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STEP Method of Multi Objective Programming : An Operational Research Tool for Efficient Resource Planning for Minor Irrigation Command

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ABSTRACT

A multi objective mathematical programming models has been used to obtain a comprehensive development plan for the minor irrigation command area subject to limited availability of resources with base as Linear Programming model. The study was undertaken in Gunduraposi Minor Irrigation Project located in Dhenkanal district of Odisha. It was conducted with the objectives of maximising profit, production and minimising investment subject to constraints of land, water, fertilizer, labour, water requirement, nutritional and farmers affinity. The vegetable production of STEP model was increased by 25.16 and 21.23 per cent compared to production maximization and Net return maximization LP model, respectively. The suggested cropping pattern yielded maximum net contribution and minimum investment. It also ensured availability of crops to meet the minimum nutrient requirements of the population. In the recommended plan, the total net return increased from Rs.18.69 million to Rs.46.4 million.

Key Words: Multi objective Mathematical Programming, Minor Irrigation Project, STEP model, Production, Maximization, Net returns.

INTRODUCTION

A planning for the optimal use of productive resources in agricultural systems in Minor Irrigation Project leads to the conservation of resources in addition to the upliftment of farmers' socio-economical conditions. Hence, optimal crop planning with limited resource has been taken up for different minor irrigation projects by linear programming model (Dash *et al,* 2014). The national goals of high production do conflict with farmer's interest of maximizing net benefit and at the same time minimizing investment which demands planning a better solution within the resource constraints. This can be fulfilled through integrated management approach of command area at micro level. Therefore the Planning for the optimal use of productive resources in agricultural systems needs to be done in order to conserve the resources and promote farmers' socio-economical conditions. Integrated planning for optimal allocation of resources can only be possible by operational research tools like Global Criterion method, STEP method, STEP method and linear Goal programming etc. Sahoo *et al* (2006) developed linear programming and STEP optimization models for planning and management of available land-water-crop system of Mahanadi-Kathajodi delta in eastern India. The models are used to optimize the economic return, production and labour utilization, and to search the related cropping patterns and intensities with specified land, water, fertilizer and labour availability, and water use pattern constraints.

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Vivekanandan and Viswanathan (2007) used linear and linear Goal programming module to optimize the cropping pattern of Barna Irrigation project. Three different objectives such as maximization of net return, protein and calorie values were considered for optimization of cropping pattern. Amini (2015) used the multi-objective STEP Goal Programming (FGP) approach to identify the optimal cropping pattern and land use planning of a rural region located in the central of Iran. Srinivasa and Nagesh (2000) developed a STEP LP irrigation planning model for the evaluation of management strategies for the case study of Sri Ramsagar Project of Andhra Pradesh. Three conflicting objectives net benefits, crop production and labour employment were considered in the irrigation planning scenario. Their study was demonstrating the vagueness and imprecision in the objective function values could be quantified by membership functions in STEP multiobjective framework. Panigrahi *et al* (2010) formulated a mathematical model for optimal allocation of area to different crop sequences with different objectives *viz*. minimization of soil loss, minimization of investment and maximization of net return from agriculture and solved using linear goal programming technique. Mohanty *et al* (2015) have also used STEP model for crop planning and maximization of net profit in Mandakini Balinala watershed of Khurda district of Odisha.

MATERIALS AND METHODS

Location of study

The study was conducted in the command area of Gundura posi, Minor Irrigation Project (latitude 20^0 43' 40" N, Longitude – 85^0 48' 40" E) system coming under Mid Central Table Land zone of Dhenkanal district in Odisha. There are three numbers of villages coming under project *i.e*. Bidharpur, Gunduraposi and Poruakhoj. The gross command area of the project is 1012ha, out of which the culturable command area is 817ha. The maximum water level of the MIP dam is at 94.20m and catchment area is of 22.02 sq.km.

Procedure for command area planning

Socio-economic data of the command area were collected during personal interview with groups of people from village through a questionnaire. Analyzed last 25 yr daily rainfall and evaporation data of the command area to find out trend, surplus and deficit period and water requirement of crops. Due attention was given to the attitude of the people for their affinity to particular crops. The major was to keep area under different vegetables and oilseed crops for crop diversification. Accordingly, prepared a comprehensive development plan for the command area by utilizing both single and multi objective mathematical programming models.

The following three objectives were considered in this study as under:

I .Maximization of Production :

$$\sum_{i=1}^{6}\sum_{j=1}^{2}\sum_{k=1}^{2} P_{ijk} X_{ijk}$$

Max Z_P =

Where,

$Z_P(X)$ = Value of the production function corresponding to a feasible solution X

P_{ijk} = Positive production from ith crop (if feasible) in jth season for kth irrigation activity and zero otherwise

X_{ijk} = Area of ith Crop in jthseason for kthirrigation activity

II.Net Return Maximization:

$$\sum_{m=1}^{3} B_m Y_m \sum_{i=1}^{6}\sum_{j=1}^{2}\sum_{k=1}^{2} B_{ijk} X_{ijk} +$$

Max Z_R =

Where,

B_{ijk}= Net return from ith crop in jth season under kth irrigation condition, Rs/ha

B_m = Benefit from animal type m per year (Rs)

X_{ijk} = Area of land cultivated under ith crop in jth season under kth irrigation condition, ha

Y_m = Number of animal type 'm'

Z_R = Value of Net Return, Rs.

III.Investment Minimization:

$$\sum_{i=1}^{6}\sum_{j=1}^{2}\sum_{k=1}^{2} C_{ijk}X_{ijk} + \sum_{m=1}^{3} C_m Y_m$$

MinZ_I=

Where,

C_{ijk}= Cost of cultivation of ith crop in jth season for kth irrigation activity (Rs/ha)

X_{ijk} = Area of land cultivated under ith crop in jth season under kth irrigation condition, ha

m = A subscript (m=1,2,3) representing three types of animal i.e. m =1 for Cow, m=2 for Buffalo, m=3 for poultry

C_m = Cost of rearing of animal of type m per year (Rs.)

Y_m = Number of animal of type m

Multiple Objective Programming techniques

Step Method (STEM)

It is a method proposed by Banayoun *et al* (1971) for solving Multiple Objective Linear Programming (MOLP) problems. The process of arriving at an acceptable solution to a MOLP problem by step method gives enough opportunity to the DM to learn. Here a decision maker not only gets a chance to compare more than one solution to find the best among them but guides the analyst by giving his preferences to explore alternate solutions. The solution procedure has two distinct phases, the computation phase and the decision phase. The mathematical formulations and its solution steps if one uses the step method for the MOLP problem of the command area are given below.

$$Max\left[Z_B(X), Z_P(X), -Z_I(X)\right]$$

Subject to the above constraints

The above problem in vector form can be written as

$$Max\left\{C\frac{T}{B}X, C\frac{T}{P}X, C\frac{T}{I}X\right\}$$

Subject to $A_X \le b$

$X \ge 0$

Where

The constraints are expressed in the form $A_X \le b$

$\left\{C\frac{T}{B}, C\frac{T}{P}, C\frac{T}{I} and C\right\}$ is the coefficients of the objective functions respectively.

X is a feasible point in the solution space.

The above single and multi objective Linear programming module calculations were performed by using LINDO Software.

RESULTS AND DISCUSSION

The results were discussed with district officials and as per their preference and district requirement compromise solution was prepared using STEP method. In the STEP method, α_B , α_P ,α_I have been calculated from the pay-off table and the weights are calculated.

$$\alpha_B = \frac{Z_B^* - Z_B^+}{Z_B^*}\left[\sum C_B^2\right]^{-0.5}$$

$$\alpha_P = \frac{Z_P^* - Z_P^+}{Z_P^*}\left[\sum C_P^2\right]^{-0.5}$$

$$\alpha_I = \frac{Z_I^* - Z_I^+}{Z_I^*}\left[\sum C_I^2\right]^{-0.5}$$

When $Z_B^+ = Min\left[Z_B^*, Z_B, Z_B\right]$

$$Z_P^+ = Min\left[Z_P, Z_P^*, Z_P\right]$$

$$Z_I^+ = Min\left[Z_B, Z_P, Z_I^*\right]$$

$$W_B = \frac{(\alpha_B)}{(\alpha_B + \alpha_P + \alpha_I)}$$

$$W_P = \frac{(\alpha_P)}{(\alpha_B + \alpha_P + \alpha_I)}$$

$$W_I = \frac{(\alpha_I)}{(\alpha_B + \alpha_P + \alpha_I)}$$

The value of $\alpha_{B,} \alpha_P, \alpha_I$ are found to be 2.74x10^{-7}, 9.8x10^{-5} and -2.93x10^{-7} respectively. Similarly the value of $W_B, W_P and W_I$ are found to be 2.79x10^{-3}, 1 and -0.003 respectively.

Table 1. Production status of crops and livestock from different LP models and STEP Models.

Sr. No	Name of crop /Animal	Production of crops in different models (q)			
		Production maximization LP Model	Net Return Maximization LP Model	Investment Minimization LP Model	STEP Programming Model
***Kharif*-Rainfed**					
1	Paddy	25350	24000	23250	25350
2	Arhar	1634	1634	1634	1634
3	Groundnut	1838.2	1838.2	1838.2	1838.2
4	Cowpea	1824.9	1824.9	1824.9	1824.9
Total		30647.1	29297.1	28547.1	30647.1
***Rabi*-Irrigated**					
1	Paddy	6060	6024	5082	6060
2	Groundnut	2042.5	2042.5	2042.5	2042.5
3	Potato	2050	2050	2050	2050
4	Brinjal	7000	7000	7000	7000
5	Tomato	0	0	0	3600
6	Onion	3000	3000	3000	3000
7	Cabbage	3000	3552	3000	3690
8	Cauliflower	2000	2000	2000	2000
9	Coriander	0	0	0	0
10	Garlic	0	0	0	0
11	Greengram	960	960	960	960
12	Blackgram	480	480	480	480
13	Mustard	157.5	157.5	157.5	157.5
14	Horsegram	0	0	0	859.5
Total		26750	27266	25722	31899.5
Grand Total (Kharif-Rainfed+Rabi-Irrigated)		57397.1	56563.1	54319.1	62546.6
15	Cow	2400	2400	2400	2400
16	Poultry	109.6	454.7	109.6	109.6
Livestock Total Production		2509.6	2854.7	2509.6	2509.6

Status of optimal crop production

Production potential in *Kharif* in STEP model is more or less same in comparison to production maximization model (Table 1) but it was lesser to 4.6 per cent compared to net return maximization model. In *Rabi* season production potential in STEP model was19.25 per cent more in comparison to production maximization model. Total production potential in STEP model was 8.97 per cent higher than total production in production maximization model.

Status of Optimal Net return

The data (Table 2) represent net return from different crops in all the four models. The variation from minimum net return in investment minimization model to maximization return in STEP model was

Table 2. Net Return status of crops and livestock from different LP models and STEP Models

Sr. No	Name of crop /Animal	Net return of crops in (Rs. in lakh) obtained in different models			
		Production maximization LP Model	Net Return Maximization LP Model	Investment Minimization LP Model	STEP Programming Model
***Kharif*-Rainfed**					
1	Paddy	189.6	179.5	173.9	189.6
2	Arhar	36.8	36.8	36.8	36.8
3	Groundnut	25.3	25.3	25.3	25.3
4	Cowpea	4.8	4.8	4.8	4.8
Total		256.6	246.5	240.9	256.6
***Rabi*-Irrigated**					
1	Paddy	43.12	42.87	36.16	43.12
2	Groundnut	37.33	37.33	37.33	37.33
3	Potato	4.77	4.77	4.77	4.77
4	Brinjal	27.76	27.76	27.76	27.76
5	Tomato	0	0	0	14.85
6	Onion	12.21	12.21	12.21	12.21
7	Cabbage	8.0	9.48	8.0	9.85
8	Cauliflower	7.0	7.0	7.0	7.0
9	Coriander	0	0	0	0
10	Garlic	0	0	0	0
11	Greengram	24.64	24.64	24.64	24.64
12	Blackgram	12.32	12.32	12.32	12.32
13	Mustard	3.18	3.18	3.18	3.18
14	Horsegram	0	0	0	17.76
15	Cow	14.20	14.20	14.20	14.20
16	Poultry	4.79	19.88	0.49	0.49
Total		199.3	215.6	188.0	229.4
Grand Total (Kharif-Rainfed+Rabi-Irrigated)		455.94	462.17	428.98	486.11

13.3per cent. STEP model gives more return than net return maximization model up to 5.18 per cent. This is due to the fact that area coverage was more in more number of crops. This is a compromising solution mainly between production maximization and net return maximization. Of course investment minimization was not achieved in STEP model.

Status of Investment

In STEP model investment was higher than production maximization, net return maximization and investment minimization by 4.36, 3.98 and 10.86 per cent, respectively. This was due to compromise solution brought out from the three models. Some more remunerative crops have been allocated in the STEP model thereby increasing investment. The ratio of return to investment is 0.993 in STEP model whereas in other three models *i.e.* production maximization, return maximization and investment minimization it is 0.972, 0.982 and 0.972, respectively. Hence STEP model is the best compromise solution.

Table 3. Investment status of crops and livestock from different LP models and STEP Models

Sr. No	Name of crop /Animal	Investment of crops in (Rs in lakh) obtained in different models			
		Production maximization LP Model	Net Return Maximization LP Model	Investment Minimization LP Model	STEP Programming Model
***Kharif*-Rainfed**					
1	Paddy	202.8	192	186	202.8
2	Arhar	28.59	28.59	28.59	28.59
3	Groundnut	48.16	48.16	48.16	48.16
4	Cowpea	4.37	4.37	4.37	4.37
***Rabi*-Irrigated**					
1	Paddy	45.45	45.18	38.11	45.45
2	Groundnut	28	28	28	28
3	Potato	7.52	7.52	7.52	7.52
4	Brinjal	21.23	21.23	21.23	21.23
5	Tomato	0	0	0	10.34
6	Onion	11.78	11.78	11.78	11.78
7	Cabbage	4.99	5.90	4.99	6.13
8	Cauliflower	4.99	4.99	4.99	4.99
9	Coriander	0	0	0	0
10	Garlic	0	0	0	0
11	Greengram	18.56	18.56	18.56	18.56
12	Blackgram	9.28	9.28	9.28	9.28
13	Mustard	3.11	3.11	3.11	3.11
14	Horsegram	0	0	0	12.31
15	Cow	26.14	26.14	26.14	26.14
16	Poultry	3.75	15.58	0.38	0.38
17	Buffalo	0	0	0	0
Total		468.72	470.39	441.21	489.14

CONCLUSION

The primary objective of the approach was to increase livelihood options in the command area. The aim is to uplift the poor people above poverty line. This can be done only if planning is done keeping with the priorities of the people. Such kind of analysis was done for Gunduraposi Minor Irrigation command area where people's priority, nutritional requirement, labours used; minimum capital investment with more production has been considered. After comparing all the three models i.e. production maximization, net returns maximization and investment minimization, STEP model comes out to be the best one. Ratio of net return to investment was highest i.e. 0.993. Cropping intensity was highest *i.e.* 153.5%. Cereal production though more or less same with production maximization model but it was higher than 112 and 102 per cent in investment minimization and net return maximization model, respectively. In STEP model pulse production increased by 123.1 per cent and vegetable production is increased by 130 per cent. Oilseed and potato production in STEP model was same as in other three models. Hence, if oilseed or potato production has to be increased, then subsidy may be given to other crops which area has to be reduced. So STEP model is a best compromising solution. Optimal cropping pattern has been evolved using STEP programming model.

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