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RESEARCH PAPER

Sustainable crop production planning in irrigated agriculture under different alternative planning strategies: A multi-criteria decision making approach

■ M. UMANATH AND D. DAVID RAJASEKAR

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ABSTRACT

The present study aimed to develop the sustainable crop production plans under different alternative scenarios and to evaluate the sustainability status of developed plans. Lexicographic goal programming was employed to develop the sustainable crop production plans under alternative scenarios. In the present model, goals were ranked according to their priorities and the higher priority goals were satisfied first before the attainment of lower priority goals. To ensure the sustainable crop production, goals were grouped in to economic, ecological and social components. The present study considered income, production and cost of cultivation as economic goals, usage of farm yard manure, nitrogen, phosphorus and potash as the ecological goals and employment generation as the social goal to indicate overall sustainability of the existing and optimum plans. Accordingly six plans were proposed by altering the priorities of economic, ecological and social components one after another. Sustainable Livelihood Security Index was used to evaluate the sustainability of existing and derived plans. Results of the all optimum plans indicated that there was an increased profit and reduced cash requirement over existing plans while there was conservation of ecology of agriculture through minimizing the chemical fertilizer usage. Also, the optimum plans such as plan 1, plan 2, plan 4 and plan 6 had more overall sustainability index score when compared to the all other plans. It was concluded that such normative agricultural planning through mathematical programming techniques could be helpful to undertake the crop production planning at farm and regional level to minimise environmental problems from intensive agriculture without worsening the economic benefits of farmers.

KEY WORDS : Farm planning, Sustainable indicators, Economic efficiency, Social equity and Optimum production plan

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Advances in agricultural production technology has considerably raised farm output but has created harmful impact such as land degradation, declining of soil organic carbon, pesticide residues in farm produce, degradation of genetic resource base, environmental pollution, climate change, shrinkage in water reservoir capacity, problems of water scarcity, water pollution etc. Nelleman (2009) stated that there is 2 per cent global net losses of land productivity per year due to unsustainable land use practices such as overuse, poor land management and nutrient mining. Thus, over exploitation of natural resources under green revolution has become a major threat to sustainable agricultural production, especially in irrigated farming systems.

There are many approaches to address this serious problems and to maintain the sustainability of agriculture with ecological security. One among them is agricultural planning,

MEMBERS OF THE RESEARCH FORUM

Correspondence to:
M. UMANATH, Department of Agricultural Economics, Agricultural College and Research Institute (T.N.A.U.), MADURAI (T.N.) INDIA
Email: umanatheconomics@gmail.com

Authors' affiliations:
D. DAVID RAJASEKAR, Department of Agricultural Economics, Agricultural College and Research Institute (T.N.A.U.), MADURAI (T.N.) INDIA

which have to satisfy the requirement of economic, ecological and social goals. Agricultural planning exercise is complex and it involves integration of numerous natural factors interacting with the socio economic environment of the farmers. Thus, development and promotion of agricultural planning models and their management based on scientific principles in any country seems to be the probable approach to address the problem of sustainable production and to meet its economic, ecological and social objectives. Multi-objective goal programming analysis is one among the established methods for developing the normative agricultural plans which serve as a useful tool in policy-making. Applications of such methods in agriculture include the Lexicography Goal programming (LGP) approach. Shalendra and Tewari (2005) had used lexicographic goal programming to develop the optimum crop plan for sustainable crop production. Mansoori *et al.* (2009) had also attempted to derive farm planning to minimize the consequences of environmental burden. Latinopoulos and Mylopoulos (2005) had applied lexicographic goal programming to develop farm planning with economic, environmental and social goals and found that the economic scenarios may not satisfy the environmental goals. With this end in view, the present study intended to develop sustainable crop production plans for small irrigated farm under different alternative scenarios representing priorities of economic, ecological and social goals by using lexicographic goal programming model and to evaluate the sustainability status of developed plans.

METHODOLOGY

Study area and data :

Kottampatti block of Madurai district in Tamil Nadu was purposively selected, considering the immanency of undertaking agricultural development in the light of paucity of rainfall, inadequate irrigation and presence of resource poor environment at farm level when compared to other blocks in the district. A two stage random sampling method was adopted to select the sample farms. At first stage, all the 32 revenue villages in Kottampatti block were arranged in ascending order based on the gross cropped area and six revenue villages were selected at random. In second stage, 20 sample farmers were selected at random from each of the six selected revenue villages, thus constituting a total sample size of 120 farmers. Further, the sample farms were post stratified into three size groups as small, medium and large based on Mean+-SD criterion with respect to net area sown. Based on the Mean+-SD criterion, the sample farms were stratified into 24 small farms, 74 medium farms and 22 large farms. These 24 small farms selected were sub-grouped into small irrigated, small partially irrigated, small dry farms based on irrigation status and a farm from small irrigated category was selected as the modal farm which was lying closed to the mean values of selected variables such as cropping intensity, size of holdings, human labour utilization, manure, water and capital requirements, worked out for the entire small irrigated farms category and the selected model farm used to derive optimum plans employing Lexicographic Goal Programming .

Formulation of lexicographic goal programming (LGP) :

LGP model based on Romero and Rehman (2003) was used to generate sustainable optimum plans for sustainable crop production in small irrigated farms under different alternative scenarios. In LGP, the goals are ranked according to their priorities and the goals with higher priority are satisfied first, before lower priority goals are considered. The following general Lexicographic Goal Programming model under pre-emptive priority structure was used to develop the optimum plans :

Min $Z = \sum P_i (W_i^+ d_i^+ + W_i^- d_i^-)$ (achievement function)

Subject to constraints:

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

$x \ \varepsilon \ b$ (set of linear constraints)

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

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

where:

P_i = Priority assigned to the ith 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 ith objective, *i.e.,* the over achievement (d^+) and under achievement (d^-),

W^+ and W^- = Relative weight assigned to goal deviation for the ith objective,

Z = Vector of i priority achievement function,

$F_i(x)$ = ith objective function in linear form,

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

T_i = Target set for the ith objective as a goal,

b = Level of constraint,

Let, the parameters of the operational model for the small irrigated farm is defined as follows :

X_j = Area under jth crop activity in ha.

Productive resources :

L_S = Available area of land currently in use for cultivating the crops 'C' in any season 'S' in hectares.

P_C = Available production of crop 'C' per hectare of land cultivated during the season 'S' in kilograms.

M_P = Available profit for all the yielding crops in different season during the year in rupees.

C_R = Available amount of cash require per annum for supply of productive resource during the year in rupees.

F_R = Available amount of farm yard manure during the year in tones.

N_R = Available amount of nitrogen during the year in kilograms.

PH_R = Available amount of phosphorus during the year in kilograms.

K_R = Available amount of potash during the year in kilograms.

M_D = Available labour during the year in man days equivalent.

M_H = Available machine labour during the year in hours.

W_S = Available amount of water during the season 'S' in ha mm.

Input co-efficients :

P_{CS} = Production per hectare of crop 'C' cultivated during the season 'S' in kilograms.

M_{PCS} = Profit in per hectare of the crop 'C' cultivated during the season 'S' in rupees.

A_{CS} = Cost of seeds fertilizers and other materials purchased per hectare of land for cultivating the crop 'C' during the season 'S' in rupees.

N_{CS} = Amount of nitrogen required per hectare of land cultivated under the crop 'C' during the season 'S' in kilograms.

PH_{CS} = Amount of phosphorus required per hectare of land cultivated under the crop 'C' during the season 'S' in kilograms.

K_{CS} = Amount of potash required per hectare of land cultivated under the crop 'C' during the season 'S' in kilograms.

F_{CS} = Amount of farm yard manure required per hectare of land under the crop 'C' during the season 'S' in tones.

M_{DCS} = Labour required per hectare of land for the crop 'C' during the season 'S' in man day equivalents.

M_{HCS} = Machine hours required per hectare of land for cultivating the crop 'C' during the season 'S' in hours.

W_{CS} = Amount of water consumed per hectare of land for cultivating the crop 'C' during the season 'S' in ha mm.

Then, the achievement function Z is minimized subject to the following operational goals and economic constraints :

$\sum P_{CS}\ x_j d_1^- + d_2^+ = P_C$	Production goal
$\sum A_{CS}\ x_j d_1^- + d_2^+ = C_R$	Cash requirement goal
$\sum M_{PCS}\ x_j d_1^- + d_2^+ = M_P$	Total profit goal
å $F_{CS} x_j d_1^- + d_2^+ = F_R$	Farm yard manure requirement goal
$\sum N_{CS} x_j d_1^- + d_2^+ = N_R$	Nitrogen requirement goal
$\sum PH_{CS} x_j d_1^- + d_2^+ = PH_R$	Phosphorus requirement goal
$\sum K_{CS} x_j d_1^- + d_2^+ = K_R$	Potash requirement goal
$\sum M_{DCS}\ x_j d_1^- + d_2^+ = M_D$	Man days (employment) goal
$\sum X_j <= L_S$	Land use constraint
$\sum M_{HCS}\ x_j <= M_H$	Machine use constraint
$\sum W_{CS}\ x_j <= W_S$	Irrigation water constraint

In the present study, maximizing profit and production goals and minimizing cash requirement goal were taken as the economic aspect of sustainable agriculture, because production, income and cash requirement of farmers are important economic issues in agriculture. Minimizing usage of nitrogen, phosphorus and potash and maximizing usage of farm yard manure were taken as the ecological goals, because increased use of inorganic chemical fertilizers would cause detrimental effect on the eco-systems, whereas farm yard manure improves the soil fertility. Maximizing employment goal was taken to capture the social equity, because unemployment is an important social concern in rural areas. Land use, machine hours and water requirement were taken as the constraints. The targets for the different goals and constraints and input co-efficients were taken from the primary data collected.

Selection of real activities :

The crop activities actually observed in the small irrigated farms were taken as feasible activities and the crop activities which were technically feasible, but not found in the sample farms were also included in the LGP model after having thorough discussion with soil survey organization officials, agronomists and extension officers working in Kottampatti block. The activities selected for the programming were *Rabi* paddy, sugarcane, banana, irrigated groundnut and brinjal.

Optimum plans under different alternative scenarios :

The following six different sets of optimum plans were proposed by altering the priorities of economic, ecological and social goals so as to test the effects of priority of goals on the allocation of area under different crops and input use pattern. The details on these different alternative scenarios are presented in Table 1.

Sustainable livelihood security index (SLSI) :

In the present study, SLSI as furnished by Swaminathan (1991) was used to evaluate the sustainability status of existing and optimum plans derived by using LGP. This SLSI has been used to evaluate the agricultural sustainability in Orissa state by Hatai and Sen (2008). The SLSI is a relative measure to

Table 1 : Crop production plans with priorities under different alternative scenarios

Sr. No.	Priorities	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
1.	Priority 1	Economic	Ecological	Social	Economic	Ecological	Social
2.	Priority 2	Ecological	Economic	Ecological	Social	Social	Economic
3.	Priority 3	Social	Social	Economic	Ecological	Economic	Ecological

evaluate the relative sustainability status with a given set of variables. The concept of Sustainable Livelihood Security (SLS) is a livelihood option which is ecologically secure, economically efficient and socially equitable. Thus, the SLSI is a composite of indices representing individual variables under three components, *viz.*, Ecological Security Index (ESI), Economic Efficiency Index (EEI) and Social Equity Index (SEI), so that it may account for both the conflicts and synergies among ecological, economic and equity goals.

Further, the following variables were identified for the construction of SLSI. The variables such as usage of farm yard manure, nitrogen, phosphorus and potash were considered to capture the ecological security. Economic efficiency was measured by the quantity of output realized in crop production, profit and cash requirement. The man power employed (labour usage) in the production process captures the employment generation in farming and used as a measure of social equity. After identification of variables, SLSI was constructed by following a three step process. In the first step, indices for individual variables representing different components were constructed. The following generalized equation was used to construct such indices for the variables which have the positive impact on sustainable agriculture :

$$I_{ijk} = \frac{X_{ijk} - \min_j X_{ijk}}{\max_j X_{ijk} - \min_j X_{ijk}}$$

Similarly for the variables which have the negative impact on agricultural sustainability, the following equation was used:

$$I_{ijk} = \frac{\max_i X_{ijk} - X_{ijk}}{\max_j X_{ijk} - \min_j X_{ijk}} \quad i=1, 2, 3, ...I, j=1, 2, 3.......J \text{ and}$$

k = 1, 2, 3,..........K

where :

X_{ijk} represents the value of the i[th] variable under the j[th] component of SLSI of k[th] plan.

The numerator in the equations measure the extent to which the k[th] plan fared well in i[th] variable representing the j[th] component of SLSI as compared to the plan(s) with worst performance. The denominator indicates the range between the maximum and minimum values of each variable across different plans. Thus, SLSI is a simple statistical measure capturing total variation present in that variable in a composite manner. The denominator serves as a scale or measuring rod, through which the performance of each crop plan is evaluated for a given variable.

In the second step, indices for three sustainability components such as EEI, ESI and SEI are constructed by taking the average of the corresponding variables in a particular component.

The generalized equation used for this purpose is given below :

$$SLSI_{jk} = \frac{\sum_{j=1}^{I} W_{jk} SLSI_{jk}}{J}$$

In the third step, the composite index for each plan ($SLSI_k$) was developed as the average of the component indices ($SLSI_{jk}$) using the following equation :

$$SLSI_{k} = \frac{\sum_{j=1}^{I} W_{jk} SLSI_{jk}}{J}$$

where,

W_{jk} denotes the weights assigned to the j[th] component of the SLSI of k[th] plan and has the property that the sum of such weights equals to one. If the weights assigned to the different components are identical, then SLSI is computed as a single mean. When the weights are different, then SLSI is computed as a weighted mean. In the present study, equal weights were assigned for all indices. The values of the all indices of $SLSI_k$ are ranging from 0 to 1.

ANALYSIS AND DISCUSSION

The results of the present study alongwith relevant discussion have been presented as under :

Cropping pattern in existing and optimum plans under alternative scenarios for small irrigated farm :

The optimum plans derived for small irrigated farm along with existing plans under alternative scenarios are presented in Table 2. The cropping pattern under existing plan was 0.40 ha of paddy and 0.40 ha of sugarcane with gross cropped area of 1.6 ha. It could be observed that in the case of optimum

Table 2 : Existing and optimum crop plans under alternative scenarios for small irrigated farms (in hectare)

Sr. No.	Crops	Existing plan	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
1.	Paddy	0.40	0.57 (42.33)	0.57 (42.33)	0.40 (0.00)	0.56 (40.00)	0.64 (60.00)	0.56 (40.00)
2.	Banana	0.00	0.58 [a]	0.58 [a]	0.00	0.61 [a]	0.00	0.61 [a]
3.	Sugarcane	0.40	0.05 (-87.50)	0.05 (-87.50)	0.40 (0.00)	0.00 (-100.00)	0.40 (0.00)	0.00 (-100.00)
4.	IGN	0.00	0.57 [a]	0.57 [a]	0.36 [a]	0.59 [a]	0.32 [a]	0.59 [a]
5.	Brinjal	0.00	0.00 (0.00)	0.00 (0.00)	0.43 [a]	0.00 (0.00)	0.48 [a]	0.00 (0.00)
	Gross cropped area	0.80	1.77 (121.25)	1.77 (121.25)	1.59 (98.75)	1.76 (120.00)	1.59 (98.75)	1.76 (120.00)

Figures in parentheses are indicating percentage change in area of optimum plans to existing plan; [a] New crops to optimum plans over existing plans; IGN- Irrigated Groundnut plan 1 and plan 2, there was increment in the area of paddy by 0.57 ha and reduction in the area of sugarcane by 0.05 ha. Banana and irrigated groundnut (IGN) were introduced as new enterprises into the optimum plans with an area of 0.58 and 0.57 ha, respectively. The gross cropped area of 1.60 ha in the existing plan had increased to 1.77 ha in the optimum plans. The area allocation under plan 3 showed that the area under paddy and sugarcane were maintained at the same level as in existing plan. Irrigated groundnut and brinjal were introduced as new crops with 0.36 ha and 0.43 ha, respectively with an increase in gross cropped area to 1.59 ha as compared to 1.60 ha in existing plan. As regards plan 5, the area under paddy had increased to 0.64 ha from 0.40 ha while area under sugarcane was maintained at the same level as in the existing plan. Irrigated groundnut and brinjal were introduced as new crops in plan 5 with the area allocation of 0.32 ha and 0.48 ha, respectively. The gross cropped area increased to 1.59 ha from 1.60 ha as observed in existing plan. With respect to plan 4 and plan 6, an increase in the area under paddy by 40 per cent was observed along with introduction of irrigated groundnut and banana as new crops and the complete removal of sugarcane and brinjal from the plans when compared to the existing plan. Gross cropped area had increased by 120 per cent in plan 4 and 6 over existing plan. The results of the analysis revealed that every plan derived under six alternative scenarios showed distinct cropping pattern and the increase in the gross cropped area over the existing plan was found more in the case of plan 1 and plan 2 when compared to other optimal plans.

Achievements of economic goals under alternative scenarios for small irrigated farm :

The achievement of economic goals under six optimum plans for alternative scenarios in small irrigated farms along with the existing plan are presented in Table 3. The optimal plan 1 and plan 2 resulted in an increase of additional profit by 22.82 per cent with a reduction in cash requirement by 19.75 per cent when compared to existing plan. Production of paddy had increased by 42.33 per cent and sugarcane production decreased by 88.38 per cent, when compared to existing plan. The new crops such as banana and irrigated groundnut added additionally to the production when compared to the existing plan. As regards optimum plan 3, profit was maintained as much as in the existing plan with a reduction in cash requirement by 39.90 per cent. Production of paddy and sugarcane were maintained along with the additional production of irrigated groundnut and brinjal in plan 3 when compared to existing plan. Under plan 5, an incremental profit by 5.19 per cent with a reduction in cash requirement by 32.97 per cent was observed over existing plan. In the case of optimum plan 5, production of paddy increased by 60 per cent, while there was no change in the production of sugarcane. Additional production in the newly introduced enterprises such as irrigated groundnut and brinjal was also observed in optimum plan 5. As regards optimum plan 4 and plan 6, profit increased by 23.15 per cent with a reduction in cash requirement by 20.85 per cent. In these plans, production of paddy increased by 40 per cent along with additional production in the case of newly introduced irrigated ground nut and banana and no production in the case of sugarcane than in existing plan. The results of the optimum plans, revealed that there was more profit and lesser cash requirement in the case of optimum plan 4 and plan 6 than the existing and other optimum plans.

Achievements of ecological and social goals under alternative scenarios for small irrigated farm :

The achievement of ecological and social goals in six

Table 3 : Achievements of economic goals under different alternative scenarios for small irrigated farms

Sr. No.	Goals	Existing plan	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
1.	Working capital (in Rs.)	75696.91	60748.85	60748.85	45490.48	59914.16	50737.01	59914.16
			(-19.75)	(-19.75)	(-39.90)	(-20.85)	(-32.97)	(-20.85)
2.	Profit (in Rs.)	41365.59	50806.95	50806.95	41365.59	50943.62	43512.06	50943.62
			(22.82)	(22.82)	(0.00)	(23.15)	(5.19)	(23.15)
3.	Paddy (in kg.)	1550.00	2206.14	2206.14	1550.00	2170.00	2480.00	2170.00
			(42.33)	(42.33)	(0.00)	(40.00)	(60.00)	(40.00)
4.	Banana (in kg.)	0.00	1460.10 [a]	1460.10 [a]	0.00	1520.91 [a]	0.00	1520.91 [a]
5.	Sugarcane (in kg.)	35.00	4.08	4.08	35.00	0.00	35.00	0.00
			(-88.38)	(-88.34)	(0.00)	(-100.00)	(0.00)	(-100.00)
6.	IGN (in kg.)	0.00	996.32 [a]	996.32 [a]	637.07 [a]	1035.36 [a]	563.81 [a]	1035.36 [a]
7.	Brinjal (in kg.)	0.00	0.00	0.00	7797.05 [a]	0.00	8600.83 [a]	0.00

Figures in parentheses are indicating percentage change in area of optimum plans to existing plan; [a] additional crop production in optimum plans over existing plans; IGN- Irrigated groundnut optimum plans derived for alternative scenarios in small irrigated farms along with the existing plan are presented in Table 4. The usage of farm yard manure had increased by 85.98 per cent in optimum plan 1 and plan 2 over existing plan. Also, there was a reduction in the usage of chemical fertilizers such as nitrogen, phosphorus and potash by 38.27 per cent, 7.65 per cent and 2.78 per cent, respectively in these plans. In the case of plan 3, there was an increase in the usage of farm yard manure by 3.27 per cent. In contrast, there was reduction in the usage of nitrogen, phosphorus and potash by 50.74 per cent, 33.15 per cent and 81.93 per cent, respectively. Regarding optimum plan 5, there was an increase in the usage of farm yard manure by 14.92 per cent when compared to the existing plan. In contrast, optimum plan 5, showed a reduction in the existing usage of nitrogen, phosphorus and potash requirement by 42.63 per cent, 21.72 per cent and 79.94 per cent, respectively. Under optimum plan 4 and plan 6, there was an increase in farm yard manure usage by 89.50 per cent, whereas the usage of nitrogen and phosphorus decreased by 40.08 per cent and 7.98 per cent, respectively. The usage of potash was maintained in optimum plan 4 and 6 in the same level as in existing plan.

As far as employment as social goal, a reduction in the level of employment as indicated by man day labour requirement was observed in all the six optimum plans derived when compared to the existing plan. The reduction in the level of employment was found high in optimum plan 3 with 40.00 per cent followed by plan 5 (32.61 per cent), plan 4 and plan 6 (10.20 %) and plan 1 and plan 2 with 9.55 per cent.

The results of the resource use pattern in the optimum plans showed that the optimum plan 4 and plan 6 were found to be the better plans in terms of higher usage of farm yard manure when compared to the existing and other optimum farm plans. The optimum plan 3 was found as the better plan in the usage of nitrogen, phosphorus and potash fertilizers, in which there was a reduction in the usage of inorganic fertilizers such as nitrogen, phosphorus and potash when compared to the other plans and the existing plan. Plan 1 and plan 2 were doing as the better plans in terms of level of employment, since the percentage of reduction in the level of employment was less when compared to the existing plan and other optimum plans.

Evaluation of sustainability of existing and optimum plans derived under alternative scenarios for small irrigated farms:

The values of EEI, ESI, SEI and SLSI for the existing and optimum crop plans derived under different alternative scenarios are given in Table 5. It could be observed that the values of EEI

Table 4 : Achievements of ecological and social goals under different alternative scenarios for small irrigated farms

Sr. No.	Goals	Existing plan	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
	Ecological goals							
1.	FYM (in tonnes)	15.75	29.29 (85.98)	29.29 (85.98)	16.27 (3.27)	29.85 (89.50)	18.10 (14.92)	29.85 (89.50)
2.	Nitrogen (in kg)	417.50	257.71 (-38.27)	257.71 (-38.27)	205.68 (-50.74)	250.16 (-40.08)	239.51 (-42.63)	250.16 (-40.08)
3.	Phosphorus (in kg)	112.00	103.43 (-7.65)	103.43 (-7.65)	74.87 (-33.15)	103.06 (-7.98)	87.67 (-21.72)	103.06 (-7.98)
4.	Potash (in kg)	561.02	545.45 (-2.78)	545.45 (-2.78)	101.39 (-81.93)	561.02 (0.00)	112.56 (-79.94)	561.02 (0.00)
	Social goal							
5.	Employment in number of man days	435.08	393.51 (-9.55)	393.51 (-9.55)	261.03 (-40.00)	390.71 (-10.20)	293.21 (-32.61)	390.71 (-10.20)

Figures in parentheses are indicating percentage change in optimum plans to existing plan

Table 5 : Sustainability status of existing and optimum crop plans for small irrigated farms

Sr. No.	Sustainability indicator	Existing plan	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
1.	EEI	0.57	0.46	0.46	0.36	0.46	0.50	0.46
	Rank	I	III	III	IV	III	II	III
2.	ESI	0.00	0.49	0.49	0.76	0.51	0.66	0.51
	Rank	V	IV	IV	I	III	II	III
3.	SEI	1.00	0.76	0.76	0.00	0.75	0.18	0.75
	Rank	I	II	II	V	III	IV	III
4.	SLSI	0.52	0.57	0.57	0.37	0.57	0.45	0.57
	Rank	II	I	I	IV	I	III	I

EEI-Economic efficiency index; ESI-Ecological security index; SEI-Social equity index; SLSI-sustainable livelihood security index was ranging from 0.36 to 0.57, while ESI was ranging from 0 to 0.76 and SEI ranging from zero to one. The analysis on values of EEI showed that existing plan contributed to the highest level to the economic aspects of sustainable agriculture followed by optimum plan 5. As regards the ecological aspects, optimum plan 3 found to be the most effective plan while the existing plan contributed least to the ecological concern in current agriculture scenario. The existing plan was found to be most effective in its contribution to social aspects of sustainability, followed by optimum plan 1 and plan 2, while plan 3 was found to be the least contributor to the social aspects of sustainability. The values of SLSI are ranging from 0.37 to 0.57. The values of the SLSI indicated that the optimum plans 1, 2, 4 and 6 were found to have better overall sustainability than the optimum plans 3 and 5 and the existing plan.

It is important to note that even if the scores of the EEI and SEI in existing plan were more than the optimum plans, the score of ESI in the existing plan was lesser than the optimum plans. This revealed that optimum plans was found to contribute better towards ecological conservation and also to the economic goals in terms of profit when compared to existing plan. In addition, the present study also indicated the limitation to bring in the overall sustainability in small irrigated agricultural farms by resorting to alteration of crop plans and patterns due the conflict existing between the achievement of economic, ecological and social goals in the farm production environment.

Conclusion :

– From the results of the study it may be concluded that all the optimum plans derived were found better than the existing plan due to the increase in gross cropped area by way of extending the area under existing enterprises and also by introduction of new enterprises such as banana and irrigated groundnut in to the farm.

– Optimum plan 4 and plan 6 may serve better to the economic aspects of sustainability than the existing and other optimum plans, since these plans contributed more to the profit and required less cash requirement.

– Optimum plan 4 and plan 6 were found to be better plans in terms of higher usage of farm yard manure when compared to the existing and other optimum farm plans. The optimum plan 3 was found to be the better plan in terms of usage of nitrogen, phosphorus and potash fertilizers, in which, there was a reduction in the usage of inorganic fertilizers such as nitrogen, phosphorus and potash when compared to the other plans and the existing plan. These plans may be preferred when the ecological conservation was the main concern in the production environment.

– Even though the existing plan was contributing to the social goal of employment generation better than the optimum plans, it was found poor in its contribution to ecological conservation and thus making it less preferable to optimum plans.

– The evaluation of existing and the optimum farm plans derived under different alternative scenarios indicated that the optimum plans 1, 2, 4 and 6 were found to have better overall sustainability than the optimum plans 3 and 5 and the existing plan and making them the most preferable plans to be adopted in small irrigated farm situation in the study region.

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