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Selection of Appropriate Priority Structure for Optimal Land Allocation in Agricultural Planning through Goal Programming

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INTRODUCTION

In the farm planning context, several variants of linear programming (LP) models have been proposed by many researchers. The potentiality of using LP in the farm planning context has been discussed by Sankhayan and Cheema (1991). But most of the LP based agricultural planning models are involved with the optimisation of a single objective subject to the limited supply of resources. Nowadays, most of the agricultural planning problems are multi-objective in character with the objectives often being incommensurable and conflicting in nature, and the decision situation is affected by different factors, such as natural conditions, social demands, technology and the economy. Eventually, the crop planning programmes need now be analysed in the multi-objective framework.

In management science, several multi-objective techniques have been discussed by Hwang and Masud (1979), Steuer (1986) and Zeleny (1982). A very powerful and flexible technique in the multi-objective decision area is the goal programming (GP). Actually, GP has appeared as a robust tool in the multi-objective decision-making area after introducing the priority based GP by Ijiri (1965), and then developed by Lee (1972), Ignizio (1976) and others. In priority based GP, priorities are assigned to the goals according to their importance of achieving the respective target levels. The set of commensurable goals are included at the same priority level and then numerical weights are assigned to them to represent their relative importance at the same priority level. The objective is then to minimise the sum of the weighted deviational variables of the goals according to the priorities, where the achievement of the goals at a higher priority level can never be sacrificed for achieving the goals at a lower priority level. GP and its variants have been surveyed in detail by Zanakis and Gupta (1986).

In the agricultural planning horizon, GP has been introduced by many researchers and is considered to be better than LP due to its flexibility of making decision to any real-world problem. Wheeler and Russell (1977) introduced minsum GP for farm planning, where sensitivity analysis was used to display different possible solutions in the decision-making environment. GP with penalty functions was successfully introduced in livestock ration formulation by Rehman and Romero (1987) and in fertiliser combination planning by Minguez *et al.* (1988). The use of different operational research techniques in farm planning has been surveyed by Glen (1987). Currently, Ghosh *et al.* (1993) have demonstrated the use of penalty functions in the GP model of the land allocation problem for optimal production of seasonal crops.

This paper demonstrates a land use planning model of the agricultural sector through the

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priority based GP. In the solution process, the sensitivity analysis with the variations of priority structure is performed to present how the solution is sensitive to the change in priority structure. Then, the 'Euclidean distance function' is addressed to measure the appropriate priority structure in the planning situation. The priority structure under which the solution is closest to the recognised ideal solution is identified as the appropriate priority structure for obtaining the most satisfactory solution.

THE MODEL FORMULATION

The general priority based GP model is of the form:

$$\text{Minimise } Z = [P_1(d^-, d^+), P_2(d^-, d^+), \ldots, P_k(d^-, d^+), \ldots, P_K(d^-, d^+)]$$

$$\text{Subject to} \quad f_i(X) + d_i^- - d_i^+ = b_i,$$

$$X, d_i^-, d_i^+ \geq 0$$

$$\text{and} \quad d_i^- \cdot d_i^+ = 0.$$

where Z is the vector of K priority achievement functions, X is the vector of decision variables, and d_i^-, d_i^+ are the under- and over-deviational variables respectively for the i-th goal. $P_k(d^-, d^+)$ is a linear function of the weighted deviational variables at the k-th priority level, where $P_k(d^-, d^+)$ is of the form:

$$P_k(d^-, d^+) = \sum_{i=1}^{m} (w_{ik}^- d_{ik}^- + w_{ik}^+ d_{ik}^+),$$

$$w_{ik}^-, w_{ik}^+, d_{ik}^-, d_{ik}^+ \geq 0 \text{ for } k = 1, 2, \ldots, K; K \leq m.$$

where the k-th priority factor (P_k) is assigned to the set of commensurable goals that are grouped together in the problem formulation, and the priority factors have the relationship

$$P_1 > P_2 > \text{-----} > P_k > \text{-----} > P_K,$$

which implies that the goals at the highest priority level (P_1) are achieved to the extent possible before the set of goals at the next priority level (P_2) is considered, and so on. w_{ik}^- and w_{ik}^+ are numerical weights associated with the deviational variables d_{ik}^- and d_{ik}^+ respectively, where d_{ik}^- and d_{ik}^+ are renamed for actual deviational variables d_i^- and d_i^+ respectively, to represent them at the P_k priority level. The i-th function $f_i(X)$ is linear in nature, and b_i is the target level of the i-th goal.

The decision variables, the constraints and the coefficients associated with the model of the problem are defined as follows:

A_{cs} = Area of land allocated for cultivating the crop c during the season s, where c = 1, 2, ... C; s = 1, 2, ... S.

L_s = Available land in hectares (ha) under cultivation in any season s.
EW_s = Estimated total amount of water available in cubic meters (cms) during the season s.
EMH = Estimated total machine-hours (in hours) available during the year.
EMD = Estimated number of man-days (in days) available during the year.
ETC = Estimated total cash (in Rs.) available per annum for seeds, fertilisers and insecticides, etc.
MD_{cs} = Man-days (in days) required per unit area of land for cultivating the crop c during the season s.
MH_{cs} = Machine-hours (in hours) required for tillage per unit area of land for cultivating the crop c during the season s.
W_{cs} = Amount of water consumed (in cms) per hectare of land for cultivating the crop c during the season s.
AVC_{cs} = Average cost (in Rs.) of seeds, fertilisers and insecticides used per unit area of land for cultivating the crop c during the season s.
EP_{cs} = Estimated production [in quintals (qtl.)] per unit area of land cultivated for the crop c during the season s.
ATP_c = Annual target level of total production (in qtl.) of the crop c.
MP_{cs} = Market price (in Rs. per qtl.) at the time of harvest of the crop c cultivated during the season s.
EMP = Estimated total market value (in Rs.) of all the yielding crops in different seasons in a year.
$R_{u,w}$ = Ratio of total annual production between u-th and w-th crops (u, w = 1, 2 .... C and u ≠ w).

The Goals Description

I. Land utilisation goal

The goal equations for total land utilisation plans appear as follows:

$$\sum_{c=1}^{C} A_{cs} + d_s^- - d_s^+ = L_s, \quad \text{for } s = 1, 2, \ldots S.$$

II. Production target goal

To meet the demand of the society, the production goal equations take the form:

$$\sum_{s=1}^{S} A_{cs} \cdot EP_{cs} + d_{S+c}^- - d_{S+c}^+ = ATP_c, \quad \text{for } c = 1, 2, \ldots C.$$

III. Production ratio goal

There are some similar types of crops which, more or less, serve the same purpose. From the viewpoint of the nutritional value as well as the advantage of future preservation, a certain ratio between the total production of any two of them may be required. Since the total number of crops is C, the number of possible ratios appear as:

$$\frac{C(C-1)}{2} = G \text{ (say)}$$

The associated goal equations can be presented as:

$$\frac{\sum_{s=1}^{S} A_{us} \cdot EP_{us}}{\sum_{s=1}^{S} A_{ws} \cdot EP_{ws}} + d^{-}_{S+C+G} - d^{+}_{S+C+G} = R_{u,w,} \quad \text{for all } G,$$

where u, w = 1, 2, ..., C and u ≠ w.

IV. (a) Water consumption goal

To meet the target levels of production of all the seasonal crops, water consumption goal equation appears as:

$$\sum_{c=1}^{C} A_{cs} \cdot w_{cs} + d^{-}_{S+C+G+s} - d^{+}_{S+C+G+s} = EW_{s},$$

$$\text{for } s = 1, 2, \ldots. S.$$

(b) Manpower goal

To avoid the uncertainty of labourers and involvement of extra cost for hiring at peak time, an estimated number of labourers may be employed during the year. The goal equation can be presented as:

$$\sum_{c=1}^{C} \sum_{s=1}^{S} A_{cs} \cdot MD_{cs} + d^{-}_{2S+C+G+1} - d^{+}_{2S+C+G+1} = EMD$$

(c) Machine-hour goal

To serve the purpose of tilling the land, an estimated total machine hours is to be provided during the year. The goal equation for the total required machine-hours takes the form:

$$\sum_{c=1}^{C} \sum_{s=1}^{S} A_{cs} \cdot MH_{cs} + d^{-}_{2S+C+G+2} - d^{+}_{2S+C+G+2} = EMH$$

(d) Cash expenditure goal

For purchasing seeds, fertilisers, insecticides, etc., the goal equation can be expressed as:

$$\sum_{c=1}^{C} \sum_{s=1}^{S} A_{cs} \cdot AVC_{cs} + d^{-}_{2S+C+G+3} - d^{+}_{2S+C+G+3} = ETC$$

V. Total market value

The crop plan may aim at achieving a targeted value of gross agricultural production estimated at the price forecasted at the time of harvest.

The goal equation can be presented as:

$$\sum_{c=1}^{C} \sum_{s=1}^{S} (MP_{cs} \cdot EP_{cs}) \cdot A_{cs} + d^{-}_{2S+C+G+4} - d^{+}_{2S+C+G+4} = EMP$$

Priority Selection Procedure

Now, the objective is to minimise the sum of the weighted deviational variables of the goals according to the priorities and relative weights at the same priority level for achieving their respective target levels in the decision-making situation.

In the conventional priority based GP, the solution under the decision-maker's imposed priority structure is considered as the optimal solution. But, in different complex decision-making situations, the derived solution may be regrettable under the imposed priority structure. That is, a better solution may well be expected in the decision-making situation.

In the planning context, the decision-maker is usually confused with the assignment of priorities due to the conflicting nature of the goals for their achievement. If the solution is not satisfactory, then under flexible character of priority based GP, the priority preferences of some conflicting goals are generally changed for the betterment of the solution. But it does not seem to be a good basis for making decisions and appropriate priority structure may not be determined.

In this paper, the selection of appropriate priority structure for proper allocation of land is presented below:

Let 'P' be the total number of different possible priority structures appearing in the planning situation. As a result, P different solutions are generally found.

Let A^{t}_{cs}, $c = 1, 2, \ldots, C;$
$s = 1, 2, \ldots, S$

be the solution corresponding to the t-th priority structures, $t = 1, 2, \ldots, P$.

Now within the available production supporting systems, maximum production of any variety of a crop in any season is possible for the maximum possible allocation of land for that variety of crop. Hence an ideal solution associated with allocation of land is recognised as:

$$A^{*}_{cs} = \max_{t=1,2,\dots,P} \{A^{t}_{cs}\} \qquad c = 1, 2, \dots, C; \quad s = 1, 2, \dots, S$$

Now, since the ideal solution may not be achievable in a realistic situation, the solution which is closest to the ideal solution is accepted as the most satisfactory solution and the associated priority structure is identified as the appropriate priority structure in the planning context. To find the closeness of the P different solutions from the ideal solution, the conventional 'Euclidean distance function' is used.

The distance of the t-th solution from A^{*}_{cs} can be presented as:

$$D^{(t)} = \left[\sum_{c=1}^{C} \sum_{s=1}^{S} (A^{*}_{cs} - A^{t}_{cs})^2 \right]^{1/2}, \quad t = 1, 2, \dots, P,$$

where $D^{(t)}$ denotes the distance associated with the solution from the t-th priority structure.

Now, from the point of view of closeness to the ideal, the minimum distance provides the optimal decision.

$$\text{Let} \quad \min_{t=1,2,\dots,P} \{D^{(t)}\} = D^{P}.$$

Then p-th priority structure is identified as the appropriate priority structure for the problem of properly allocating the land under cultivation in the decision making situation.

A CASE STUDY OF HOOGHLY DISTRICT

Land use planning for the Hooghly district of West Bengal in India is considered to expound the proposed model. The data for the production of crops (qtl./hectare), available man-days (days/ha), machine-hours (hours/ha) and cash (Rs./ha) were collected from the publication of the Directorate of Agriculture, Socio-Economic and Evaluation Branch, Government of West Bengal (1993). The data of the total area of available land (ha) under cultivation, market price (Rs./qtl.), annual production target (qtl.) of each crop, available man-days, machine-hours, total cash requirements (per annum) for all the crops and the target level of the expected total market value of all the crops were collected from the District Plan (1992-93) of Hooghly (District Magistrate, Hooghly, 1993).

In West Bengal, three cropping seasons - summer, monsoon and winter generally appear sequentially during a year. The main crops cultivated during the summer season are a single variety of paddy (*boro*) and the early and late varieties of jute. *Boro* is generally sown in the beginning of the summer season, i.e., at the middle of February and jute is generally sown in the middle of April. During the rainy season, a single variety of paddy (*aman*) is sown by the end of July. Potato, *rabi* pulse crop, wheat and mustard, each of which is a single variety of crop is grown during the winter season.

To present the model explicitly, the crops are numbered as: c = 1 for *boro* paddy, c = 2 for *aman* paddy, c = 3 for early variety of jute, c = 4 for late variety of jute, c = 5 for potato, c = 6 for *rabi* pulse, c = 7 for wheat and c = 8 for mustard respectively.

The three seasons in a year are numbered as s = 1 for summer, s = 2 for rainy and s = 3 for winter.

The total area of land under cultivation ('000 hectares) = 253.432.

The collected data are presented in Table 1.

TABLE 1. THE DATA DESCRIPTION

Crop	Paddy		Jute		Potato	*Rabi* pulse	Wheat	Mustard
	Boro	*Aman*	Early variety	Late variety				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Production (qtl./ha)	49.80	27.07	23.83	26.10	234.90	5.70	20.73	16.15
Market price (Rs./qtl.)	355.30	396.00	552.90	426.50	176.50	841.50	512.60	852.50
Cash expenditure (Rs./ha)	10,334.50	5,241.50	8,808.20	8,203.20	5,417.50	1,482.20	4,045.20	2,493.70
Required machine hours (hrs/ha)	7.30	7.30	5.15	5.15	12.15	5.15	5.15	5.15
Required man-days (man-days/ha)	340	195	375	350	95	47	156	93
Water requirement (cms)	140	75	150	145	25	20	40	16
Annual production target ('000 qtls.)	10,845			3,400	32,392	180	1,310	505

Ratio of total production of paddy and wheat		8.28:1
Total available man-days (days)		1,55,412
Total available cash (Rs.)		45,25,850.66
Total available machine-hours (hours)		5,259.23
Target of total market value (Rs.)		1,14,15,765.57
Total available water (cms)	(i) Summer season	36,512
	(ii) Monsoon season	50,680
	(iii) Winter season	9,487

Now, based on these data, the goal equations can be stated as follows:

I. Land utilisation goals

(i) During the summer season (s=1), the total land is available for cultivating the summer crops - the boro paddy (c=1), early variety (c=3) and late variety (c=4) of jute. The goal equation takes the form:

$$A_{11} + A_{31} + A_{41} + d_1^- - d_1^+ = 253.432$$

(ii) After harvesting the boro paddy at the end of the summer season and early variety of jute at the beginning of the rainy season, the available land can again be cultivated for *aman* paddy (c=2). The land utilisation goal equation takes the form:

$$A_{22} + A_{41} + d_2^- - d_2^+ = 253.432$$

(iii) The late variety of jute is harvested at the end of rainy season and the *aman* paddy is harvested just before the coming winter. So, at this stage, the total land is again available and that can be utilised for the winter crops.

The goal equations for re-utilisation of the total land for winter crops appear as:

$$A_{53} + A_{63} + A_{73} + A_{83} + d_3^- - d_3^+ = 253.432$$

II. Production target goal

The goal equations for attaining the targets of total production of the respective crops appear as:

(i) $23.83\ A_{31} + 26.10\ A_{41} + d_4^- - d_4^+ = 3,400$ (jute)

(ii) $49.80\ A_{11} + 27.07\ A_{22} + d_5^- - d_5^+ = 10,845$ (paddy)

(iii) $234.90\ A_{53} + d_6^- - d_6^+ = 32,392$ (potato)

(iv) $5.70\ A_{63} + d_7^- - d_7^+ = 180$ (*rabi* pulse)

(v) $20.73\ A_{73} + d_8^- - d_8^+ = 1,310$ (wheat)

(vi) $16.15\ A_{83} + d_9^- - d_9^+ = 505$ (mustard)

III. Production ratio goal: paddy and wheat

The paddy and wheat are the two major crops from the point of view of serving the same purpose of cereals requirement. Hence, a certain ratio between the total production of paddy and wheat is desired which is fixed at 8.28:1, keeping in view the local taste preferences.

The goal equation appears as:

$$49.80\ A_{11} + 27.07\ A_{22} - 171.63\ A_{73} + d_{10}^- - d_{10}^+ = 0$$

IV. The productive resource goal equations are presented as below:

(a) Water consumption goals

(i) $140\ A_{11} + 150\ A_{31} + 145\ A_{41} + d_{11}^- - d_{11}^+ = 36,512$ (summer)

(ii) $75\ A_{22} + d_{12}^- - d_{12}^+ = 50,680$ (monsoon)

(iii) $25\ A_{53} + 20\ A_{63} + 40\ A_{73} + 16\ A_{83} + d_{13}^- - d_{13}^+ = 9,487$ (winter).

(b) Manpower goal

$$340\ A_{11} + 195\ A_{22} + 375\ A_{31} + 350\ A_{41} + 95\ A_{53} + 47\ A_{63} +$$
$$156\ A_{73} + 93\ A_{83} + d_{14}^- - d_{14}^+ = 1,55,412.$$

(c) Machine-hour goal

$$7.30\ A_{11} + 7.30\ A_{22} + 5.15\ A_{31} + 5.15\ A_{41} + 12.15\ A_{53} + 5.15\ A_{63}$$

$$+ 5.15\ A_{73} + 5.15\ A_{83} + d_{15}^{-} - d_{15}^{+} = 5,259.23$$

(d) Cash expenditure goal

$$10,334.50\ A_{11} + 5,241.50\ A_{22} + 8,808.20\ A_{31} + 8,203.20\ A_{41} + 5,417.50\ A_{53}$$

$$+ 1,482.20\ A_{63} + 4,045.20\ A_{73} + 2,493.70\ A_{83} + d_{16}^{-} - d_{16}^{+} = 45,25,850.66.$$

V. Total market value goal

The goal equation for total expected market value appears as:

$$17,693.94\ A_{11} + 10,719.72\ A_{22} + 13,175.607\ A_{31} + 11,131.65\ A_{41} + 41,459.85\ A_{53}$$

$$+ 4,796.55\ A_{63} + 10,626.198\ A_{73} + 13,767.875\ A_{83} + d_{17}^{-} - d_{17}^{+} = 1,14,15,765.57.$$

In the present planning situation, the following four priority factors are addressed to include all the goals.

(a) minimise the over-utilisation of total land and under-utilisation of the available land at any stage in all the seasons.
(b) minimise the under-achievement of the production targets of all the crops and the ratio associated with paddy and wheat.
(c) minimise the over-consumption of water in all the seasons and the under-achievement of the target level of the expected total market value.
(d) minimise the over-utilisation of labourers, machine-hours and cash expenditure.

Now, in the priority based GP, one goal can be achieved with the sacrifice of the other goal(s), and the goals are achieved according to their priorities. Also, the achievement of the goals at higher priority levels can never be sacrificed for achievement of the goals at lower priority levels. In the present case, the goal equation associated with the utilisation of land is given the highest priority level (P_1) and cannot be shifted to a lower priority level, because there is no scope for providing extra land in the planning situation. The priority factors associated with other goal equations can be interchanged with a view to obtaining more satisfactory results. In the solution process, sensitivity analysis is performed for three alternative priority structures.

A package, developed by Ignizio (1976) for solving GP problems, is used to solve the problem. The environment of package is:

WIPRO Z-650/IBM-PC 386, DBOS/DOS Ver. 3.1 A,
FORTRAN - 77

The forms of the three GP objective functions under the three selected priority structures, and the results corresponding to the respective runs are presented in Table 2.

TABLE 2. SENSITIVITY ANALYSIS ON THE PRIORITY STRUCTURE

Run (1)	Objective with priority structure (2)	*Boro* A_{11} (3)	*Aman* A_{22} (4)	Early variety of jute A_{31} (5)	Late variety of jute A_{41} (6)	Potato A_{53} (7)	Rabi-pulse A_{63} (8)	Wheat A_{73} (9)	Mustard A_{83} (10)
1.	$P_1(d_1^+ + d_2^+ + d_3^+)$	110.314	201.05	86.958	52.382	158.702	31.570	63.180	0.000
	$P_2(1.5d_4^- + d_5^- + d_6^- + 2d_7^-$ $+ 2d_8^- + 1.5d_9^- + d_{10}^-)$								
	$P_3(1.5d_{14}^+ + d_{15}^+ + d_{16}^+)$								
	$P_4(2d_{11}^+ + d_{12}^+ + 1.5d_{13}^+ + d_{17}^-)$								
2.	$P_1(d_1^+ + d_2^+ + d_3^+)$	108.46	201.05	92.590	52.382	137.870	31.570	63.180	20.812
	$P_2(1.5d_4^- + d_5^- + d_6^- + 2d_7^-$ $+ 2d_8^- + 1.5d_9^- + d_{10}^-)$								
	$P_3(2d_{11}^+ + d_{12}^+ + 1.5d_{13}^+ + d_{17}^-)$								
	$P_4(1.5d_{14}^+ + d_{15}^+ + d_{16}^+)$								
3.	$P_1(d_1^+ + d_2^+ + d_3^+)$	110.314	201.05	88.848	52.382	137.870	31.570	63.180	20.812
	$P_2(2d_{11}^+ + d_{12}^+ + 1.5d_{13}^+ + d_{17}^-)$								
	$P_3(1.5d_4^- + d_5^- + d_6^- + 2d_7^-$ $+ 2d_8^- + 1.5d_9^- + d_{10}^-)$								
	$P_4(1.5d_{14}^+ + d_{15}^+ + d_{16}^+)$								

Now, the ideal solutions based on maximum possible land allocation under different crops can be recognised (from Table 2) as:

(110.314, 201.05, 92.590, 52.382, 158.702, 31.570, 63.180, 20.812).

The Euclidean distances, $D^{(t)}$ ($t = 1, 2, 3$), of the three solutions from the ideal solution are obtained as:

$$D^{(1)} = 21.56, \quad D^{(2)} = 20.91, \quad D^{(3)} = 21.16.$$

The result indicates that the minimum distance corresponds to

$$D^{(2)} = 20.91$$

Hence, the priority structure corresponding to the Run-2 is identified as the appropriate priority structure for the question of attainment of the production targets of the crops to the satisfactory levels in the present planning context.

The result of Run-2 is:

$A_{11} = 108.46$, $A_{22} = 201.05$, $A_{31} = 92.590$, $A_{41} = 52.382$, $A_{53} = 137.870$, $A_{63} = 31.570$, $A_{73} = 63.180$, $A_{83} = 20.812$, $d_4^+ = 173.59$, $d_9^- = 168.88$, $d_{11}^+ = 156.29$, $d_{12}^- = 35{,}601.25$, $d_{13}^- = 2{,}548.658$, $d_{14}^+ = 97.136$, $d_{15}^+ = 17.063$, $d_{16}^- = 4{,}737.55$, $d_{17}^+ = 12{,}86{,}943.218$.

All other variables are zero.

Under the identified appropriate priority structure, the achievement of the target levels of various goals is discussed in Table 3.

TABLE 3. GOAL ACHIEVEMENT UNDER THE IDENTIFIED APPROPRIATE PRIORITY STRUCTURE

Priority (1)	Goal description (2)	Achievements (3)	Deviations (4)
P_1	Utilisation of land in all the seasons	Achieved	All are zero
P_2	Production of crops in all the seasons	Not all fully achieved	Under-achievement of the production target of mustard is 33.44 per cent. Over-achievement of the production target of jute is 5.1 per cent. All other goals are achieved.
P_3	Consumption of water in all the seasons and the market value	Not all fully achieved	0.42 per cent of the available water is required more during the summer season. 70.24 per cent and 26.86 per cent of the available water is not utilised in the monsoon and winter seasons respectively. 11.27 per cent of the total estimated market value is increased.
P_4	Available man-days, machine hours and cash expenditure	Not all fully achieved	0.06 per cent and 0.32 per cent of the available man-days and machine hours respectively are required more in the planning system. 0.1 per cent of the estimated cash expenditure is not utilised.

COMPARISON WITH THE EXISTING CROPPING SYSTEM OF HOOGHLY DISTRICT

It may be pointed out that the agricultural sector of Hooghly district is at a growing stage and the management science model is yet to be adopted for optimal cropping sequence. As such, utilisation of productive resources is erratic and the agricultural potential of the district is not fully utilised.

The land allocated for different crops in different seasons during the year 1992-93 by the Planning Department (Hooghly) and thereby the levels at which the production of the crops achieved are presented in Table 4.

The utilisation levels of other productive resources had not been published in the District Plan.

The results in Table 4 reflect that the allocation of land was not optimal and productive resources were not properly utilised because the achievement levels of the production of crops are far from the desired target levels. Consequently, it needs quick implementation of agricultural planning model for developing proper cropping system. In this context, the GP method prescribed in the paper should be useful in providing guidelines for land use planning and project implementation.

TABLE 4. PRODUCTION ACHIEVEMENT (1992-93) UNDER THE EXISTING PRODUCTION PLAN

Crop (1)	Land allocation ('000 hectares) (2)	Crop production ('000 qtls.) (3)
Boro	51.451	6,151.5
Aman	192.411	2,278.8
Early variety of jute	14.87	357.861
Late variety of jute	7.33	176.403
Potato	65.727	14,379.27
Rabi pulse	1.258	38.998
Wheat	1.439	115.4
Mustard	10.302	386.35

CONCLUSION

The land use planning method outlined in this paper provides a good basis for analysing the decision-maker's perception on the use of priorities for achieving the target levels of various conflicting objectives. In any realistic situation, it is difficult to achieve the desired target levels of all the objectives, but the best possible solution can always be obtained under the proposed model.

Generally, a question about the computational burden of different arrangement of priorities may arise. Because, if K be the total number of priorities, then K! priority arrangements may occur. But, not more than 'two' to 'five' priority levels typically arise in any real-world problem (Ignizio, 1976) and conflict of the assigning priorities arises for at the most 'two' to 'three' priority levels.

Also, in different agricultural planning horizons, different environmental constraints generally occur which can easily be incorporated under the framework of the proposed land allocation planning model. However, the method outlined in this paper may open up many new vistas into the way of taking decisions in complex agricultural planning situations in the current multi-objective decision making arena.

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