Ind. Jn. of Agri. Econ.
Vol. 60, No. 4, Oct.-Dec. 2005

Crop Production Planning for Sustainable Agriculture in Western Uttar Pradesh through Lexicographic Goal Programming

Shalendra and S.K. Tewari*

I

INTRODUCTION

Over-exploitation and degradation of natural resources under 'Green Revolution' has become a major threat to sustainable agricultural production in Uttar Pradesh, particularly in its western region which experienced green revolution in the very first stage of its introduction. The low-input sustainable agriculture based on organic and integrated farming systems has almost been abandoned. The adoption of monoculture, specialised and high chemical input agriculture, which is unsustainable, has led to severe environmental damage and resource degradation in Western Uttar Pradesh (Singh, 2003). One among the important approaches to address this serious problem relates to the development and promotion of crop plans that are ecologically consistent in meeting their economic and social objectives. Using a Lexicographic Goal Programming (LGP) framework and secondary data relating to the western Uttar Pradesh, this paper attempts to develop such optimum crop plans for sustainable crop production under alternative scenarios and measure their comparative sustainability status. Since sustainable agriculture requires the integration of economic, ecological and social components, there is a need to use a multiobjective planning framework. As a result, the paper uses Goal Programming to identify and evaluate alternative crop plans. As to the focused scope, the present study is confined to western agro-climatic zone[1] of Western Uttar Pradesh and is largely based on secondary data pertaining to the triennium ending 2000-01.[2]

Western Agro-Climatic Region: Agro-Economic Features

The agriculture of Western Uttar Pradesh is characterised as irrigated agriculture. More than 90 per cent of the net cropped area was under irrigation cover in the

*Research Associate, National Centre for Agricultural Economics and Policy Research (NCAP), Library Avenue, Pusa, Post Box No.11305, New Delhi and Professor of Agricultural Economics, G.B. Pant University of Agriculture and Technology, Pantnagar-263 145 (Udham Singh Nagar) (Uttaranchal), respectively.

The authors are thankful to the anonymous referee of the Journal for his valuable suggestions on the earlier draft of the paper.

triennium ending 2000-01, with tubewells being the single largest source accounting for more than 70 per cent of the net irrigated area. Canal irrigation covered about 20 per cent of the net irrigated area. Irrigation status of important crops reveals that the three major crops of the region, i.e., paddy, wheat and sugarcane, together covering around 70 per cent of gross cropped area, are almost fully irrigated. As irrigation is one of the most important inputs in modern agriculture, its assured supply has led to an input intensive cropping pattern in the region. Despite an impressive performance of its agriculture, the region is displaying a number of negative concerns on the ecological front.

The area under various land use classes in western agro-climatic region during the period from triennium ending 1995-96 to triennium ending 2000-01 indicates that the forest cover has been low at 4.77 per cent of the reported area and was declining, showing poor performance on the ecological front. Pastures, another element of ecology, was also found to be very low at 0.13 per cent and was declining. Increase in area under miscellaneous trees and hedges from 0.35 per cent to 0.65 per cent and marginal decrease in barren land during the period provided some consolation on the ecological front. Area under non-agricultural uses was high at 11.92 per cent and was increasing, thus putting pressure on agricultural land. However, a marginal decrease in culturable waste from 1.56 per cent to 1.26 per cent and fallow lands from 3.25 per cent to 3.13 per cent was somewhat comforting. Around 76 per cent of the area has consistently been under plough leaving very little scope to bring any further area under cultivation. Cropping intensity ranged between 150 to 160 per cent during the period.

The above information on changes in area under various land use classes can be grouped into three broad sectors to facilitate meaningful inferences about the direction and magnitude of interclass land transfers (Pandey and Tewari, 1987). It is observed that the area under non-agricultural sector increased from 11.57 per cent to 11.92 per cent while area under agricultural sector increased from 80.76 per cent to 80.84 per cent during the period. These seemingly small shifts, which occurred partly at the cost of ecological sector during the period, can have serious consequences to the eco-system of the region. Therefore, these need to be checked, and if possible, reversed.

II

METHODOLOGY

The critical dimensions of sustainable agriculture are economic, ecological and social. Therefore, resource allocation and crop planning for sustainable agriculture must consider all these three dimensions. Income goal, foodgrain production goal (Economic); nitrogen goal, phosphorus goal, potash goal (Ecological); and employment goal (Social) were considered to reflect the three different dimensions of sustainable agriculture.

Lexicographic Goal Programming (LGP) model based on Romero and Rehman (1989) was used to generate optimum crop plans under alternative scenarios to ensure sustainable crop production. In LGP, the goals are ranked according to their priorities and the higher priority goals are satisfied first, before lower priority goals are considered. In the present study, economic, ecological and social components of sustainability are given first, second and third priority, respectively. This is because we want to minimise ecological and social problems associated with input intensive agriculture without adversely affecting the economic incentives of the farmers.

THE LGP MODEL

The general form of the Lexicographic Goal Programming Model used in this paper was of the form:

Let,

P_i = Priority assigned to the i-th objective as a goal, i = 1,2,…….m (number of objectives),

d_i^+ and d_i^- = Positive and negative deviation from the targeted goal for the i-th objective, i.e., over achievement (d^+) and underachievement (d^-),

w_i^+ and w_i^- = Relative weights assigned to goal deviations for the i-th objective,

Z = Vector of i priority achievement functions,

$F_i(x)$ = i-th objective function in linear form,

x = Feasible region from which the choices of vector x (activities) must be affected,

Ti = Target set for the i-th objective as a goal,

b = Level of constraint,

Then,

(1) Minimize Z = $\sum\left[P_i\left(w_i^+ d_i^+ + w_i^- d_i^-\right)\right]$ (achievement function)

Subject to:

(2) $F_i(x) - d_i^+ + d_i^- = T_i$ (set of goals)

(3) $x \in b$ (set of linear constraints)

(4) $x, d_i^+, d_i^- \geq 0$ (non-negativity constraints)

(5) $d_i^+ . d_i^- = 0$ (for all goals)

Let, the parameters of the operational model be as follows:

X_j = Area under j-th crop activity (ha),

y_j = Output from one unit of j-th crop activity (quintals per ha),

f = Existing level of foodgrain production (quintals),

r_j = Gross returns from j-th crop activity (Rs. per ha),

R = Existing level of income (Rs.),

n_j = Nitrogen consumption of j-th crop activity (kg per ha),

N = Total nitrogen consumption (kgs),
s_j = Phosphorus consumption of j-th crop activity (kg per ha),
S = Total phosphorous consumption (kgs),
k_j = Potash consumption of j-th crop activity (kg per ha),
K = Total potash consumption (kgs),
e_j = Labour requirement of j-th crop activity (mandays per ha),
E = Total labour employment (mandays),
X_{jc} = Area under j-th crop grown in c-th season (ha),
L_c = Total area available in c-th season (ha),
X_t = Area under t-th major crop of the region (ha),
A = Aggregate area under the major crops (ha),
t_j = Water requirement of j-th crop activity (mm per ha),
T = Total existing irrigation water available (mm),
Y_{ce} = Output from one unit of cereal crop activity (qtls per ha),
X_{ce} = Area under cereal crop activity (ha),
Y_{pl} = Output from one unit of pulse crop activity (qtls per ha),
X_{pl} = Area under pulse crop activity (ha),
g = Ratio of cereal-pulse production.

Then, the achievement function (Z) is minimised subject to the following operational goals and constraints

(6) $\sum y_j X_j + d_f^- - d_f^+ = f$ Food production goal

(7) $\sum r_j X_j + d_r^- - d_r^+ = R$ Income goal

(8) $\sum n_j X_j + d_n^- - d_n^+ = N$ Nitrogen consumption goal

(9) $\sum s_j X_j + d_s^- - d_s^+ = P$ Phosphorus consumption goal

(10) $\sum k_j X_j + d_k^- - d_k^+ = K$ Potash consumption goal

(11) $\sum e_j X_j + d_e^- - d_e^+ = E$ Employment generation goal

(12) $\sum X_{jc} \le L_c$ Land use constraint

(13) $\sum X_t \le A$ Area constraint on major crops

(14) $\sum t_j X_j \le T$ Irrigation water use constraint

(15) $\sum y_{ce} X_{ce} - g \sum y_{pl} X_{pl} = 0$ Constraint for balanced food production.

In the above operational model, Income goal and Foodgrain production goal were taken to represent the economic aspect of sustainable agriculture because foodgrain production and income are important economic issues in agriculture. Nitrogen goal, Phosphorous goal and Potash goal were included to reflect ecological aspect because increased use of chemical fertilisers produces various deleterious effects on the eco-system. Employment goal was considered to represent social aspect because unemployment is an important social concern. The model attempted to achieve these goals are subject to constraint on land use, area constraint on three major crops of the region, namely, paddy, sugarcane and wheat, irrigation water constraint and, cereal-pulse ratio constraint for balance food production. Water availability and cereal-pulse ratio were worked out according to the existing cropping pattern.

Application of Goal Programming with targets for goals fixed at pessimistic levels may lead to an inferior solution, i.e., an optimum solution dominated by another feasible solution. To avoid such a possibility, targets for different goals, except economic goals, were developed through separate optimisation exercises using the conventional Linear Programming. Economic goals were kept at the existing level as we want favourable changes on ecological and social fronts without adversely affecting the existing level of income and foodgrain production. Subsequently, in alternative scenarios, income goal and foodgrain production goal levels were upscaled, one at a time, for sensitivity testing, under the given set of constraints.

Approach for Evaluating the Sustainability of Optimum Crop Plans

Optimum crop plans generated by the LGP model under alternative scenarios were evaluated for their sustainability status using Sustainable Livelihood Security Index (SLSI) technique (Saleth and Swaminathan, 1993 and Saleth, 1993). The concept of Sustainable Livelihood Security is a livelihood option, which is economically efficient, ecologically secure and socially equitable. In an operational context, sustainability of agriculture measured through SLSI is a composite of three indices, i.e., Economic Efficiency Index (EEI), Ecological Security Index (ESI) and Social Equity Index (SEI), so that it can take into account both the conflicts and synergy between economic, ecological and social components of sustainable agriculture. Saleth *et al.* used their SLSI methodology to measure the comparative status of sustainability in different agro-climatic regions. But in the present study its application has been modified to evaluate the comparative status of sustainability of different optimum crop plans generated for western Uttar Pradesh.

The SLSI is flexible about the number and kind of variables to be included to represent different components of sustainable agriculture. However, to make SLSI more effective and information efficient, the selection of variables to represent different components of sustainable agriculture has to be done very carefully keeping in mind, the nature of study and relation among different variables. Although more variables can be selected, in the present study two variables each were selected to represent the three components. Land productivity (Rs./hectare) which influences income and, cereal-pulse ratio which influences balanced food production were used to represent economic efficiency component. Ecological security component was reflected by consumption of fertilisers and, use of irrigation water. Social equity component was reflected by employment of labour and, labour productivity. These specific variables in SLSI were chosen for two reasons. First, that these variables are already built-in the LGP model and, therefore, have the ability to show the sustainability of the generated optimum crop plans. Second, that the two variables each in the three components are by nature counter-balancing to avoid any bias. Take the case of Economic efficiency which is represented by land productivity in Rs. per hectare and cereal-pulse ratio. Although expressing productivity in monetary units does help to capture not only physical productivity as influenced by soil fertility, climate, irrigation, technologies etc., it has, however, the potential to bias in favour of plans specialised in high value crops. It is to counter such a bias that the variable of cereal-pulse ratio has been included. Despite their limitations, the selected variables do have a fairly good capacity to reflect the ecological, economic and equity aspect of alternative crop plans. Further, the selected variables display both positive and negative correlation among them which, rather than being a problem, actually enhances the capacity of SLSI to capture both the inherent conflicts as also the intrinsic synergy among various aspects of sustainability in agriculture.

The Sustainable Livelihood Security Index (SLSI)

First, indices for individual variables under different components were developed. For the following variables, namely, labour employment, land productivity and labour productivity, which have positive effects on sustainable agriculture, equation (16) was used to develop such indices.

$$SLSI_{ijk} = \frac{X_{ijk} - \min_j X_{ijk}}{\max_j X_{ijk} - \min_j X_{ijk}} \qquad \text{….(16)}$$

where, X_{ijk} and $SLSI_{ijk}$ denote respectively the value and index of the i-th variable representing j-th component of the SLSI of k-th plan.

Equation (17) was applied to the following variables, namely, fertiliser consumption, irrigation water and cereal-pulse ratio which have adverse effect on sustainable agriculture.

$$SLSI_{ijk} = \frac{\max_j X_{ijk} - X_{ijk}}{\max_j X_{ijk} - \min_j X_{ijk}} \qquad \text{….(17)}$$

where, i = 1, 2, …..I, j = 1, 2, …..J and k = 1, 2, …..K

The numerator in equations (16 and 17) measure the extent by which the k-th plan did better in the i-th variable representing j-th component of its SLSI as compared to the plan(s) showing the worst performance. The denominator shows the range, between the maximum and minimum values of a given variable across different plans. Thus, it is a simple statistical measure of total variation present in that variable. The denominator, in fact, serves as a scale or measuring rod by which the performance of each crop plan is evaluated in a given variable.

Indices for each of the three components of SLSI were developed ($SLSI_{jk}$) as a simple mean of the indices of their representative individual variables ($SLSI_{ijk}$) using equation (18).

$$SLSI_{jk} = \frac{\sum_{i=1}^{I} SLSI_{ijk}}{I} \qquad \text{....(18)}$$

The composite index for each plan ($SLSI_k$) was developed as a weighted mean of the component indices ($SLSI_{jk}$) using equation (19).

$$SLSI_k = \frac{\sum_{j=1}^{J} W_{jk}\, SLSI_{jk}}{J} \qquad \text{....(19)}$$

The W_{jk} in the above equation denotes the weight assigned to the j-th component of the SLSI of k-th plan and has the property that, their sum equals to one. If the weights assigned to different components are identical then SLSI is computed as a simple mean. When the weights are different, SLSI is computed as a weighted mean. For distinction, the former is denoted simply as SLSI and the latter as SLSI*. Obviously, all the indices and hence, both the SLSI and SLSI*, will be bound by 0 and 1.

For developing the weights, first the inverse of the proportional contribution of EEI, ESI and SEI to the SLSI was obtained. The ratio of this inverse of the contribution of each component to the sum of the inverse of the contributions of all the three components was taken as weight. Despite its heuristic nature, this approach has the following appeals: (i) since the relative significance of the components of SLSI varies by plans, it assigns differential weights not only across components but also across plans and (ii) the weights assigned are also inverse to the relative significance of the three components as reflected by their values. This is due to the fact that as one has more (less) of something(s) he will value it less (more). This approach has been used by Saleth (1993) and Saleth and Swaminathan (1992).

Thus, in the present study LGP and SLSI are integrated by constructing SLSI wherein the values of its component variables are drawn from the results of the LGP generated optimum crop plans.

III

RESULTS AND DISCUSSION

Optimum Crop Plans and Goal Achievements

Economic outcome is the basic notion that drives farmers while considering a change in the farming practices. Thus, wider adoption of sustainable farming plans requires that they should be, at least, as profitable as the existing plan along with non-monetary gains. Considering this, LGP Model was employed to develop crop plans under the alternative scenarios incorporating economic, ecological and social components of sustainable agriculture. These alternative plan scenarios are as follows.

Plan-1: Optimum plan which minimises ecological goals and maximises social goal while maintaining the economic goals at the existing level (P1).

Plan-2: Optimum plan which minimises ecological goals and maximises social goal with increased income goal while maintaining the foodgrains production goal at the existing level. This plan helps to see the effect of increase in income on ecological and social factors associated with agriculture (P2).

Plan-3: Optimum plan which minimises ecological goals and maximises social goal with increased foodgrains production goal while maintaining income goal at the existing level. This plan helps to see the effect of increase in foodgrains production on ecological and social factors associated with agriculture (P3).

The model employed is purely allocative and thus, optimisation is sought through allocation of area among different crop production activities. Therefore, the results presented and discussed here show only the impact of allocative efficiency on selected ecological and social consequences associated with input intensive agriculture. However, sustainable agriculture is affected not by these factors alone but also by various other factors as well.

The existing crop plan is dominated by input-intensive crops namely wheat, sugarcane and paddy listed in that order. These three crops together account for more than three-fourth of the gross cropped area in western agro-climatic zone of Uttar Pradesh (Table 1). Maize is the next in importance with a share of 6.59 per cent in the cropped area. The share of pulses is very low in the existing area allocation. According to our results, based on the application of LGP model, crop plan P1 suggests no change in acreage under paddy and sugarcane while wheat acreage decreased by 25.37 per cent over the existing plan. The acreage under the rest of the crops such as barley, maize, urad, gram and potato increased over the existing plan whereas others such as arhar and oilseed find no place in the plan. In the plan P2 and P3, there is no change in area under paddy and sugarcane acreages over the existing plan; however, area under wheat is reduced by 14.35 and 7.53 per cent, respectively.

Except bajra, arhar and oilseeds, which could find no place in the plans, all other crops registered an increase in their acreage in both the plans. These modifications help in minimising the use of fertilisers and increasing employment without adversely affecting the existing level of income and foodgrains production.

TABLE 1. EXISTING AND OPTIMUM CROP PLANS UNDER ALTERNATIVE SCENARIOS FOR WESTERN AGRO-CLIMATIC ZONE OF UTTAR PRADESH

('*000 ha*)

			Optimum plans		
Sr. No.	Crops	Existing Plan	P1	P2	P3
(1)	(2)	(3)	(4)	(5)	(6)
1.	Paddy	211.11	211.11	211.11	211.11
		(11.86)	(11.86)	(11.86)	(11.86)
2.	Maize	117.26	132.84	144.72	144.72
		(6.59)	(7.74)	(8.13)	(8.13)
3.	Bajra	22.98	11.89	0.00	0.00
		(1.29)	(0.67)	(--)	(--)
4.	Wheat	720.18	537.50	616.80	665.92
		(40.47)	(30.21)	(34.66)	(37.42)
5.	Barley	22.32	216.29	129.52	98.28
		(1.25)	(12.15)	(7.28)	(5.52)
6.	Urd	1.89	1.92	1.93	1.93
		(0.11)	(0.11)	(0.11)	(0.11)
7.	Gram	1.94	13.55	13.53	13.90
		(0.11)	(0.76)	(0.76)	(0.78)
8.	Arhar	16.85	0.00	0.00	0.00
		(0.95)	(--)	(--)	(--)
9.	Oilseeds	23.84	0.00	0.00	0.00
		(1.34)	(--)	(--)	(--)
10.	Potato	23.55	36.82	44.31	26.05
		(1.32)	(2.70)	(2.49)	(1.46)
11.	Sugarcane	617.55	617.55	617.55	617.55
		(34.70)	(34.70)	(34.70)	(34.70)

Oilseeds include – rapeseed/mustard and groundnut.
Figures in parentheses indicate percentages of gross cropped area.

The achievement level of different goals in the existing plan and their comparison with different optimum crop plans is presented in Table 2. The income level is maintained at their existing level of Rs.39,579.04 million in plan P1 and P3 but gets increased by 1.56 per cent (Rs.617.25 million) in plan P2. The foodgrain production remains at the existing level (32.65 million quintals) in plan P1 and P2 but gets increased in plan P3 by 2.11 per cent (0.69 million quintals). In case of fertilisers, nitrogen use registered a decrease of 4.21 per cent (10.5 million kgs) in P1, 1.60 per cent (4.0 million kgs) in P2 and 0.82 per cent (2.0 million kgs) in P3. phosphorus use also gets decreased in all the plans in the range of 0.51 to 3.27 per cent (0.66 to 4.22 million kgs). However, the use of potash registered an increase in all the cases. Employment also gets increased by 0.22 per cent (3.9 lakh man-days) in P1, 0.89 per cent (16.0 lakh man-days) in P2 and, 0.32 per cent (5.7 lakh man-days) in P3.

TABLE 2. GOAL ACHIEVEMENTS IN EXISTING AND OPTIMUM CROP PLANS UNDER ALTERNATIVE SCENARIOS FOR WESTERN AGRO-CLIMATIC ZONE OF UTTAR PRADESH

(*in millions*)

Sr. No.	Goal	Existing plan	Optimum plans P1	P2	P3
(1)	(2)	(3)	(4)	(5)	(6)
(A)	*Economic*				
1.	Income (Rs.)	39579.04	39579.04	40196.29	39579.04
			(0.00)	(1.56)	(0.00)
2.	Foodgrain production (qtls)	32.65	32.65	32.65	33.34
			(0.00)	(0.00)	(2.11)
(B)	*Ecological*				
3.	Nitrogen (kg)	249.60	239.10	245.60	247.56
			(-4.21)	(-1.60)	(-0.82)
4.	Phosphorus (kg)	128.90	124.68	127.67	128.24
			(-3.27)	(-0.95)	(-0.51)
5.	Potash (kg)	87.37	87.37	88.93	88.13
			(0.00)	(1.79)	(0.87)
(C)	*Social*				
6.	Employment (Number)	180.25	180.64	181.85	180.82
			(0.22)	(0.89)	(0.32)

Figures in parentheses show percentage change over existing levels.

Sustainability Status of Different Crop Plans

The relative sustainability status of different optimum crop plans as indicated by the value and rank of SLSI and SLSI* as well as their components, i.e., EEI, ESI and SEI are shown in Table 3. The values of EEI range from 0.124 to 0.500, that of ESI from zero to one and that of SEI from 0.160 to 1.000. These results indicate that the optimum crop plans display wider variation in the ecological aspect than in the economic and equity aspects. The value of EEI reveals that plan P2 and P3 contribute the highest while P1 contributes lowest to the economic aspect of sustainable agriculture. On ecological aspect, plan P1 appeared as the most effective while the existing plan turned out to be least effective in solving the ecological problems associated with current agriculture. Social aspect was best served in plan P2 while existing plan was found to be the least serving in this regard.

TABLE 3. COMPARATIVE SUSTAINABILITY STATUS OF EXISTING AND OPTIMUM CROP PLANS UNDER ALTERNATIVE SCENARIOS FOR WESTERN AGRO-CLIMATIC ZONE OF UTTAR PRADESH

Sr. No.	Indicators of sustainability	Existing	Optimum plans P1	P2	P3
(1)	(2)	(3)	(4)	(5)	(6)
1.	EEI	0.491	0.124	0.500	0.500
	Rank	II	III	I	I
2.	ESI	0.000	1.000	0.378	0.215
	Rank	IV	I	II	III
3.	SEI	0.160	0.171	1.000	0.178
	Rank	IV	III	I	II
4.	SLSI	0.217	0.432	0.626	0.298
	Rank	IV	II	I	III
5.	SLSI*	0.001	0.201	0.531	0.245
	Rank	IV	III	I	II

EEI – Economic Efficiency Index; ESI – Ecological Security Index; SEI – Social Equity Index; SLSI – Sustainable Livelihood Security Index; SLSI* – Weighted Sustainable Livelihood Security Index.

The values of SLSI (which is simple average of EEI, ESI and SEI) range from 0.217 to 0.626. The SLSI* (which is weighted average of the three indices) display a range of 0.001 to 0.531. The values of SLSI reveal better performance of all the three optimum crop plans over the existing one. However, plan P2 showed the strongest sustainability status followed by plan P1 and P3. The existing plan was found to be the least sustainable. The relatively narrower range of SLSI as compared to their component indices (EEI, ESI and SEI) indicates that the performance of different crop plans was not consistent across the three dimensions of sustainable agriculture. Based on the value of SLSI*, plan P2 again appeared as having the strongest sustainability status followed by P3 and P1. The existing plan again appeared as the least sustainable. The results on relative sustainability status of crop plans under the both SLSI and SLSI* methods are by and large identical. The choice between the two methods and the resulting crop plans will be guided by the notion of social welfare function indicating the relative importance of economic efficiency, ecological security and social equity as perceived by development planners and policy makers.

IV

CONCLUSIONS AND POLICY IMPLICATIONS

The results presented and discussed earlier indicate the possibility of ecological gains by reducing the input use and social gains by increasing the employment without any adverse effect on the economic gains to the farmers. However, the scope of such studies can be further enhanced by including a larger set of activities to work towards more diversified agriculture which can be absorbed by market. The SLSI functions only as a mere litmus test or screening device for ranking different plans according to their sustainability status but fails to provide any accurate quantitative information on agricultural sustainability. Despite these drawbacks of the SLSI approach of evaluating the sustainability status, its simplicity, information efficiency and generalisability makes it a readily available and understandable tool for evaluating the relative status of agricultural sustainability. Future researches can focus at sensitivity analysis in terms of alternative priority structures of economic, ecological and social objectives in the LGP model and the resultant trade-off in goal achievements. Inclusion of uncertainties and non-linearity aspects could further enhance its utility.

The optimum crop plans generated in this study do not involve a drastic change in the cropping pattern over the existing plan and hence obviate the need for any new kind of marketing systems. However, rationalising price policy for crops and, inputs like electricity and water along with emphasis on the adoption of optimal crop plans through extension education would constitute promising policy measures. Directorates of Agricultural Extension in SAUs, state government, civil organisations, NGOs, banks, and private sector, if they work in a co-ordination, can provide the necessary awareness, training, credit and insurance mechanisms for adoption of sustainable crop plans. The study also indicates that agro-climatic zone wise planning of agriculture is essential for sustainability of crop production over a longer period of time.

Received December 2004. *Revision accepted December 2005.*

NOTES

1. National Agricultural Research Project (NARP), 1979 (Ghosh, 1991), has divided Uttar Pradesh in twelve agro-climatic zones. Western agro-climatic zone, which consists of districts Saharanpur, Muzaffarnagar, Meerut, Bagpat, Bulandsahar, Ghaziabad and G. Buddha Nagar, has been considered in the present study to represent Western Uttar Pradesh.

2. The farm harvest prices are for the triennium ending 1997-98. Three-year lag in FHPs is not expected to affect the allocation, as the results are sensitive to the relative price ratios of different crops and not to the absolute value. It is assumed that relative price ratios would not have changed in the triennium ending 2000-01.

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