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Research Article

An Economic Analysis of Sustainability and Crop Planning in Different Irrigation Systems of Coimbatore District, Tamil Nadu, India

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ABSTRACT

The study was undertaken in Kinathukadavu block of Coimbatore district of Tamil Nadu, India. A comparative analysis was made between three irrigation systems namely ground water, both canal and ground water, canal irrigation system and dry land. Sustainable Rural livelihood analyses revealed that both canal and ground water irrigation system was more sustainable than all other irrigation systems and dry land. The optimum planning analyses revealed that groundwater irrigation system satisfied all the three goals of economic, ecological and social goals while all other three systems satisfied economic and ecological goals only. In ground water irrigation system, the economic goal of maximizing profit was satisfied, since optimum plan increased the additional profit by Rs.9980.76 over the existing plan. The optimum plan satisfied two ecological goals namely reduction in usage of phosphorus and potash. The sociological goal of increasing employment for men and women work force were satisfied as the optimum plan increased the men and women labour usage in ground water irrigation system. In both canal and ground water irrigation system, the economic goal of maximizing profit was satisfied, since optimum plan increased the additional profit by Rs.23967 over the existing plan. The optimum plan satisfied two ecological goals namely reduction in usage of nitrogen and phosphorus. In canal irrigation system, the economic goal of maximizing profit was satisfied, since optimum plan increased the additional profit by Rs.17837.67 over the existing plan. The optimum plan satisfied two ecological goals namely reduction in usage of potash and cash expenses on plant protection. In dry land, the economic goal of maximizing profit was satisfied, since optimum plan increased the additional profit by Rs.2673.23 over the existing plan. The optimum plan satisfied two ecological goals namely reduction in usage of phosphorus and potash.

Keywords: *Sustainable Rural Livelihood Framework, Optimum farm plan, Goal programming,*

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INTRODUCTION

A scarce natural resource, water is elementary to life, livelihood, food security and sustainable development. Globally of 324 million hectares equipped for irrigation, 275 million hectare (85 per cent) is actually irrigated. The irrigated cropping intensity is highest in Asian continent with 141 per cent of all the economic section; agriculture is the one where water scarcity has greater relevance. World's chief irrigated crop is rice,covering 47 per cent of irrigated cereals area. The ratio of total volume of water used to the quantity of production of rice in India is 2020 m^3 a year when compared to china with 970 m^3 and a global average of 1325 m^3 per year. India accounts for 2.40 per cent of the world's total area with 16 per cent of the world's population, but has only 4 per cent of the existing fresh water. India has the world's largest ground water well equipped irrigation system which is 67 per cent (39 million hectares) of the total irrigation. About one third of water withdrawal is from ground water. Total net irrigated area in India constitutes about 681 lakh hectares. India has 957.72 lakh hectares of total gross irrigated area under all crops. In Tamilnadu, the total crop area covers 6.50 million hectares, in which 1.61 million hectares is irrigated using canal irrigation. The total crop area actually irrigated is 2.66 million hectares. The present study was undertaken with the following objectives.

1. To evaluate the sustainability with Sustainable Rural Livelihood (SRL) Framework in different irrigation regimes and dry land.
2. To develop optimum crop planning by using goal programming.

MATERIALS AND METHODS

2.1 Sustainable Rural Livelihood framework

The SRL framework analysis was done for all the three irrigation systems and dry land. (Saranya, 2013) (Mouna, 2014). Sustainable Rural Livelihood (SRL) framework consists of five capital assets. The selected indicators under Sustainable Rural Livelihood framework are natural capital, financial capital, physical capital, human capital and social capital.

Natural capital

Total land value and total area under irrigation represents the natural capital for all the three irrigation systems and dry land.

Financial capital

Financial capital or livelihoods was deliberated in terms of income and saving of the sample farmers in all the three irrigation systems and dry land.

Physical capital

Durable assets such as implements and machineries depict the physical assets in all the three irrigation systems and dry land.

Human capital

Human capital was measured in terms of health and educational status. It was measured on the basis of expenditure.

Social capital

Social capital was measured in terms of migration, gender ratio and equity. In case of migration 'low' reflects positive and 'high' reflects negative dimension. Equity was defined in terms of inequalities among household's total income and measured by Gini-coefficient.

2.2 Lexicographic Goal Programming

Critical dimension 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 (Economic); nitrogen goal, phosphorous goal, potash goal (Ecological); and employment goal (Social) were considered to reflect the three different dimension of sustainable agriculture. (Díaz-Balteiro, Luis, and Carlos Romero. 2003) (Zografos, Christos, and David Oglethorpe. 2004 (Umanath, M. 2008)

Formulation of Lexicographic Goal Programming (LGP)

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 priority and goals with higher priority are satisfied first, before lower priority goals are considered in accordance with their order of ranking.

Priority of Goals for Farm Plans

In the present study, economic, ecological and socio components of sustainability are given first, second and third priority, respectively. This is because we want to minimize ecological and social problems associated with input intensive agriculture without adversely affecting the economic incentives of the farmers.

The goals arrived for the farm level planning models are:

Economic goal

1. Income goal

Ecological goal

2. Nitrogen consumption goal
3. Phosphorous consumption goal
4. Potash consumption goal

Social goal

1. Employment generation goal

Formulation of Lexicographic Goal Programming Model

The parameters of the operational model are as follows:

r_j - Gross return from j^{th}crop activity (Rs. per ha).

R_j - Existing level of income (Rs)

n_j - Nitrogen consumption of j^{th}crop activity (kg per ha)

N - Total Nitrogen consumption (Kgs)

s_j - Phosphorous 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 for j^{th}crop activity (man days per ha)

E - Total labour Employment (man days)

X_{jc} - Area under of 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}majorcrop of the region (ha)

A - Aggregate area under the majorcrop (ha)

Cr - Capital requirement for j^{th}crop activity (Rs. per ha)

C - Total available capital (Rs.)

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

1) ∑rjxj d1- + d2+ = R Income goal
2) ∑njxj d1- + d2+ = N Nitrogen consumption goal
3) ∑sjxj d1- + d2+ = S Total Phosphorous consumption
4) ∑kjxj d1- + d2+ = K Total Potash consumption
5) ∑ejxj d1- + d2+ = E Total labour Employment
6) ∑Xjc< = Lc Land use constraint
7) ∑Xt< = A Area use constraint
8) ∑Xcr< = C Capital use constraint

In the above operational model, income goal was taken to represent the economic aspect of sustainable agriculture because food grain production and income are important economic issue in agriculture. Nitrogen goal, Phosphorous goal and Potash goal were include to reflect ecological aspect because increasing use of chemical fertilizers produces various deleterious effects on the ecosystem. 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 constraints on land use and area constraint on major crops of the region and capital use constraint.

RESULTS AND DISCUSSION

3.1 Sustainable rural livelihood framework analyses

The selected indicators under Sustainable Rural Livelihood framework (SRL) were natural capital, financial capital, physical capital, human capital and social capital. These selected indicators were furnished in the Table 1.

Table 1: Sustainable Rural Livelihood assets

S. No.	Assets	Ground water	Both Canal and ground water	Canal	Dry land
I	**Natural assets**				
	Land value (in ₹)	2295396	2591686	1698457	1342467
	Area under irrigation (in ha)	85	68.2	41.5	-
II	**Financial assets**				
	Income (in ₹)	334869	340839	202946	169441
	Saving (in ₹)	143454	147942	94314	78632
III	**Physical assets**				
	Durable assets (in ₹)	72043	78423	53426	35788
IV	**Human assets**				
	Expenditure on education (in ₹)	40187	42210	37850	31388
	Expenditure on health (in ₹)	20847	21300	18265	15241
V	**Social assets**				
	Migration(per cent)	5.11	6.12	6.45	7.33
	Gender ratio	962	963	811	862
	Equity	0.24	0.21	0.18	0.16

3.1.1 Natural assets

Natural assets were measured in terms of land value and total area under irrigation. It could be observed from the Table 1 that land value was ₹2295396, ₹2591686, ₹1698457 and ₹ 1342467 in ground water, both canal and ground water, canal and dry land system respectively. The land value of both canal and ground water irrigation system was higher with ₹2591686 which were high over ground water irrigation system by 12.91 per cent, high over canal irrigation system by 52.59 per cent and high over dry land system by 93.05 per cent. The total area under irrigation was 85 hectare in ground water system which was high over both canal and ground water system by 24.63 per cent and high over canal irrigation system by 104.82 per cent.

3.1.2 Financial assets

The table 1.clearly depicts the financial assets such as income and saving were higher in both canal and ground water irrigation system than other irrigation systems. Income of both canal and ground water irrigation system was higher with ₹340839 which were high over ground water system by 1.78 per cent, high over canal irrigation system by 67.95 per cent and high over dry land system by 101.15 per cent. Savings of both canal and ground water irrigation system was higher with ₹147942 which were high over ground water system by 3.13 per cent, high over canal irrigation system by 56.86 per cent and high over dry land system by 88.14 per cent.

3.1.3 Physical assets

The value of durable assets reflects the physical assets of the irrigation system. The value of durable assets was ₹72043,₹ 78423, ₹ 53426 and₹ 35788 in ground water, both canal and ground water, canal and dry land system respectively. The physical assets of both canal and ground water system were higher with 78423 which were high over ground water system by 8.86 per cent, high over canal irrigation system by 46.79 per cent and high over dry land system by 119.13 per cent.

3.1.4 Human assets

Human assets such as health and education were measured on the basis of expenditure.

Expenditure on education was ₹ 40187,₹ 42210,₹ 37850 and₹ 31388 in ground water, both canal and ground water, canal and dry land system respectively. Expenditure on health was ₹ 20847,₹21300,₹ 18265 and₹ 15241 in ground water, both canal and ground water, canal and dry land system respectively. The expenditure on education of both canal and ground water irrigation system was higher with ₹ 42210 which were high over ground water system by 5.03 per cent, high over canal irrigation system by 11.52 per cent and high over dry land system by 34.48 per cent. The expenditure on health of both canal and ground water irrigation system was higher with ₹21300 which were high over ground water system by 2.17 per cent, high over canal irrigation system by 16.62 per cent and high over dry land system by 39.75 per cent.

3.1.5 Social assets

It could be observed from the Table 1that the migration was 5.11, 6.12, 6.45 and 7.33 per cent in ground water, both canal and ground water, canal and dry land system respectively. Migration percentage was high in dry land system over ground water system by 43.44 per cent, high over both canal and ground water system by 19.77 per cent and high over canal irrigation system by 13.64 per cent. The gender ratio of males per thousand females was high in both canal and ground water irrigation system (963) followed by ground water system (962), dry land system (862) and canal irrigation system (811). The gender ratio was high in both canal and ground water irrigation system over ground water system by 0.10 per cent, high over canal system by 18.74 per cent and high over dry land system by 11.72 per cent. The gini co-efficient value of income for the ground water, both canal and ground water, canal and dry land system was 0.24, 0.26, 0.31 and 0.34 respectively. The lower gini coefficient ratio reflects that equity was higher in ground water irrigation system as compared to other irrigation systems. Thus the Sustainable Rural livelihood analyses revealed that both canal and ground water irrigation system was more sustainable than all other irrigation systems and dry land.

3.2 Optimum farm plan based on Lexicographic Goal Programming (LGP)

The Lexicographic objective Goal Programming models were constructed for the three irrigated ecological systems namely ground water, both canal and ground water, canal irrigation system and dry land system to develop the optimum farm plans.

The real crop activities were first identified for the goal programming in all the irrigation systems and dry land system. Further, in addition to crop activities, as discussed earlier economic, ecological and social goals were specified along with constraints were also included in the model. Thus the goals used for the irrigation system farms were income goal, nitrogen consumption goal, phosphorus consumption goal, potash consumption goal cash expenses on plant protection goal and employment generation goal. The decision variable was the allocation of the land for cultivating the crop 'j' during the season's'.

3.2.1 Optimum farm plan for ground water irrigation system

The derived optimum sustainable farm plan with existing plan for ground water irrigation system is presented in the table 2. The existing plan for ground water irrigation farm had a gross cropped area 5.10 ha, of which 1.80 ha was under coconut, 1.20 ha under tomato, 0.80 ha under chilli and 1.30 ha under sorghum. The existing plan utilized 5.88 hours of machine power, 13.82 tonnes of farm yard manure, Rs.1347.78 of nitrogen, Rs.1917.22 of phosphorus, Rs.3289.11 of potash, Rs.2560 of cash expenses on plant protection, 78.78 women days, 39.38 men days, 423.96 ha mm of water and Rs.8926.55 as working capital and earned a profit of Rs.89826.89.

The existing gross cropped area of 5.10 hectare was increased to 5.64 hectare in the optimum sustainable plan derived for canal irrigation system. The area under coconut(1.80 ha) was increased by 0.33 ha and the area under tomato was increased by 0.60 ha in the optimum sustainable plan. The crop enterprise under chilli was decreased by 0.13 ha and sorghum was decreased by 0.26 ha. The gross cropped area under existing plan was 5.10 ha and was increased to 5.64 ha in the optimum sustainable plan.

The real activities identified in the ground water system were coconut, sorghum, tomato, chilli, cowpea, cotton, green gram, bhendi and groundnut. The optimum plan derived along with existing plan for canal irrigation system is presented in table 4.

As regards the resource utilization, the optimal plan derived for ground water irrigation system indicated an additional resource requirement of machine power by 0.83 hours (12.37 per cent), farm yard manure by 1.53 tonnes (9.97 per cent), nitrogen by Rs.149.75 (9.99 per cent), Cash expenses on plant protection by Rs. 284.44 (9.99 per cent) and 72.66 hectare mm of water consumption (14.63 per cent), women labour by 8.76 man days (10.01 per cent), men labour by 4.39 days (10.03 per cent) and working capital by Rs.779.62 (8.03 per cent). In contrast, the optimum plan envisaged a reduction in the usage of phosphorus by Rs.213.03 (10.00 per cent) and potash by Rs.365.46 (10.00 per cent). The optimum plan envisaged additional profit over the existing plan by Rs.9980.76 (9.99 per cent), which clearly indicated the superiority of the optimum sustainable plan over the existing plan in the canal irrigation system.

From the results, it could be inferred that the optimum sustainable plan increased the gross cropped area from the existing plan for ground water irrigation system. The economic goal of maximizing profit was satisfied, since optimum plan increased the additional profit by Rs.9980.76 over the existing plan. The optimum plan satisfied two ecological goals namely reduction in usage of phosphorus and potash. The sociological goal of increasing employment for men and women work force were satisfied as the optimum plan increased the men and women labour usage in ground water irrigation system.

Table 2: Optimum farm plan for ground water irrigation system

S.No	**Activities/Resources**	**Existing plan**	**Optimum plan**	**Percentage Change in area and resource allocation**
I	**Area under different crops (in ha)**			
1.	Coconut	1.80	2.13	0.33
2.	Tomato	1.20	1.80	0.60
3.	Chilli	0.80	0.67	-0.13
4.	Sorghum	1.30	1.04	-0.26
	Gross Cropped Area	**5.10**	**5.64**	**0.54 (9.57)**
II	**Resource Allocation**			
1.	Machine power(in hours)	5.88	6.71	0.83 (12.37)
2.	Farm Yard Manure (in tonnes)	13.82	15.35	1.53 (9.97)
3.	Nitrogen (in kg)	1347.78	1497.53	149.75 (9.99)
4.	Phosphorus (in kg)	2130.25	1917.22	-213.03 (-10.00)
5.	Potash (in kg)	3654.57	3289.11	-365.46 (-10.00)
6.	Cash expenses on plant protection (in Rs.)	2560	2844.44	284.44 (9.99)
7.	Women Labour (in days)	78.78	87.54	8.76 (10.01)
8.	Men labour (in days)	39.38	43.77	4.39 (10.03)
9.	Water Consumption (in ha mm)	423.96	496.62	72.66 (14.63)
10.	Working capital (Rs.)	8926.55	9706.17	779.62 (8.03)
11.	Profit (Rs.)	89826.89	99807.65	9980.76 (9.99)

3.2.2 Optimum farm plan for both canal and ground water irrigation system

The optimum sustainable farm plan with existing plan for both canal and ground water system is presented in the table 3. The existing plan for both canal and ground water farm had a gross cropped area 3.80 ha, of which 1.80 ha was under coconut, 1.00 ha under onion and 1.00 ha under lablab. The existing plan utilized 6.42 hours of machine power, 13.82 tonnes of farm yard manure, Rs.1822.78 of nitrogen, Rs.2222.78 of phosphorus, Rs.3938.22 of potash, Rs.3298.89 of cash expenses on plant protection, 65.36 women days, 37.22 men days, 446.96 ha mm of water and Rs.8735.56 as working capital and earned a profit of Rs.119913.

The existing gross cropped area of 3.80 hectare was increased to 4.67 hectare in the optimum sustainable plan derived for both canal and ground water irrigation system. The area under coconut(1.80 ha) was increased by 1.64 ha and the area under onion was increased by 0.07 ha in the optimum sustainable plan. The crop enterprise under lablab was decreased by 0.84 ha. The gross cropped area under existing plan was 3.80 ha and was increased to 4.67 ha in the optimum sustainable plan.

The real activities identified in the both canal and ground water irrigation were tomato, coconut, banana, onion, chilli, sorghum, brinjal, lablab and green gram. The optimum plan derived along with existing plan for both canal and ground water irrigation system is presented in table 3.

As regards the resource utilization, the optimal plan derived for both canal and ground water irrigation system indicated an additional resource requirement of 1.11 tonnes of farm yard manure (7.43 per cent), 1796.35 rupees of potash (31.32 per cent), cash expenses on plant protection by Rs.1330.83 (28.75 per cent), 46.25 hectare mm of water consumption (9.38 per cent) and working capital by Rs.5011.34 (36.45 per cent). In contrast, the optimum plan envisaged a reduction in the usage of existing nitrogen by Rs.657.03 (36.04), phosphorus by Rs.16.12 (0.73 per cent), women labour by 15.2 man days (23.26 per cent) and men labour by 14.96 days (40.19 per cent). The optimum plan envisaged additional profit over the existing plan by Rs.23967 (16.65 per cent), which clearly indicated the superiority of the optimum sustainable plan over the existing plan in the both canal and ground water irrigation system.

From the results, it could be inferred that the optimum sustainable plan increased the gross cropped area from the existing plan for both canal and ground water irrigation system. The economic goal of maximizing profit was satisfied, since optimum plan increased the additional profit by Rs.23967 over the existing plan. The optimum plan satisfied two ecological goals namely reduction in usage of nitrogen and phosphorus. The sociological goal of increasing employment for men and women work force were not satisfied as the optimum plan decreased the men and women labour usage in both canal and ground water irrigation system.

Table 3: Optimum farm plan for both canal and ground water irrigation system

S.No	Activities/Resources	Existing plan	Optimum plan	Percentage Change in area and resource allocation
I	**Area under different crops (in ha)**			
1.	Coconut	1.80	3.44	1.64
2.	Onion	1.00	1.07	0.07
3.	Lablab	1.00	0.16	-0.84
	Gross Cropped Area	**3.80**	**4.67**	**0.87 (18.63)**
II	**Resource Allocation**			
1.	Machine power(in hours)	6.42	6.42	0.00 (0.00)
2.	Farm Yard Manure (in tonnes)	13.82	14.93	1.11 (7.43)
3.	Nitrogen (in kg)	1822.78	1165.75	-657.03

				(-36.04)
4.	Phosphorus (in kg)	2222.78	2206.66	-16.12 (-0.73)
5.	Potash (in kg)	3938.22	5734.57	1796.35 (31.32)
6.	Cash expenses on plant protection (in Rs.)	3298.89	4629.72	1330.83 (28.75)
7.	Women Labour (in days)	65.36	50.16	-15.2 (-23.26)
8.	Men labour (in days)	37.22	22.26	-14.96 (-40.19)
9.	Water Consumption (in ha mm)	446.96	493.21	46.25 (9.38)
10.	Working capital (Rs.)	8735.56	13746.9	5011.34 (36.45)
11.	Profit (Rs.)	119913	143880	23967 (16.65)

3.2.3 Optimum farm plan for canal irrigation system

The derived optimum sustainable farm plan with existing plan for canal is presented in the table 4.

The existing plan for canal farm had a gross cropped area 5.40 ha, of which 1.60 ha was under green gram, 1.40 ha under maize, 1.20 ha under cowpea and 1.20 ha under Tomato. The existing plan utilized 6.42 hours of machine power, 13.81 tonnes of farm yard manure, Rs.1382.22 of nitrogen, Rs.1963.89 of phosphorus, Rs. 2159.44 of potash, Rs.1538.89 of cash expenses on plant protection, 63.97 women days, 32.65 men days, 446.96 ha mm of water and Rs.8735.56 as working capital and earned a profit of Rs.81899.22.

The existing gross cropped area of 5.40 hectare was increased to 5.99 hectare in the optimum sustainable plan derived for canal irrigation system. The area under green gram(1.60 ha) was increased by 0.72 ha and the area under maize was increased by 0.19 ha in the optimum sustainable plan. The crop enterprise under cowpea was increased by 0.28 ha and tomato was decreased by 0.60 ha. The gross cropped area under existing plan was 3.80 ha and was increased to 4.67 ha in the optimum sustainable plan.

The real activities identified in the canal irrigation were tomato, cowpea, brinjal, green gram, ground water, maize, radish, sorghum and sesame. The optimum plan derived along with existing plan for canal irrigation system is presented in table 4.

As regards the resource utilization, the optimal plan derived for canal irrigation system indicated an additional resource requirement of nitrogen by Rs.12.66 (0.91 per cent), phosphorus by Rs.643.45 (32.76 per cent) and 675.49 hectare mm of water consumption (51.13 per cent). In contrast, the optimum plan envisaged a reduction in the usage of machine power by 1.19 hours (0.18 per cent), farm yard manure by 1.08 tonnes (0.08 per cent), potash by Rs. 242.21(11.21 per cent), Cash expenses on plant protection by Rs. 355.35 (23.09 per cent), existing women labour by 42.93 man days (67.10 per cent), men labour by 9.39 days (28.76 per cent) and working capital by Rs.3087.98 (35.35 per cent). The optimum plan envisaged additional profit over the existing plan by Rs. 17837.67 (21.78 per cent), which clearly indicated the superiority of the optimum sustainable plan over the existing plan in the canal irrigation system.

From the results, it could be inferred that the optimum sustainable plan increased the gross cropped area from the existing plan for canal irrigation system. The economic goal of maximizing profit was satisfied, since optimum plan increased the additional profit by Rs.17837.67 over the existing plan. The optimum plan satisfied two ecological goals namely reduction in usage of potash and cash expenses on plant protection. The sociological goal of increasing employment for men and women work force were not satisfied as the optimum plan decreased the men and women labour usage in canal irrigation system.

Table 4: Optimum farm plan for canal irrigation system

S.No	Activities/Resources	Existing plan	Optimum plan	Percentage Change in area and resource allocation
I	**Area under different crops (in ha)**			
1.	Cowpea	1.20	1.48	0.28
2.	Tomato	1.20	0.6	-0.6
3.	Green gram	1.60	2.32	0.72
4.	Maize	1.40	1.59	0.19
	Gross Cropped Area	**5.40**	**5.99**	**0.59 (9.85)**
II	**Resource Allocation**			
1.	Machine power(in hours)	6.42	5.23	-1.19 (-18.53)
2.	Farm Yard Manure (in tonnes)	13.81	12.73	-1.08 (-7.82)
3.	Nitrogen (in kg)	1382.22	1394.88	12.66 (0.91)
4.	Phosphorus (in kg)	1963.89	2607.34	643.45 (24.68)
5.	Potash (in kg)	2159.44	1917.23	-242.21 (-11.21)
6.	Cash expenses on plant protection (in Rs.)	1538.89	1183.54	-355.35 (-23.09)
7.	Women Labour (in days)	63.97	21.04	-42.93 (-67.11)
8.	Men labour (in days)	32.65	23.26	-9.39 (-28.76)
9.	Water Consumption (in ha mm)	446.96	675.49	228.53 (33.83)
10.	Working capital (Rs.)	8735.56	5647.58	-3087.98 (-35.35)
11.	Profit (Rs.)	81899.22	99736.89	17837.67 (17.88)

3.2.4 Optimum farm plan for dry land system

The derived optimum sustainable farm plan with existing plan for dry land is presented in the table 5.

The existing plan for dry land farm had a gross cropped area 4.60 ha, of which 1.60 ha was under black gram, 1.20 ha under groundnut, 1.00 ha under cowpea and 0.80 ha under sesame. The existing plan utilized 6.51 hours of machine power, 13.81 tonnes of farm yard manure, Rs.1237 of nitrogen, Rs.1816.11 of phosphorus, Rs.2131.89 of potash, Rs.1148.56 of cash expenses on plant protection, 64.87 women days, 33.82 men days, 346.28 ha mm of water and Rs.8735.56 as working capital and earned a profit of Rs.59957.89.

The existing gross cropped area of 4.60 hectare was increased to 6.21 hectare in the optimum sustainable plan derived for canal irrigation system. The area under black gram(1.60 ha) was increased by 0.77 ha and the area under groundnut was increased by 0.53 ha in the optimum sustainable plan. The crop enterprise under sesame was increased by 0.81 ha and cowpea was decreased by 0.50 ha. The gross cropped area under existing plan was 4.60 ha and was increased to 6.21 ha in the optimum sustainable plan.

The real activities identified in the dry land system were black gram, cowpea sorghum, groundnut, bhendi, tomato, fodder maize, horse gram and sesame. The optimum plan derived along with existing plan for canal irrigation system is presented in table 5.

As regards the resource utilization, the optimal plan derived for dry land irrigation system indicated an additional resource requirement of machine power by 1.47 hours (18.42 per cent), farm yard manure by 0.44 tonnes (03.09 per cent), nitrogen by Rs.381.04 (23.55 per cent), Cash expenses on plant protection by Rs. 485.04 (29.69 per cent) and 28.31 hectare mm of water consumption (7.56 per cent). In contrast, the optimum plan envisaged a reduction in the usage of phosphorus by Rs.17.3 (0.95 per cent), potash by Rs.266.34 (12.49 per cent), existing women labour by 42.68 man days (65.79 per cent), men labour by 22.25 days (65.79 per cent) and working capital by Rs.898.87 (10.28 per cent). The optimum plan envisaged additional profit over the existing plan by Rs. 2673.23 (4.27 per cent), which clearly indicated the superiority of the optimum sustainable plan over the existing plan in the canal irrigation system.

From the results, it could be inferred that the optimum sustainable plan increased the gross cropped area from the existing plan for canal irrigation system. The economic goal of maximizing profit was satisfied, since optimum plan increased the additional profit by Rs.2673.23 over the existing plan. The optimum plan satisfied two ecological goals namely reduction in usage of phosphorus and potash. The sociological goal of increasing employment for men and women work force were not satisfied as the optimum plan decreased the men and women labour usage in dry land system. Thus the optimal planning analyses revealed that ground water irrigation system satisfied all the three goals of economic, ecological and social goals while all the other three systems satisfied economic and ecological goals.

Table 5: Optimum farm plan for dry land system

S.No	Activities/Resources	Existing plan	Optimum plan	Percentage Change in area and resource allocation
I	**Area under different crops (in ha)**			
1.	Black gram	1.60	2.37	0.77
2.	Groundnut	1.20	1.73	0.53
3.	Cowpea	1.00	0.5	-0.5
4.	Sesame	0.80	1.61	0.81
	Gross Cropped Area	**4.60**	**6.21**	**1.61 (25.93)**
II	**Resource Allocation**			
1.	Machine power(in hours)	6.51	7.98	1.47 (18.42)
2.	Farm Yard Manure (in tonnes)	13.81	14.25	0.44 (3.09)
3.	Nitrogen (in kg)	1237	1618.04	381.04 (23.55)
4.	Phosphorus (in kg)	1816.11	1798.81	-17.3 (-0.95)
5.	Potash (in kg)	2131.89	1865.55	-266.34 (-12.49)
6.	Cash expenses on plant protection (in Rs.)	1148.56	1633.60	485.04 (29.69)
7.	Women Labour (in days)	64.87	22.19	-42.68 (-65.79)
8.	Men labour (in days)	33.82	11.57	-22.25 (-65.79)
9.	Water Consumption (in ha mm)	346.28	374.59	28.31 (7.56)
10.	Working capital (Rs.)	8735.56	7836.69	-898.87 (-10.28)
11.	Profit (Rs.)	59957.89	62631.12	2673.23 (4.27)

CONCLUSION

Sustainability was analysed with Sustainable Rural livelihood (SRL) framework in all three irrigation systems and dry land. Sustainability was assessed by combining the three sustainability criteria of ecological soundness, economic viability and social acceptability. The results revealed that the canal and ground water system was more sustainable than other systems followed by ground water irrigation system. In ground water, canal and ground water, canal irrigation system and dry land system, the optimum farm plan was developed using the lexicographic goal programming model to satisfy economic, ecological and social goals. The results revealed that ground water irrigation system satisfied all the three goals of economic, ecological and social goals while all the other three systems satisfied economic and ecological goals.

POLICY IMPLICATIONS

The sustainability analyses revealed that both canal and ground water irrigation system was more sustainable with regard to economic viability, ecology and social acceptability and hence steps should be taken by the agricultural department to promote this system by providing subsidies and other extension facilities for the sustainable development.

The sustainable farm plans suggested from goal programming in both canal and ground water, canal irrigation system and dry land system should be popularized by Agriculture Department as it achieved the economic and ecological goals. Further, ground water irrigation system should be given more impetus by the agriculture Department since it achieved all the three goals of economic, ecological and social goals.

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