less variance of gross margin and 19.71% more total labor than the existing plan.

Table 2
Existing and optimum farm plan for the selected region (100 acres)

Items	Existing farm plan	MCDM model	
		Values	%deviation
Farm plans			
Aus	0	0	0
Aman	18.90	18.18	−3.82
Boro	4.82	4.82	0.00
Wheat	7.41	4.15	−44.02
Maize	7.04	0	−100.00
Gram	5.19	0	−100.00
Lentil	4.67	6.1	30.62
Mung	0	0	0
Mashkhalai	0	0	0
Mustard	7.41	0	−100
Jute	2.15	2.15	0.00
Tobacco	21.87	4.27	−80.47
Tomato	11.86	51.66	335.56
Potato	8.67	8.67	0.00
Total	100	100	
Objectives			
GM	253584.51	347631.41	37.09
VAR (million)	2948.51	1746.17	−40.78
LAB	3376.01	4041.58	19.71

5. Economic, social and environmental impacts of increased fertilizer prices

The use of fertilizers in agriculture has a remarkable effect in the society, economy and in the environment. The MCDM model was used in order to examine the effect of a policy of increasing fertilizer prices on farm income, employment and environment of the region. In particular, the simulation of farmers' responses to fertilizer price increases was done using the utility function 1. This function was modified proportionally in each increasing 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.

5.1. Fertilizer consumption

Fig. 1 and Table 4 summarize the fertilizer demand for the study region in response to its price change from 6.00 Taka/kg to the level of 7.35 Taka/kg, by solving the MCDM model. Fig. 1 shows a formal declining demand curves that represents how farmers react to the increasing costs of fertilizer. The slope of the demand curve is due to changes in the crop plans, as an adaptation to the increasing cost of fertilizer resource: the low prices of fertilizer imply the crops with high consumption of fertilizer, but when the fertilizer price increases, the more fertilizer consumed crops (aman rice, boro rice, wheat, jute, tobacco, potato) either decrease or remain constant (Table 3). Consequently, the continuous increase of fertilizer price from 6.00 to 7.35 Taka/kg has the result of corresponding reduction of gross margin of farm enterprises and the achievement of different farm plans. These plans present continuous increase of the area of lentil and tomato at the reduction of the area of wheat and tobacco.

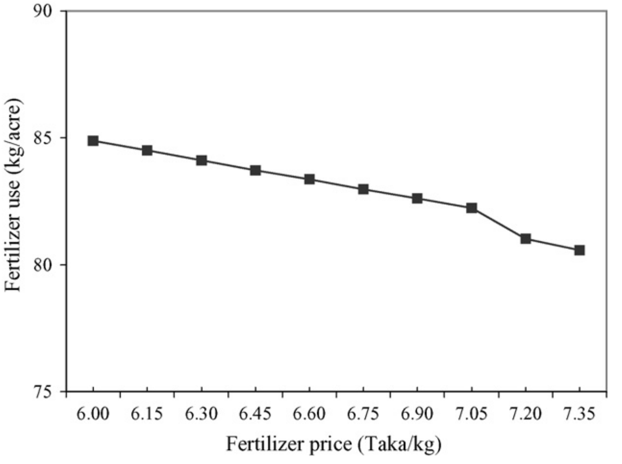

Fig. 1. Fertilizer use in response of fertilizer price changes.

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, the demand for fertilizer is decreased. The demand of fertilizer begins from 85.00 kg/acre for the price of 6.00 Taka/kg and is decreased progressively until 5.08% in the price of 7.35 Taka/kg. Specially, at the fertilizer price of 6.15, 6.30 and 6.45 Taka/kg, the fertilizer consumption is reduced by 0.46%, 0.91%, and 1.37% from its initial price. Thus, the consumption of fertilizer decreases by 4.56% at the price of 7.20 Taka and at the end of the simulation (7.35 Taka/kg) it decreases by 5.08% from its initial consumption.

5.2. *Economic impact: farm income*

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 (Fig. 2 and

Table 3
Alternative farm plans of MCDM model in response to changes in fertilizer price

Crops	Fertilizer price (Taka/kg)									
	6.00	6.15	6.30	6.45	6.60	6.75	6.90	7.05	7.20	7.35
Aus	–	–	–	–	–	–	–	–	–	–
Aman	18.18	18.18	18.18	18.18	18.18	18.18	18.18	18.18	17.52	15.83
Boro	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.66	3.5
Wheat	4.15	3.96	3.79	3.62	3.45	3.28	3.12	2.94	0.14	–
Maize	–	–	–	–	–	–	–	–	–	–
Gram	–	–	–	–	–	–	–	–	–	–
Lentil	6.1	6.43	6.76	7.09	7.4	7.73	8.04	8.37	8.70	9.03
Mung	–	–	–	–	–	–	–	–	–	–
Mashkhalai	–	–	–	–	–	–	–	–	–	–
Mustard	–	–	–	–	–	–	–	–	–	–
Jute	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
Tobacco	4.27	3.65	3.05	2.44	1.86	1.25	0.68	0.09	–	–
Tomato	51.66	52.14	52.58	53.03	53.47	53.92	54.34	54.78	59.32	62.98
Potato	8.67	8.67	8.67	8.67	8.67	8.67	8.67	8.67	7.51	6.51

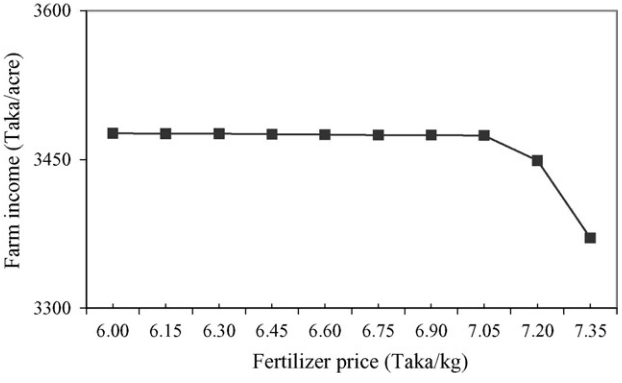

Fig. 2. Farm income in response of fertilizer price changes.

Table 4). 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.

Table 4 and Fig. 2 show that at the beginning of the simulation the farm income is 3476.31 Taka/acre. As fertilizer price increases, this value decreases, accompanying the general trend of fertilizer demand. Fertilizer price of 7.35 Taka shows a loss of income of 3.03% (3370.92 Taka/acre) comparing its initial prices.

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.

5.3. Social impact: farm employment

Fig. 3 and Table 4 show how farmers' behavior varies when demand is based on multi-attribute utility. As fertilizer price increases, a reduction in farm labor input is caused as a result of the

Table 4
Economic, social and environmental impact of changing price of fertilizer

Fertilizer price (Taka/kg)	Economic impact		Social impact		Environmental impact (fertilizer use)	
	Farm income (Taka/acre)	Decrease/ increase (%)	Farm employment (man-days/acre)	Decrease/ increase (%)	Urea (kg/acre)	Decrease/ increase (%)
6.00	3476.31	0.00	40.42	0.00	84.89	0.00
6.15	3476.08	−0.01	40.01	−0.99	84.50	−0.46
6.30	3475.76	−0.02	39.56	−2.11	84.12	−0.91
6.45	3475.40	−0.03	39.56	−2.12	83.73	−1.37
6.60	3475.12	−0.03	39.56	−2.12	83.36	−1.80
6.75	3474.76	−0.04	39.56	−2.13	82.97	−2.26
6.90	3474.43	−0.05	39.55	−2.14	82.61	−2.69
7.05	3474.22	−0.06	39.55	−2.15	82.23	−3.14
7.20	3449.02	−0.79	39.55	−2.15	81.02	−4.56
7.35	3370.92	−3.03	39.54	−2.17	80.58	−5.08

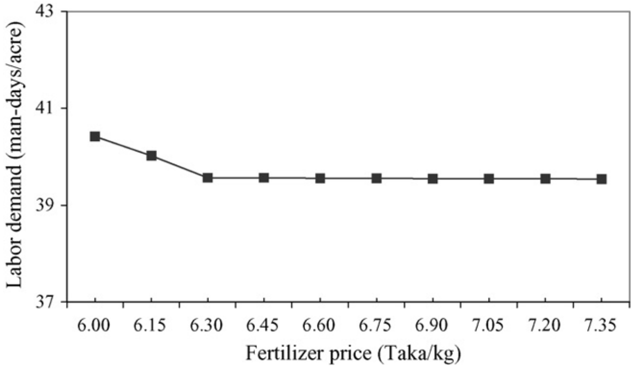

Fig. 3. Farm employment in response to changes in fertilizer price.

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. It is observed that until fertilizer price of 6.30 Taka/kg, the production plans change, inducing a large fall in the labor demand. Above this price labor demand is reduced in a lower rate.

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 and the reinforcement of its competitiveness, without ceasing to consider the possible implication for the human and socio-economic environment of the study region where agriculture is often the unique social activity propelling development.

5.4. *Environmental impact: fertilizer use*

As discussed before, Fig. 1 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. Nevertheless, fertilizer efficiency is more dependent on the use of sound fertilizing techniques than on the total amount of fertilizer used. The price of fertilizer would have to be increased to as much as 7.20 Taka/kg if it is to have a significant impact on fertilizer consumption (4.56% reduction). However, the reduction in fertilizer consumption will be accompanied by a corresponding reduction of farm income. 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.

6. Concluding comments

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 contributes to this discussion by simulating alternative fertilizer price policies.

Specifically, this paper provides a utility function that is used to analyze the farmers' behavior and the socio-economic and environmental implications of alternative fertilizer pricing in Bangladesh. The function incorporates three objectives, the maximization of gross margin, the minimization of variance of gross margin and the minimization of labor. From the results, it is observed that the minimization of hired labor is significantly higher than the two other objectives, i.e., farmers seem to have an aversion towards hiring labor. This conclusion is corroborated by reality, as the farms are currently and dramatically decreasing their workforce. Farmers are interested in the cultivation of extensive crops like cereals that need very little labor and through its compensating payments these crops generate higher profitability. However, this behavior generates an enormous decrease in the level of agricultural employment, which is causing serious social and economic problems. Risk is also proved as a significant objective for the study region. This conclusion is explained by the fact that farmers perceive risk through an index measuring the variability of total gross margins.

The estimated utility function was used to simulate fertilizer prices and take alternative farm plans that achieve different levels of income, labor and environmental impacts. The received alternative farm plans achieve smaller farm income up to 3.03% as the fertilizer price increases from 6.00 to 7.35 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 crops with high demands, there is a significant loss of employment, both directly on farms and indirectly on processing facilities.

On the other hand, in response of higher fertilizer prices, there is an important reduction in its consumption; this has a positive impact on environment because low fertilizer consumption implies less environmental problems.

Nevertheless, the fertilizer price's increase as a single instrument seems to be not the most appropriate means of significantly reducing the fertilizer consumption. This is because consumption is not reduced substantially until prices reach such a level that they negatively affect farm income and agricultural employment. The reduction of fertilizer and its subsequent positive impact to the environment should be further combined with other means as for example improved agricultural practices. This means that the farmers should be educated to adopt practices which are not only economical but also environmental friendly.

Fertilizer is a critical input for the sustained growth of agricultural production in Bangladesh. The results of the study introduce a compromised solution from the social, economic and environmental point of view balancing these dimensions on behalf of the future fertilizer-intensive agriculture in Bangladesh and the support of its agricultural productivity. The conclusions constitute a challenge for any future fertilizing policy and we believe that they are capable in contributing to the policy debate on normative innovations on the fertilizing sector of Bangladesh.

From the empirical point of view we remark that our results show how farmers' behavior on alternative fertilizer prices 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 in the present study. The analytical tools used in this paper constitute a valid methodology and they can be applied to other farm regions for producing realistic policy-impact simulations and other agricultural policies.

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