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Optimizing Farm Plan in Saline and Normal Areas of West Bengal - A Lexicographic Goal Programming Approach

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Salinity has deleterious effects on both crops and livestock. An optimum farm plan is essential to adapt to this hazard. The present study made an effort to develop an optimum farm plan for the livestock-based farming systems in saline and normal areas of West Bengal. In the case of both saline and normal areas, farmers put the highest priority on maximizing gross margin, followed by achieving self-financial support and minimizing the income risk of the farm. Optimal solutions under a few farming systems were over-achieved in the second goal (achieving self-financial support). Since it is maximizing type of goal constraint, over-achievement is not a problem. However, the third goal (minimizing income risk of the farm) was also over-achieved in most of the farming systems. The optimal solution does not always satisfy all the goals, but it will provide a solution that satisfies the goal with the highest priority and comes as close as possible to satisfy the least prioritized goal *i.e.*, minimizing the income risk of the farm. The result of the optimum farm plan shows that if a farmer wants to maximize his income, he has to bear some risks. Since the major share of total income is received from livestock, the optimum plan suggests increasing the number of livestock in the systems and hence the farmers should divert available resources to this enterprise.

(***Key words:*** *Garett's ranking technique, Lexicographic goal programming, Livestock-based farming systems, Normal areas, Optimum farm plan, Saline areas*)

Saline soil is increasing year by year and farmers are making great efforts to manage their land (Wongsomsak, 1986). The problem of salinity has reduced the potential for agriculture (Ladeiro, 2012). Globally, 20% of all cultivated land and 33% of irrigated farmland are affected by high salinity (Shrivastava and Kumar, 2015). In India, the degraded land covers approximately 147 million ha, of which 23 million ha are affected by salinity. In the coastal areas, rice is the major crop and its yield and yield attributes such as, spikelet sterility and 1000-kernel weight are severely affected by salt content in the soil. This is responsible for approximately 20% reduction in yields in these areas (Clermont *et al.,* 2010). Due to salt content, there is a shortage of forage crops in coastal saline areas, which reduces cow milk production (Wistrand, 2003). In saline areas, livestock suffers from skin diseases, liver flukes, diarrhoea, weight loss and immune system disruption due to the consumption of over-salt feed crops (Alam *et al.,* 2017). Agricultural planning problems generally involve multiple goals such as maximizing crop production, maximizing overall profit, minimizing cost, minimizing input used, etc. which are conflicting in nature. It is not possible to maximize or minimize all goals simultaneously. Goal

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programming is a useful tool for dealing with such types of multiple-goal problems. The Indo-Gangetic Plain (IGP) is known to provide nearly 50% of all food consumption to feed 40% of the country's population (Pal *et al.,* 2009). The plains are the most agriculturally fertile region of the country and are home to almost 36% of the country's cattle population (Singh *et al.,* 2005). Within the livestock sector, the beef sector alone contributes ₹ 235 billion to the IGP economy (Singh *et al.,* 2005). Almost 10% of the additional land will be salinized each year, and by 2050 about 50% of the arable land will turn saline (Kumar and Sharma, 2020). If the area under the Indo-Gangetic Plain is affected by the increase in salt content, it will affect our food security. Out of the total salt flats (5,59,719 ha) in the IGP region, 78.84% (4,41,272 ha) is found in West Bengal (Mandal *et al.,* 2010). Coastal saline areas are plagued by both soil and water salinity and milk and livestock shortages have also been observed in coastal saline areas (Wistrand, 2003). West Bengal is blessed with world-famous Black Bengal goat and Garole sheep, and both indigenous and crossbred cattle can be found in thisstate. Therefore, West Bengal state was considered to be a good place to conduct a comparative study on the economic assessment of livestock systems in saline and normal areas.

Besides, the availability of livestock products is below the norm of the Indian Council of Medical Research (ICMR). Despite the effort over the past three decades to reduce the demand-supply gap of livestock products by augmenting the productivity of livestock and poultry birds, the annual shortfall is about 36 million tonnes of milk, 4644 million numbers of eggs and 378 thousand tonnes of meat (Halder *et al.,* 2018). Hence, this study has attempted to identify different livestock-based farming systems in both saline and normal areas and also to suggest to the farmers an optimum farm plan using a lexicographic goal programming approach. The optimum farm plans will help the farmers to reduce the demand and supply gap of livestock products.

MATERIALS AND METHODS

Sampling plan

The major part of the coastal saline areas in West Bengal is in the Sundarban area of districts South 24 Parganas, parts of North 24 Parganas and Purba Midnapore (Bandyopadhyay *et al.,* 2003). Sampling units were selected with the help of the multistage sampling technique. Within the selected districts, 17 blocks of South 24 Parganas, 6 blocks of North 24 Parganas and 10 blocks of Purba Midnapore are having saline areas. The rest of the blocks *i.e.*, 12 blocks of South 24 Parganas, 16 blocks of North 24 Parganas and 15 blocks of Purba Midnapore are considered normal areas for the comparison of livestock-based farming systems in saline and normal areas (GoWB, 2018). Finally, from the above-mentioned blocks in saline and normal areas, a number of blocks were randomly selected for saline areas such as Basanti, Namkhana and Canning II from South 24 Parganas; Hingalganj from North 24 Parganas; Khejuri II and Nandigram I from Purba Midnapore district. For normal areas, randomly selected blocks were Mograhat I and Mograhat II from South 24 Parganas; Barasat I and Bongaon from North 24 Parganas; Bhagwanpur I and Bhagwanpur II from Purba Midnapore district. Twenty households from each block were selected based on random sampling. A total of 120 households were selected from each of the saline and normal areas, thus total sample size constituted 240 households. The primary data was collected through the personal interview method on a structured interview schedule from the doorsteps of the respondents on various aspects of livestock and crop enterprises from the selected households for the year 2019-2020. Farmers who were having 50% or more income from livestock were only considered as respondents for the present study.

Identification of different types of livestock-based farming systems was done based on the highest income contribution from livestock enterprises. For example, if the highest share of income earned by a household from livestock enterprises is through sheep rearing, then the system was named the sheep-based farming system and so on.

Description of the model

Agricultural planning problems generally involve multiple goals such as maximizing crop production, maximizing overall profit, minimizing cost, minimizing input use, etc. which are conflicting in nature. Optimum farm plan helps the decision-maker to allocate the resources properly to achieve the objective of maximization of production, profit and even minimization of cost. Several mathematical programming techniques such as linear programming, dynamic programming and goal programming is used to develop farm plans. The refined method of linear programming to solve the multi-objective problem is goal programming. The goal programming technique helps the decision-makers to find a feasible and optimal solution for multiple and conflicting objectives. Goal programming is a useful tool for dealing with multiple goal problems where it is not possible to maximize or minimize all goals simultaneously.

According to Charnes and Cooper (1961), goal programming extends the linear programming formulation to accommodate mathematical programming with multiple objectives. The major differences are an explicit consideration of goals and the various priorities associated with the different goals.

In case of lexicographic goal programming, the goals are ranked from most important (Goal 1) to the least important (Goal m) and the objective function coefficient assigned for the deviational variable representing the goal is P_i. It is assumed that no two goals have equal priority. The goals are given an ordinal ranking and are called pre-emptive priority factors. These priority factors have the relationship $P_1 >> P_2 >> \ldots >> P_i >> P_{i+1} >> \ldots >> P_m$, where >> means "much greater than". This priority ranking is absolute. Therefore, the P_1 goal is so much more important than the P_2 goal and the P_2 goal will never be attempted until the P_1 goal is achieved to the greatest extent possible. The priority relationship implies that on multiplication by n, however large it may be, cannot make the lower-level goal the higher goal (*i.e.*, $P_i > P_{i+1}$).

Measurement of farmer's preferences

Garett's ranking technique was used to measure and rank the preferences of the farmers. With the use of this technique, the prioritization of goals was done based on Garett's score. The farmers were asked to rank the goals, they wanted to achieve through the farming system. These orders of merit were transformed into units of scores by using the following formula:

$$Per\ cent\ position = \frac{100(R_{ij} - 0.50)}{N_j}$$

Where,

R_{ij}= Rank given for the i^{th} goal by the j^{th} individual

N_j= Number of goals ranked by the j^{th} individual

The per cent position was converted into scores by referring to the table given by Garett and Woodworth (1969). After that, for each factor, the scores of the individual respondents were added together and divided by the total number of respondents for whom scores were added to obtain the mean score. These mean scores for all the goals were then arranged in descending order and the most preferred goals were identified through the ranks assigned.

Multi-criteria farm model structure

Goal programming is designed to achieve several objectives consisting of several alternative activities and resource constraints analyzed at the farm level. The goals were taken based on the literature review as well as by considering the needs of farmers in the study area. The resource constraints such as land, labour, capital and forage availability were the major resources used in the current study. Similar resource constraints were used in the earlier studies of Saha (2003), Rohaeni *et al.* (2014), Lalrinsangpuii (2017) and Kumari (2020). There were three objectives to be achieved in this study, namely;

1. Maximizing farmer's gross margin (₹)
2. Achieving self-financial support (₹)
3. Minimizing income risk of the farm (₹)

Functional constraints are constraints limiting the realization of the goals, in this study, there were several functional constraints, *i.e.*,

1. The area of land available for crop and

livestock farming (acre)

2. Availability of labour for farming (₹ yr^{-1})

3. Capital owned by farmers to run their farming (man days)

4. Forage availability (kg yr^{-1})

An optimum farm plan was developed for each of the farming systems. The plans were comprised of goal and resource constraints. Crop cultivation, fish cultivation, livestock (cattle, goat and sheep) and poultry were taken as the decision variables. Four resources namely land, labour, capital and forage were included in the model.

Available resources

Land

The average land available per unit of each activity under a particular farming system was taken as the input-output coefficient and the average of the total operational area was taken as the maximum available land for cultivation for a particular farming system.

Labour

The average of the family labour available per unit of each activity under a particular farming system was considered as the input-output coefficient, while an average of the family labour available for the whole year was considered as the maximum available labour for a particular farming system.

Capital

The source of capital for the farm family is generally through the sale of farm products and borrowing. Thus, an average of gross return plus borrowing was considered as the maximum capital available for a particular farming system and average expenditure on various inputs like feed, labour, seed, fertilizer, pesticide and fixed costs per unit of each activity under a particular farming system was considered as the input-output coefficient.

Forage

Dry fodder produced from crop farming was considered as forage available for each farming system. The average value of dry fodder consumed per unit of each activity under a particular farming system was considered as the input-output coefficient.

Goal achievement function

Maximizing farmer's gross margin

The gross margin of the enterprise is its value of enterprise output less the variable costs attributed to it. The mean of the margin per unit of each activity within the system was taken as the goal coefficient and the maximum gross margin observed for a particular farming system was considered as the goal which is needed to achieve.

Achieving self-financial support

The preferences for borrowing money varied under different livestock-based farming systems in the study area. The farmers in the study area are small and marginal. They generally take loans for farming purposes and are worried about the repayment of the loans. Therefore, financial self-support was regarded as an important objective in farm planning. To incorporate this goal, the average net return per unit of each activity within the system was taken as the goal coefficient and the average loan amount taken by the farmers for a particular farming system was considered as a goal that need to be achieved.

Minimizing income risk of farm

The decision-making process at the farm level is important due to the complex nature of agricultural production. Agricultural production faces different types of risks such as price risk, market risk, institutional risk and production risk. Natural factors like climatic conditions are responsible for production risk. In the present study, the standard deviation of income was taken as a measure of risk. To incorporate this goal, the standard deviation of net return per unit of each activity within the system was taken as the goal coefficient and the mean of the standard deviation of total income for a particular farming system was considered as a goal that needs to be achieved.

Mathematical formulation of the model

In goal programming, each goal is considered as a constraint after adding deviational variables. The first goal in the current study, maximizing gross margin is a greater than equal to type (≥) constraint, hence there is a need to minimize the negative deviational variable (d_1^-) as much as possible. The second goal of achieving self-financial support is also a greater than equal to type (≥) constraint, hence the study needs to minimize the negative deviational variable (d_2^-). Finally, the third goal, minimizing the income risk of the farm is a lesser than equal to type (≤) constraint, hence we need to minimize the positive deviational variable (d_3^+). Thus, the objective of the model is to minimize the above-mentioned deviational variables according to their priority. Farmers were asked how they prioritize different goals and goals were ranked based on the mean score obtained from Garett's ranking technique. The priority was estimated based on farmers' preferences among three goals under each farming system. Garett's ranking technique was used to prioritize the goals (Kumari, 2020; Lalrinsangpuii, 2017). The comprehensive farm planning model for livestock-based farming systems with the goal achievement function vector, the absolute constraints, the goal constraints and the non-negative and zero constraints is given as follows:

RESULTS AND DISCUSSION

The farming systems identified in saline and normal areas of the study area in West Bengal are presented in Table 1.

Find $x=(x_1, x_2, x_3.....x_n)$ so as to minimize

Minimize $Z = (P_1 d_1^-, P_2 d_2^-, P_3 d_3^+)$

Subject to linear constraints:

Goal constraints:

$$\sum_{j=1}^{n} g_{1j}x_j + d_i^- - d_i^+ = G_{1,}$$

$$\sum_{j=1}^{n} g_{2j}x_j + d_2^- - d_2^+ = G_{2,}$$

$$\sum_{j=1}^{n} g_{3j}x_j + d_2^- - d_2^+ = G_{3,}$$

System constraints:

$$\sum_{j=1}^{n} a_{1j}x_j \leq b_1$$

$$\sum_{j=1}^{n} a_{2j}x_j \leq b_2$$

$$\sum_{j=1}^{n} a_{3j}x_j \leq b_3$$

$$\frac{n}{}$$

$$\sum_{j=1}^{n} a_{4j} x_j \leq b_4$$

Such that,

$$x_{j,} d_1^-, d_1^+, d_2^-, d_2^+, d_3^-, d_3^+, \geq 0, \text{ where, j= 1, 2, 3….n}$$

Where,

x_j = Vector of n activities in the model

P_1, P_2, P_3 = Priority of 1st, 2nd and 3rd goal, respectively.

d_1^+ and d_1^- = Under and over achievement of expected gross margin goal

$d_2^+$and d_2^- = Under and over achievement of expected financial self-support goal

d_3^+ and d_3^- = Under and over achievement of expected standard deviation of net return

g_{1j} = Sample mean of gross margin per unit of j^{th} activity (goal coefficient)

g_{2j} = Sample mean of net return per unit of j^{th} activity (goal coefficient)

g_{3j} = Sample mean standard deviation of net return per unit of j^{th} activity (goal coefficient)

G_1 = Goal of maximum gross margin

G_2 = Goal of total loan amount (credit)

G_3 = Goal of standard deviation of total income

a_{1j} = Requirement of land per unit of j^{th} activity (input-output coefficient)

a_{2j} = Requirement of labour per unit of j^{th} activity (input-output coefficient)

a_{3j} = Requirement of capital per unit of j^{th} activity (input-output coefficient)

a_{4j} = Requirement of forage per unit of j^{th} activity (input-output coefficient)

b_1 = Supply level of land

b_2 = Supply level of labour

b_3 = Supply level of capital

b_4 = Supply level of forage

Optimum farm plan for different farming systems in saline areas

Optimum farm plans were developed using the lexicographic goal programming technique. The lexicographic goal programming model will achieve goals according to their priority (Kumari, 2020; Lalrinsangpuii, 2017). Goal with the highest priority will be achieved at first and then subsequent goals. Hence, the first step of goal programming is to prioritize different goals. The preferences of farmers for different goals under different farming systems in saline areas are presented in Table 2. From the mean score of Garett's ranking technique, it was clear that maximizing the farmer's gross margin is the first goal followed by achieving self-financial support and minimizing the income risk of the farm. Rohaeni *et al.* (2014) and Kumari (2020) also considered the farmer's income as the first goal in their studies.

A perusal of Table 3 shows that the existing plan had 12.50 numbers of sheep and 13.00 numbers of poultry. Under the optimum farm plan, the number of sheep and poultry was 16.65 and 9.08, respectively. Thus, under the optimum farm plan number of sheep decreased by 4.15 and the number of poultry increased by 3.92. The goal of maximizing farmers' gross margin and achieving self-financial support are achieved but minimizing the income of the farm is over-achieved *i.e.*, under the optimal farm plan risk is increased. Under the optimizing technique, it is not always possible to achieve all the goals simultaneously as goals are frequently contradictory to each other, but the solution should achieve the goal with the highest priority and come as close as possible to satisfy the least prioritized goal. Under the optimum farm plan, the capital constraint was utilized but there was a labour surplus of 64.47 man-days.

In the case of S_2 farming system, the existing plan had 12 cattle and 15 poultry (Table 4). Under the optimal farm plan, both goats and poultry had increased to 14.75 and 18.35, respectively, thus the number of both goats and poultry increased by 2.75 and 3.35, respectively.

Table 1. *Identified farming systems in the study area*

Code	Type of farming systems identified
Farming systems in saline areas	
S_1	Sheep + Poultry
S_2	Goat + Poultry
S_3	Cattle + Goat + Crop + Fish
S_4	Cattle + Poultry + Crop + Fish
Farming systems in normal areas	
N_1	Cattle + Goat + Poultry + Crop
N_2	Cattle + Goat + Crop
N_3	Cattle + Poultry + Crop

Table 2. *Ranking of goals of different farming systems under saline areas*

Goals	Mean score (Rank)			
	S_1 (Sheep + Poultry)	S_2 (Goat + poultry)	S_3 (Cattle + Goat + Crop + Fish)	S_4 (Cattle + Poultry + Crop + Fish)
Maximizing farmers' gross margin (₹)	64.25 (1)	65.43 (1)	61.87 (1)	67.81 (1)
Achieving self-financial support (₹)	54.75 (2)	53.56 (2)	57.12 (2)	51.19 (2)
Minimizing income risk of farm (₹)	35.75 (3)	34.62 (3)	38.12 (3)	32.20 (3)

Note: Figures in the parentheses are ranks

The first two goals (maximizing farmers' income and achieving self-financial support) were achieved but the third goal was over-achieved. All resources (labour and capital) were exhausted under the optimum farm plan.

In the S_3 farming system, the existing plan had 3.75 cattle, 7.50 goats, 1.10 acres of land under crop and 0.70 acres of land under fish farming (Table 5). Under the optimal plan, the number of cattle and goats had increased to 5.21 and 10, respectively, and the pond area increase to 0.85 acres. However, there was no change in crop area. The first goal (maximizing farmer's income) has been achieved. The second goal (achieving self-financial support) was over-achieved by ₹ 6,807.50. Since the second goal was maximizing type of goal constraints, over-achievement was not a problem. It implies that if the decision-maker, has taken ₹ 50,000 amount as a loan then by following this optimal plan he can take ₹ 56,807.50 amount as a loan and would be able to pay it. The third goal *i.e.*, minimizing the income risk of the farm was over-achieved. The optimal solution satisfies the top two goals with higher priority and comes as close as possible to satisfy the third goal. The capital constraint was also satisfied. There is a surplus of land and labour by 0.05 acres and 37.50 man-days, respectively under the optimum farm plan.

In the S_4 farming system, there were 4.00 cattle, 12.50 poultry, and 1.00 acres of land under cultivation and 0.55 acres of pond area allotted (Table 6). After optimizing the farm plan, cattle had increased to 6.59, poultry birds decreased to 10.00, land under cultivation increased to 1.20 acres and the pond area remained the same. In this case, the first goal was achieved, and the second goal and third goals were over-achieved. There was a surplus land of 0.25 acres and 132 kg yr^{-1} of forage, apart from which all the other resources (labour, capital) are fully utilized under the optimum farm plan.

Optimum farm plan for different farming systems in normal areas

In case of normal areas also the ranking of goals under different farming systems was similar (Table 7). The first priority was given to maximizing the farmer's gross margin followed by achieving self-financial support and minimizing the income risk of the farm.

A perusal of Table 8 shows that under the existing farm plan, there were 4.20 cattle, 6.50 goats, 12 poultry and 1.60 acres of land under cultivation. Under the optimal farm plan, cattle increased to 5.30, goats to 10, poultry decreased to 8 and crop area increased to 2.10 acres. In this case, the first goal was achieved but the second and the third goals were over-achieved. There were 6 man-days surplus of labour under the optimal farm plan and all the other resources were exhausted.

Table 3. *Optimal farm plan for S_1 farming system (sheep + poultry)*

Decision variables	Existing plan	Optimal plan	Change in resource allocation
Sheep (no.)	12.50	16.65	4.15
Poultry (no.)	13.00	9.08	-3.92
Goals	Target	Optimal plan	Deviation (d^+. d^-)
Maximizing farmers' gross margin (₹)	59473.00	59473.00	0.00 (achieved)
Achieving self-financial support (₹)	30000.00	30000.00	0.00 (achieved)
Minimizing income risk of farm (₹)	6639.85	10109.70	3170 (over-achieved)
Constraints	Availability	Optimal plan	Change in resource allocation
Labour (man days)	245.00	180.53	-64.47
Capital (₹ yr^{-1})	69660.00	69660.0	0.00

Table 4. *Optimal farm plan for S_2 farming system (goat + poultry)*

Decision variables	Existing plan	Optimal plan	Change in resource allocation
Goats (no.)	12.00	14.75	2.75
Poultry (no.)	15.00	18.35	3.35
Goals	Target	Optimal plan	Deviation (d^+. d^-)
Maximizing farmers' gross margin (₹)	73458.00	73458.00	0.00 (achieved)
Achieving self-financial support (₹)	35000.00	35000.00	0.00 (achieved)
Minimizing income risk of farm (₹)	9330.18	14581.02	4079.34 (over-achieved)
Constraints	Availability	Optimal plan	Change in resource allocation
Labour (man days)	280.50	280.50	0.00
Capital (₹ yr^{-1})	81680.00	81680.00	0.00

Table 5. *Optimal farm plan for S_3 farming system (cattle + goat + crop + fish)*

Decision variables	Existing plan	Optimal plan	Change in resource allocation
Cattle (no.)	3.75	5.21	1.76
Goats (no.)	7.50	10.00	2.50
Crop (acre)	1.10	1.10	0.00
Fish (acre)	0.70	0.85	0.15
Goals	Target	Optimal plan	Deviation (d^+. d^-)
Maximizing farmers' gross margin (₹)	1,48,515.00	1,48,515.00	0.00 (achieved)
Achieving self-financial support (₹)	50,000.00	56,807.50	6,807.50 (over-achieved)
Minimizing income risk of farm (₹)	13,843.75	35,113.89	21,270.14 (over-achieved)
Constraints	Availability	Optimal plan	Change in resource allocation
Land (acre)	2.00	1.95	-0.05
Labour (man days)	415.00	377.50	-37.50
Capital (₹ yr^{-1})	2,76,980.00	2,76,980.00	0.00
Forage (dry fodder) (kg yr^{-1})	5,000.00	5,000.00	0.00

1 acre = 0.405 ha

In the N_2 farming system, there were 4.50 cattle, 10.00 goats and 1.80 acres of land under cultivation (Table 9). After optimizing the farm plan, the number of goats and crop area have increased to 16.65 and 2.00 acres, respectively. There was no change in the number of cattle under the optimal plan. The first two goals were achieved and the third goal was over-achieved. There was 122 kg yr^{-1} excess amount of forage under the optimum farm plan and all the resources (land, labour and capital) were fully utilized.

In the existing plan of N_3 farming system, there were 4.00 cattle, 11.50 poultry and 1.50 acres of land under cultivation (Table 10). Whereas in the optimal farm plan, cattle, poultry and land under cultivation increased to 5.23, 15.00 and 1.80 acres, respectively. In this case, the first and the second goals were achieved and the third goal was over-achieved. Forage was excess by 102 kg yr^{-1} and all the other resources (land, labour and capital) were exhausted.

From the current study, it can be summarized that farmers in both saline and normal areas put the highest priority on maximizing gross margin, followed by achieving self-financial support and minimizing the income risk of the farm. In the optimal solution, a few farming systems (*i.e.*, S_3, S_4 and N_1) have over-achieved the second goal. Since it was maximizing type of goal constraint, over-achievement is not a problem. However, the third goal was also over-achieved in most of the farming systems. In goal programming, the study dealt with multiple objectives that contradict each other. An optimal solution does not always satisfy all the goals, but it will provide the solution which satisfies the goal with the highest priority and comes as close as possible to satisfy the least prioritized goal *i.e.*, minimizing the income risk of the farm. Over-achievement of the third goal indicated that if a farmer wants to increase their income, he had to bear some risk. In the case of both saline and normal areas, farmers put the highest priority on maximizing gross margin, followed by achieving self-financial support and minimizing the income risk of the farm. Livestock enterprises were providing a major share of total income in the study area. The optimal plan has suggested increasing the number of animals in all the farming systems. Hence, farmers should divert available resources to livestock enterprises.

Lalrinsangpuii (2017) used the goal programming technique to obtain an optimum plan for the dairy-based farming system in Mizoram state. Four goals were considered such as G_1 (to increase farmer's profit), G_2 (to increase the utilization of faeces as fertilizers, G_3 (to increase the utilization of agricultural waste as fodder and G_4 (to increase the absorption of agricultural labour). The study found that in the dairy + crop + poultry + fishery farming system, there was an increase in the number of cattle from nine to ten in the optimum plan. Using the same technique, Kumari (2020) conducted a study to generate optimum farm plans for the livestock-based farming systems in the tribal areas of Odisha. The optimal farm plan suggested that the number of cattle should be increased under cattle + crop (C_1), the number of goats should be increased in all the goat-based farming systems and the number of pigs should be increased under all pig-based farming systems. Crop area should be decreased under goat and pig-based farming systems. Saha (2003) used a goal programming model to develop the optimal farm plan

Table 6. *Optimal farm plan for S4 farming system (cattle + poultry + crop + fish)*

Decision variables	Existing plan	Optimal plan	Change in resource allocation
Cattle (no.)	4.00	6.59	2.59
Poultry (no.)	12.50	10.00	-2.50
Crop (acre)	1.00	1.20	0.20
Fish (acre)	0.55	0.55	0.00
Goals	Target	Optimal plan	Deviation (d^+. d^-)
Maximizing farmers' gross margin (₹)	123045.00	123045.00	0.00 (achieved)
Achieving self-financial support (₹)	50000.00	54693.25	4693.25 (over-achieved)
Minimizing income risk of farm (₹)	12837.76	26541.86	13704.10 (over-achieved)
Constraints	Availability	Optimal plan	Change in resource allocation
Land (acre)	2.00	1.75	-0.25
Labour (man days)	385.00	385.00	0.00
Capital (₹ yr^{-1})	213585.00	213585.00	0.00
Forage (dry fodder) (kg yr^{-1})	4500.00	4368.00	-132.00

1 acre = 0.405 ha

Table 7. *Ranking of goals of different farming systems under normal areas*

Goals	Mean score (Rank)		
	N_1 (Cattle + Goat + Poultry + Crop)	N_2 (Cattle + Goat + Crop)	N_3 (Cattle + Poultry + Crop)
Maximizing farmers' gross margin (₹)	60.68 (1)	66.62 (1)	64.25 (1)
Achieving self-financial support (₹)	53.56 (2)	48.81 (2)	47.62 (2)
Minimizing income risk of farm (₹)	39.31 (3)	32.18 (3)	33.37 (3)

Note: Figures in the parentheses are ranks

Table 8. *Optimal farm plan for N1 farming system (cattle + goat + poultry + crop)*

Decision variables	Existing plan	Optimal plan	Change in resource allocation
Cattle (no.)	4.20	5.30	1.10
Goats (no.)	6.50	10.00	3.50
Poultry (no.)	12.00	8.00	-4.00
Crop (acre)	1.60	2.10	0.50
Goals	Target	Optimal plan	Deviation (d^+. d^-)
Maximizing farmers' gross margin (₹)	174395.00	174395.00	0.00 (achieved)
Achieving self-financial support (₹)	75000.00	81448.00	6448.00 (over-achieved)
Minimizing income risk of farm (₹)	27071.61	44867.28	17795.67 (over-achieved)
Constraints	Availability	Optimal plan	Change in resource allocation
Land (acre)	2.10	2.10	0.00
Labour (man days)	363.00	357.00	-6.00
Capital (₹ yr^{-1})	306400.00	306400.00	0.00
Forage (dry fodder) (kg yr^{-1})	5500.00	5500.00	0.00

1 acre = 0.405 ha

and suggested that increasing the number of buffaloes is a better plan for irrigated landless, irrigated large, rain-fed marginal and rain-fed small dairy farming systems. The increment of the number of crossbred cows is the better strategy for irrigated marginal, rain-fed marginal, rain-fed small and irrigated large dairyfarming systems. Our results are also suggesting that the number of livestock should be increased under the optimum farm plan which is consistent with the findings of the above-mentioned studies.

The result of the goal programming shows that farmers have to take the risk to achieve higher income, hence they should be motivated to insure their cattle to minimize the risk. Simplification of the procedures and outreach of the facility need to be provided at the village level. For District Cooperative Society (DCS) membership, insuring the cattle might be made a mandatory criterion.

CONFLICTS OF INTEREST

There is no conflict of interest.

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Table 9. *Optimal farm plan for N_2 farming system (cattle + goat + crop)*

Decision variables	Existing plan	Optimal plan	Change in resource allocation
Cattle (no.)	4.50	4.50	0.00
Goats (no.)	10.00	16.65	6.65
Crop (acre)	1.80	2.00	0.20
Goals	Target	Optimal plan	Deviation (d^+. d^-)
Maximizing farmers' gross margin (₹)	165335.00	165335.00	0.00 (achieved)
Achieving self-financial support (₹)	50000.00	50000.00	0.00 (achieved)
Minimizing income risk of farm (₹)	27025.45	40420.52	13395.07 (over-achieved)
Constraints	Availability	Optimal plan	Change in resource allocation
Land (acre)	2.00	2.00	0.00
Labour (man days)	335.00	335.00	0.00
Capital (₹ yr^{-1})	286900.00	286,900.00	0.00
Forage (dry fodder) (kg yr^{-1})	5800.00	5678.00	-122.00

1 acre = 0.405 ha

Table 10. *Optimal farm plan for N_3 farming system (cattle + poultry + crop)*

Decision variables	Existing plan	Optimal plan	Change in resource allocation
Cattle (no.)	4.00	5.23	1.23
Poultry (no.)	11.50	15.00	3.50
Crop (acre)	1.50	1.80	0.30
Goals	Target	Optimal plan	Deviation (d^+. d^-)
Maximizing farmers' gross margin (₹)	139865.00	139865.00	0.00 (achieved)
Achieving self-financial support (₹)	40000.00	40000.00	0.00 (achieved)
Minimizing income risk of farm (₹)	26524.20	38342.70	11818.50 (over-achieved)
Constraints	Availability	Optimal plan	Change in resource allocation
Land (acre)	1.80	1.80	0.00
Labour (man days)	320.25	320.25	0.00
Capital (₹ yr^{-1})	249830.00	249830.00	0.00
Forage (Dry Fodder) (kg yr^{-1})	5000.00	4898.00	-102.00

1 acre = 0.405 ha

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