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Prospects of Increasing Farm Income through Optimum Production Pattern in Three Regions of Somasila Project in Andhra Pradesh

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ABSTRACT: The results of the study revealed that there exists sub-optimal allocation of resources in the existing plans of small and large farmers. The process of optimization under different water supply conditions resulted in the improvement in the net farm returns of both the categories of farmers in the study area. However, the optimum model developed at existing water availability resulted in higher net farm returns as compared to other models developed at 10, 20 and 30 percent reduction in the water supply on small and large farms of head, middle and tail regions. The major challenge in the present study is availability of data regarding water levels at head, middle and tail regions. The process of optimization led to increase in the area under high valued crops and thus reducing the number of crops It is also evident that the decline in the net farm returns were more pronounced on both the categories of farms of the three regions when water availability was reduced by 30 percent.

Keywords: Optimum Plans, Rational Resource Allocation, Linear Programming Model, Sensitivity Analysis.

INTRODUCTION

The importance of water as a valuable resource for agriculture can never be over emphasized. The increasing need for crop production for the growing population is causing the rapid expansion of irrigation throughout the world. The area under irrigation in India was only 19.4 M ha in 1947 and has increased to 22.6 M ha before the five-year plan commenced i.e. 1950-51 (Sivanappan, 2004). The area under irrigation has been increased to 65 million hectares during 2022 (DATA STORY: Irrigation in India, 2022).

Water being a limited resource, its efficient use is very vital and basic to the very survival of the ever-increasing population. Every effort must be made to make the best use of available water to make possible a higher level of continuous production per unit volume of water, per unit area of cropped land and per unit time.

The present study was undertaken in the Somasila Project command area, a large surface irrigation system in Nellore district of Andhra Pradesh with the specific objective of determining the income prospects of farmers through optimum reorganization of resources. It was selected purposively in view of the existences of variations in water availability at different regions of farm.

REVIEW OF LITERATURE

- Ibrahim and Omotesho (2011) in their study determined the optimal enterprise combination for vegetable production under Fadama in North Central Nigeria.
- Shrivastava *et al.* (2012) used optimization modelling for crop planning of Hasdeo Bango command area.
- Majeke *et al*. (2013) used a linear programming model in their study to determine the optimal crop combination for a rural farmer in Zimbabwe.
- Gadge *et al.* (2014) formulated a linear programming model to suggest the optimal cropping pattern for surface irrigation in a command area. The study was conducted in Mula irrigation project, Maharashtra. The optimal cropping pattern suggested to irrigate 60% of command area with the available water and allocate 25.9 ha area for papaya, 25.9 ha for sugarcane, 96.4 ha for rabi tomato, 6.17 ha for rabi onion and 12.88 ha for summer onion.
- Etedali *et al.* (2015) employed optimization technique to work out water allocation managements between irrigation and rainfed lands in different climate conditions.
- Das *et al.* (2017) used A Linear Programming Approach to Optimizing Organization Transportation System.

• Upadhyaya (2017) used the optimization technique for crop planning to improve farm productivity of ICAR-RCER, Patna. The results from the optimal solution suggested that if in total land of 8.25 ha, lentil is sown then optimal benefits of Rs. 103340.82 can be obtained which is 1.785 times higher than the existing net benefits.

• Anjum *et al.* (2018) applied linear programming technique to assess the optimum cropping pattern for mixed cropping zone of semi-arid area of Punjab. The result showed that yield and profit can be increased by allocating more area to wheat, cotton, maize and reducing area of rice, sugarcane, fodder. The profit increased by 1.04%, 1.10% and 1.07% for small, medium, and large farmers by adoption of proposed optimal plan.

• Ibrahim *et al.* (2019) developed an optimum production plan for maize-based crop farmers in Niger state. Optimal plans suggested to allocate 1.1988 ha for maize/soyabean and 0.468 ha for maize/cowpea. The gross margin in optimal plan is 76.12% increase than the existing plan.

• Bhatia and Rana (2020) used a mathematical approach to optimize the crop allocation in different districts of Rajasthan. The results showed that the farm returns increased to 68% in farm I and 16.5 % in farm II by introducing the mustard crop in farm I and eliminating the livestock and allocating more area to crops in farm II.

MATERIALS AND METHODS

Sampling Procedure. A multistage stratified purposive cum random sampling procedure was adopted to the present study. The entire command area divided into three regions *viz*., head, middle and tail regions. From each region first two mandals with maximum command area were purposively selected. Accordingly, the selected mandals were Kaluvoya and Ananthasagaram from head region, Atmakur and Chejerla from middle region and Podalakur and Kavali from tail region. All the villages in the selected mandals based on command area were arranged in descending order and the first two villages from each mandal were selected for a detailed study. The list of farmers from the selected 12 villages of three regions of command area, were obtained from the village officials. From the list of farmers in each village, five each from small and large farmers were selected at random. Thus, the number of farmers selected from each village was ten and that total number of farmers selected for purpose of present study was 120. The data on inputs and outputs of crop enterprises were collected from the respondents for the agricultural year 2003-2004.

Tools of Analysis. Optimum allocation of resources is defined as one, with given physical, technical and resource conditions, showing those activities to undertake and how much of each resource to allocate to each activity so that the net farm returns are maximized in a year. Among the various analytical tools available for allocation of available but limited farm resources among alternative enterprises, linear programming is one of the most widely and best understood operations research techniques. Hence, the deterministic linear programming technique was employed to develop farm plans under varied irrigation supply situations.

Objective Function. The objective function for the model in this study was to maximize the annual net farm returns from crop enterprises subject to the resource constraints specified in the model. In this manuscript, our aim is to study about the optimal agriculture production planning through land allocation with respect to the other relevant constraints (Basumatary and Mitra 2020).

In this model, the value of objective function (the optimum solution) which was to be maximized included the sum of the year's net cash flow. The final cash flow into the objective function was the result of changes arising from production, marketing, borrowing and debt management during the year. In interpreting the results of the model, the value of the objective function was adjusted by subtracting owned funds.

Mathematical Formulation of the Model. In linear programming analysis, a linear function of a number of variables is to be maximised subject to a number of constraints in the form of linear equalities and inequalities. In mathematical form, one-year (two seasons) linear programming model can be expressed in the following way.

$$\text{Maximise } Z = \sum_{j=1}^{n} C_j X_j$$

j= 1 to n activities

Subject to following constraints

1. $\sum_{j=1}^{n} a_{ij} X_j > b_i$ (i = 1, …….K constraints)

2. $\sum_{j=1}^{n} a_{ij} X_j < b_i$ (i = K+1,……. m constraints)

3. $\sum_{j=1}^{n} a_{ij} X_j = b_i$ (i = m+1, ……. v constraints)

4. X_j , b_i > 0 (non negativity constraint)

where,

Z = is the objective function to be maximized in the year.

C_j= is the value of j^{th} activity during *kharif* and *rabi* seasons of the year.

X_j = is the unit of j^{th} production activity during *kharif* and *rabi* seasons of the year.

a_{ij} = amount of i^{th} resource required by one unit of j^{th} activity

b_i = supply levels of i^{th} resource or input in the specified units.

Selection of Processes or Activities. The crops grown by the sample farmers were paddy (1001), Paddy

(1009), sunflower (Morden), sunflower (Hybrid), groundnut (JL-24), bajra, sugarcane, brinjal, in *kharif* season and paddy, cotton, chillies, cowpea, greengram and gingelly in *rabi* season.

Input and Output Coefficients. The individual elements in the linear programming matrix refer to input and output coefficients which indicate resource requirements per unit (hectare) of each activity considered in the model. The input coefficients included in this study were land, labour, farmyard manure, plant nutrients (N, P and K), irrigation water and capital. Capital referred to funds required to meet the cost of seeds, fertilizers, farmyard manure, plant protection chemicals, insurance charges, marketing expenses and wages of human and bullock labour and tractor power. The output coefficients referred to the average yields obtained by the average sample farmer from one unit of each crop activity. These output coefficients were specified in the model with negative signs. Coefficients of borrowing, repayment, debt management and cash transfer activities were also included in the matrix.

The average prices, which the sample farmers paid and received, were considered as the input-output prices in this study.

RESULTS AND DISCUSSION

The present study has an objective to examine the changes in income under different water availability situations. Profit maximization has been assumed as the objective function of the farmers and optimal plans for the small and large farms in the three regions *viz*., head, middle and tail were developed with the help of linear programming.

Table 1: Existing cropping pattern of small and large farms under head, middle and tail region.

Crop	Head region				Middle region				Tail region			
	Small		Large		Small		Large		Small		Large	
	Area(ha)	Percent	Area(ha)	Percent	Area(ha)	Percent	Area(ha)	Percent	Area(ha)	Percent	Area(ha)	Percent
Kharif irrigated land												
Paddy (1001)	0.34	34.69	0.72	29.63	0.32	34.04	0.63	30.14	0.58	62.37	0.62	30.85
Paddy (1009)	0.21	21.43	0.61	25.10	0.18	19.15	0.53	25.36	-	-	0.52	25.87
Sunflower (hybrid)	-	-	0.30	12.35	-	-	0.28	13.40	-	-	0.27	13.43
Sunflower (morden)	0.12	12.25	0.22	9.05	0.12	12.77	0.20	9.57	0.18	19.35	0.21	10.45
Groundnut	0.10	10.20	0.24	9.87	0.08	8.51	0.19	9.09	0.12	12.90	0.28	13.93
Bajra	0.08	8.16	0.10	4.12	0.09	9.57	-	-	-	-	-	-
Sugarcane	0.11	11.23	0.18	7.41	0.15	15.96	0.26	12.44	-	-	-	-
Brinjal	0.02	2.04	0.06	2.47	-	-	-	-	0.05	5.38	0.11	5.47
Fallow	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.98	100.00	2.43	100.00	0.94	100.00	2.09	100.00	0.93	100.00	2.01	100.00
Rabi Irrigated land												
Paddy (Molagulakulu)	0.32	32.66	0.68	27.99	0.32	34.04	0.53	25.36	0.42	45.16	0.50	24.88
Cotton	0.17	17.35	0.42	17.28	0.15	15.96	0.38	18.18	0.11	11.83	0.36	17.91
Chillies	0.02	2.04	0.07	2.88	0.05	5.32	0.12	5.74	-	-	-	-
Cowpea	0.09	9.18	0.13	5.35	0.04	4.26	0.09	4.31	-	-	-	-
Greengram	0.08	8.16	0.08	3.29	0.04	4.26	0.11	5.26	0.18	19.35	0.38	18.91
Gingelly	0.05	5.10	0.15	6.17	0.05	5.32	0.13	6.22	0.15	16.13	0.29	14.43
Sugarcane	0.11	11.22	0.18	7.41	0.15	15.96	0.26	12.44	-	-	-	-
Fallow	0.14	14.29	0.72	29.63	0.14	14.89	0.47	22.49	0.07	7.53	0.48	23.88
Total	0.98	100.00	2.43	100.00	0.94	100.00	2.09	100.00	0.93	100.00	2.01	100.00
Cropping intensity (%)	185.71		170.37		185.11		177.51		192.47		176.12	
Net Farm Returns (Rs.)	33187.79		74307.16		31716.76		71489.29		28054.68		49526.29	
Net Farm Returns per hectare of cultivated area (Rs.)	33865.09		30579.08		33741.23		34205.40		30166.32		24639.95	
Irrigation water available (ha-cm)	180		420		177		360		145		322	
Water used (ha-cm)	176		402		175		360		145		322	
Cash used (Rs.)	18007.14		49492.36		17832.67		45369.88		17609.93		41869.95	

Inadequate water supply was experienced by the farmers in number of years, the reduction in water supply ranging from 10 to 30 per cent. So, sensitivity analysis was also done with varying water levels representing three abnormal situations to study the impact on cropping pattern and income levels.

The model was first run with the existing water supply level (Model 1). Later with 10 per cent decrease in water supply (Model 2) 20 per cent decrease in water supply (Model 3) and 30 per cent decrease in water supply (Model 4) were assumed and corresponding models were solved to examine the effect of irrigation water on cropping pattern and income of farm resources.

The basic models HS_1 (small farmers, head region), HL_1 (Large farmers, head region), MS_1 (small farmers, middle region), ML_1 (Large farmers, middle region), TS_1 (small farmers, tail region) and TL_1 (large farmers, tail region) were developed with existing water level and additional runs were made with 10 per cent, 20 per cent and 30 per cent decrease in water availability.

The details on existing production pattern, cropping intensity, net farm returns and water use of small and large farms under head, middle and tail regions were computed and are presented in Table 1.

The average size of irrigated land of large farmers varied from 2.43 ha in head region to 2.01 ha in the tail region. The selected large farmers of middle region owned 2.09 ha. On an average the small farmers of head, middle and tail regions owned 0.98, 0.94 and 0.93 ha of irrigated land respectively (Babatunde *et al*., 2007).

The existing crop mix of farmers in the head, middle and tail regions consisted of food crops viz., paddy and bajra, oil seeds crops like sunflower and groundnut, commercial crop sugarcane and vegetable crop brinjal on kharif irrigated land and paddy, cotton, chillies, cowpea, gingelly and greengram on rabi irrigated land. The cropping intensity was 185.71, and 170.37, 185.11 and 177.51 and 192.47 and 176.12 per cent on the small and large farms of head, middle and tail regions respectively.

The present plan provided a net farm income of Rs. 33,187.79, Rs. 31,716.76 and Rs. 28,054.68 on the small farms of head, middle and tail regions respectively. While the same was Rs. 74,307.16, Rs. 71,489.29 and Rs. 49,526.29 on large farms of the above said regions in the same order (Gautam *et al.,* 2015).

Optimum plans for Head region. The details of the crop mix in the existing and optimum plans of small and large farmers under head region are presented in Table 2.

Table 2: Cropping pattern of different optimum plans under head region – small farmers and large farmers.

Crop	Existing Plan		HS1	HL1	HS2	HL2	HS3	HL3	HS4	HL4
	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
***Kharif* irrigated land (Area(ha))**										
Paddy (1001)	0.34	0.72	-	-	-	-	-	-	-	-
Paddy (1009)	0.21	0.61	0.42	1.08	0.31	0.80	0.20	0.51	0.20	0.32
Sunflower (morden)	0.12	0.22	0.06	-	0.17	-	0.28	-	0.23	-
Sunflower (hybrid)	-	0.30		0.25		0.53		0.82		1.30
Groundnut	0.10	0.24	0.20	0.40	0.20	0.40	0.20	0.40	0.20	0.40
Bajra	0.08	0.10	-	-	-	-	-	-	-	-
Sugarcane	0.11	0.18	0.20	0.50	0.20	0.50	0.20	0.50	0.13	0.41
Brinjal	0.02	0.06	0.10	0.20	0.10	0.20	0.10	0.20	0.10	-
Fallow	-	-	-	-	-	-	-	-	0.12	-
Total	0.98	2.43	0.98	2.43	0.98	2.43	0.98	2.43	0.98	2.43
***Rabi* irrigated land (Area(ha))**										
Paddy (Molagulakulu)	0.32	0.68	0.29	0.47	0.21	0.32	0.20	0.16	0.20	0.28
Cotton	0.17	0.42	0.25	0.60	0.25	0.60	0.09	0.60	-	-
Chillies	0.02	0.07	0.10	0.30	0.10	0.30	0.10	0.30	0.10	0.30
Cowpea	0.09	0.13	-	-	-	-	-	-	-	-
Greengram	0.08	0.08	0.14	0.56	0.22	0.71	0.39	0.87	0.55	1.44
Gingelly	0.05	0.15	-	-	-	-	-	-	-	-
Sugarcane	0.11	0.18	0.20	0.50	0.20	0.50	0.20	0.50	0.13	0.41
Fallow	0.14	0.72	-	-	-	-	-	-	-	-
Total	0.98	2.43	0.98	2.43	0.98	2.43	0.98	2.43	0.98	2.43
Cropping intensity (%)	185.71	170.37	200.00	200.00	200.00	200	200	200.00	187.76	200.00
Net Farm Returns (Rs.)	33187.79	74307.16	50963.47	107006	49957.13	106775	48592.51	106544	43763.25	101871
Net Farm Returns per hectare of cultivated area (Rs.)	33865.09	30579.08	52003.54	44035.39	50976.66	43940.33	49584.19	43845.27	44656.38	41922.22
Irrigation water available (ha-cm)	180	420	180	420	162	378	144	336	126	294
Water used (ha-cm)	176	402	180	420	162	378	144	336	126	294
Cash used (Rs.)	18007.14	49492.36	15551.44	64129.82	14607.48	60788.85	13944.53	57447.89	12338.47	51937.82

Small Farms. On *kharif* irrigated land, all the crops except bajra, which were in the existing plan, entered the optimum plan with changes in the acreage. The optimum model HS_1, suggested increasing the area under paddy (1009), groundnut, sugarcane and brinjal from 0.21, 0.10, 0.11 and 0.02 ha in the existing plan to 0.42, 0.20, 0.20 and 0.10 ha respectively. But the area under sunflower declined from 0.12 ha in existing plan to 0.06 ha in the optimum plan. Paddy and bajra, which occupied 0.34 and 0.08 ha in the existing plan, were eliminated. In *rabi*, the results of the optimal model indicated to increase the area under the production of cotton, chillies and green gram. The allocation of land for cotton, chillies and green gram was 0.25, 0.10 and 0.14 ha respectively. There was no perceptible change in the allocation of land to produce paddy. Sugarcane occupied the same area as in *kharif*. The plan did not favour the inclusion of cowpea and gingelly.

The resource optimization leads to increase in the intensity of cropping from 185.71 per cent in the existing plan to 200 per cent in the optimal plan HS_1. The net farm returns and the net farm returns per hectare of cultivated area were higher by Rs. 17, 775.68 (53.56 per cent) and Rs. 18, 138.45 (34.88 per cent) respectively over the existing plan.

The optimum model HS_2 developed by decreasing 10 per cent of water supply resulted in different cropping pattern to that of model HS_1. On *kharif*-irrigated land, the area under groundnut, sugarcane and brinjal remained the same as in optimum model HS_1. However, it recommended to increase the area for sunflower from 0.06 ha (6.12 per cent) in model HS_1 to 0.17 ha (17.35 per cent) in model HS_2. The model also suggested reducing the area for paddy (1009) from 0.42 ha in HS_1 to 0.31 ha in model HS_2 due to reduction in the water availability. During *rabi*, sugarcane continued to occupy the same area as in *kharif*. The area under cotton and chillies remained the same as in model HS_1. The area under paddy declined from 0.29 ha in model HS_1 to 0.21 ha in model HS_2. Consequently, the area under less water consuming greengram crop increased from 0.14 ha in model HS_1 to 0.22 ha in model HS_2. The cropping intensity remained the same as in model HS_1.

The cropping pattern suggested by model HS_2 resulted in the realization of Rs. 49, 957.13 as net farm returns. The net farm returns were increased by 16,769.34 over the existing plan.

The impact of 20 per cent decrease in the water supply was analyzed through model HS_3. On *kharif* irrigated land, groundnut, sugarcane and brinjal occupied the same area as in the previous optimal models. Due to less availability of irrigation water, the area under paddy (1009) decreased by 0.11 ha over model HS_2. However, the plan suggested to increase the area from 0.17 ha in model HS_2 to 0.28 ha to produce sunflower. Paddy occupied 20.41 per cent of the *rabi* irrigated land. There was no change in the allocation of area for chillies (0.10 ha). The plan suggested decreasing the area under cotton from 0.25 ha in model HS_2 to 0.09 ha in model HS_3. The area under green gram increased from 0.22 ha in model HS_2 to 0.39 ha. Sugarcane continued in the *Rabi* season with the same extent of land as in *kharif*. Cowpea and gingelly did not enter this plan also.

There was no change in the cropping intensity (200 per cent) though the irrigation water availability reduced by 20 per cent. The farmers were able to realize Rs. 48, 592.51 as net farm returns.

The programming model with 30 percent decrease in water supply (Model HS_4) resulted in different cropping pattern from that of previous models. This model suggested to allocate minimum area (0.20 ha) to produce paddy in each season. Groundnut and brinjal occupied the same area on *kharif* irrigated land as in the previous models. The plan indicated to double the area under the production of sunflower compared to the existing situation. Due to shortage of irrigation water, the model suggested to reduce the area for sugarcane from the 0.20 ha in the previous optimal models to 0.13 ha, leaving 0.12 ha of *kharif* irrigated land to be uncultivated. More than half of the *rabi* cultivated area was occupied by green gram. Chillies entered the plan with the same acreage as in the previous models. Cotton, which was in model HS_1, HS_2 and HS_3, was eliminated in this model (Bhatia and Rana 2020).

The cropping intensity declined from 200 per cent in model HS_3 to 187.76 per cent in model HS_4. The cropping pattern suggested by the model HS_4 helped small farmers of head region to realize Rs. 43, 763.25 as net farm returns.

Large Farms. Model HL_1, which was designed with currently available water suggested to increase the area to produce paddy (1009), groundnut, sugarcane and brinjal from 0.61, 0.24, 0.18 and 0.06 ha in the existing plan to 1.08, 0.40, 0.50 and 0.20 ha in the optimal plan respectively during *kharif*, eliminating less remunerative enterprises *viz.,* paddy (1001), sunflower (morden variety) and bajra. Also, this plan showed marginal decrease in sunflower area (hybrid) from 0.30 ha in the existing plan to 0.25 ha in optimal plan HL_1. On irrigated land in *rabi*, the plan indicated to increase the area of commercial crops like cotton and chillies and pulse crop namely green gram from the current level and thus occupied 0.60 ha, 0.30 ha and 0.56 ha respectively by the above-mentioned crops. However, the area of paddy declined from 0.68 ha in the current plan to 0.47 ha. The model did not favour the inclusion of cowpea and gingelly. Sugarcane continued to occupy the same area as in *kharif*.

The cropping intensity increased from 170.37 per cent in the existing plan to 200 per cent in the model HL_1

due to complete utilization of land resource. The net farm returns were higher by Rs. 32, 698.84 over the existing plan.

The optimum model HL_2 (10 per cent decrease in water availability) suggested same crops with changes in the acreage as in model HL_1. During *kharif*, groundnut, sugarcane and brinjal occupied the same area as in model HL_1. The model indicated to double the area under the production of sunflower (Hybrid) and to reduce the area from 1.08 ha in model HL_1 to 0.80 ha in model HL_2 to produce paddy. Due to inadequate water availability, paddy enters the plan with the reduction in the acreage by 0.15 ha over the optimum model HL_1, during *rabi* season. As a result, the area under the production of green gram, which requires less water increased to 0.71 ha. Cotton and chilies occupied the same area as in the previous model. Sugarcane continued to occupy the same area as in *kharif* season.

The cropping intensity remains the same as in the optimum model HL_1, though there was less water availability. The net farm returns and net farm returns per hectare of cultivated area were Rs. 1, 06,775 and Rs. 43, 940.33 respectively.

The resource optimization model with 20 per cent decrease in the water availability (HL_3) recommended the same acreage to produce groundnut (0.40ha), sugarcane (0.50 ha) and brinjal (0.20 ha) as in the previous models during *kharif*. However, it indicated drastic reduction in the area for paddy production from 1.08 ha in HL_1 and 0.80 ha in HL_2 to 0.51 ha on account of less water availability. Sunflower, which requires less irrigation water, appeared with more acreage in this plan. Its area increased from 0.25 ha in HL_1 to 0.82 ha in HL_3.During *Rabi*, the model suggested to reduce the area for paddy by 50 per cent over the previous model. Consequently, the area for green gram increased from 0.71 ha in HL_2 to 0.87 ha in HL_3. There was no change in the allocation of land to produce cotton and chillies.

The cropping intensity remained the same as in the previous optimum models. The crop mix suggested by HL_3 enabled the farmers realize a net farm returns of Rs. 1, 06,544.

The results of optimum model HL_4 designed with 30 per cent decrease in the availability of irrigation water suggested to grow fewer crops compared to the previous plans. Sunflower (hybrid) emerged as the most significant enterprise with acreage of 1.30 ha occupying 53.50 per cent of the *kharif*-irrigated land due to shortage of irrigation water availability. The remaining 46.50 per cent of *kharif*-irrigated land was allocated to produce paddy (13.17 per cent), groundnut (16.46 per cent) and sugarcane (16.87 per cent). During *rabi*, 59.26 per cent of the land was occupied by green gram followed by chillies (12.35 per cent) and paddy (11.52 per cent). Sugarcane continued to occupy the same area as in *kharif*. Brinjal and cotton found in the existing as well as in the previous optimum plans were eliminated.

The cropping intensity was 200 per cent due to complete land use both in *kharif* and *rabi* season despite decline in the water availability by 30 per cent.

The results of optimum model HL_4 revealed that it was possible for the large farmers in the head region to get a net farm income of Rs. 1, 01,871.

Optimum Plans for Middle region. The details of the crop mix in the existing and optimum plans of small and large farmers under middle region are presented in Table 2.

Small farms. The reorganization of resources with the existing irrigation water availability (MS_1) suggested to increase the area for paddy, groundnut, and sugarcane from 0.18, 0.08 and 0.15 ha in the current plan to 0.48, 0.20 and 0.20 ha in optimum model MS_1 during *kharif*. As a result, the area under sunflower (morden) declined from 0.12 ha in the existing plan to 0.06 ha. Also, bajra and paddy (1001) found in the existing plan were eliminated.

The model recommended to allocate more land for cotton and chilies by eliminating cowpea, green gram and gingelly which were grown in the existing production programme. Consequently, the area under the production of cotton and chillies during *Rabi* increased from 0.15 and 0.05 ha in the existing plan to 0.41 and 0.15 ha respectively. But the area for paddy declined from 0.32 ha in the existing plan to 0.18 ha. Sugarcane continued to occupy the same area as in *kharif* season.

The cropping intensity increased from 185.11 per cent in the existing plan to 200 per cent in model MS_1. The crop mix suggested by Model MS_1 helped in realization of Rs. 46, 868.55 as net farm returns.

The optimum model developed by decreasing 10 per cent of water supply resulted in the same cropping pattern as that of optimum plan MS_1 except decrease in paddy area from 0.48 ha in MS_1 to 0.37 ha and increase in sunflower area from 0.06 ha in MS_1 to 0.17 ha. There was no change in groundnut area (0.20 ha) and sugarcane (0.20) during *kharif* season. Cotton which occupied 0.41 ha in model MS_1 was eliminated from the plan, yielding its area to cowpea (0.26 ha) and green gram (0.10). There was a marginal increase in the paddy area from 0.18 ha in MS_1 to 0.23 ha. However, chillies occupied the same acreage as in MS_1.

The cropping intensity remained the same as in model MS_1. The cropping pattern suggested by model MS_2 resulted in the realization of Rs. 45, 933.67 as net farm returns. The net farm returns were increased by Rs. 14, 216.91 over the existing plan.

The impact of 20 per cent decline in the water supply was analyzed through model MS_3. This plan suggested to reduce the area of paddy and sugarcane from 0.37 and 0.20 ha in model MS_2 to 0.34 and 0.08 ha respectively during the *kharif* season due to scarcity of

irrigation water. As a result, the area of sunflower almost doubled. The area under the production of groundnut remained the same as in the previous optimum plans. During *rabi*, the plan suggested to increase the area of green gram from 0.10 ha in MS_2 to 0.44 ha by eliminating cowpea, which found in MS_2 with 0.26 ha. There was a slight increase in paddy area over MS_2. Chillies continued to occupy the same area as in the previous models.

The crop mix recommended by the model MS_3 enabled the small farmers of middle region to realize Rs. 40,658.25 as net farm returns.

The optimum plan developed with 30 per cent decrease in the water availability (Model MS_4) included the same crops as in the previous model with changes in the allocation of land resource. The area to produce sunflower was declined drastically from 0.32 ha in MS_3 to 0.09 ha, keeping 0.23 ha of *kharif* irrigated land fallow due to paucity of irrigation water. Also, the area of sugarcane was declined from 0.08 ha in MS_3 to 0.04 ha. The proportionate area under paddy increased from 36.17 per cent in MS_3 to 40.43 per cent in MS_4.About 56 per cent of the *rabi* irrigated land was occupied by green gram followed by paddy (23.40 per cent) and chillies (15.96 per cent).

The cropping intensity dropped from 200 per cent in the previous optimum plans to 175.53 per cent in MS_4 due to under use of 0.23 ha of *Kharif* land. The net farm returns were higher by Rs. 3, 165.12 over the existing plan.

Large Farms. The optimum farm plan ML_1 developed for the large farmers of middle region suggested to increase the area under paddy (1009), groundnut and sugarcane from 0.53, 0.19 and 0.26 ha in the existing plan to 0.67, 0.60 and 0.60 ha respectively. The process of reallocation of land resource resulted in the decline of land use for sunflower (Hybrid) from 0.28 ha in the existing plan to 0.22 ha and the elimination of paddy (1001) and sunflower (morden variety).During *rabi*, the plan recommended to increase the area of cotton, chillies and cowpea from the present level of 0.38, 0.12 and 0.09 ha to 0.60, 0.40 and 0.36 ha by eliminating green gram and gingelly and by drastically reducing area of paddy from 0.53 ha in the current plan to 0.13 ha. Sugarcane continued to occupy the same area as in *kharif*.

The cropping intensity increased from 177.51 per cent in the existing plan to 200 per cent due to complete utilization of land in both the season. The present income of Rs. 71, 489.29 ha increased to Rs. 99, 199.60 indicating an increase of 38.76 per cent over the existing plan.

The optimum model ML_2 (10 per cent decrease in water availability) suggested almost the same cropping pattern as that model ML_1 during *kharif*. During *Rabi*, paddy was favored in 0.14 ha, maintaining the same area for chillies as in optimum plan ML_1. The plan indicated to reduce the area of cotton by 0.26 ha over the model ML_1 and eliminated cowpea. Consequently, green gram which did not enter the previous optimal plan appeared in this plan with 0.61 ha.

There is no change in the intensity of cropping between ML_1 and ML_2 but net farm returns declined from Rs. 99, 199.60 in optimum plan ML_1 to Rs. 96, 404 in optimum model ML_2.

The optimum model ML_3 recommended reducing the area of paddy and sugarcane from 0.66 and 0.60 ha in model ML_2 to 0.55 and 0.40 ha due to decrease in the water availability by 20 per cent. As a result, the area under the production of sunflower increased from 0.23 ha in the optimum plan ML_2 to 0.54 ha. Groundnut maintained the same area as in previous optimum models. During *rabi*, the plan recommended the expansion of area from 0.61 ha in ML_2 to 1.04 ha for green gram. This plan did not favour the inclusion of cotton. The area under paddy showed an increase from 0.14 ha in the previous optimum plan to 0.25 ha. The plan also favoured the same area as in the previous optimum plans for chillies. The intensity of cropping was 200 per cent. This normative plan helped the large farmers of middle region to realize Rs. 87, 284.00 as net farm returns.

The optimum model ML_4 favored the extension of area under sunflower from 0.54 ha in ML_3 to 0.88 ha, by reducing area of sugarcane to the extent of 0.29 ha over the ML_2. There was no change in the allocation of land for groundnut production and it remained the same as in the previous models. Half a hectare of land was allotted for paddy production during *kharif*. Sixty-one per cent of the *Rabi* irrigated land was occupied by green gram followed by chilies (19.4 per cent) and paddy (14.35 per cent) sugarcane occupied the same area as in *kharif*.

The reduction in the water availability by 30 per cent over the existing level did not result in underutilization of land resource either in *kharif* or *Rabi*. Hence, the intensity of cropping remained the same as in the previous normative plans. The optimization plan resulted in the realization of Rs. 76, 873.03 as net farm income.

Optimum plans for Tail region. The details of the crop mix in the existing and optimum plans of small and large farmers under tail region are presented in Table 3.

Small farms. Model TS_1 included fewer activities compared to the existing plan. The plan suggested increasing the area of groundnut and brinjal from 0.12 and 0.05 ha in the existing plan to 0.36 and 0.40 ha in optimal plan TS_1 respectively during *kharif* season. As a result, land allotted for paddy declined from 0.58ha in the existing plan to 0.17 ha in the model TS_1. Also, sunflower was eliminated from the plan.

On *Rabi* irrigated land, paddy, cotton and green gram occupied 0.23, 0.40 and 0.30 ha respectively. The area

under cotton and green gram increased by 0.29 and 0.12 ha while that of paddy decreased by 0.19 ha respectively over the existing plan. The plan did not favour the inclusion of gingelly.

Due to complete utilization of land in both the seasons, the cropping intensity increased from 192.47 per cent in the existing plan to the maximum attainable level of 200 per cent in the model TS_1. The net farm returns were higher by Rs. 13, 674.28 over the existing plan.

Model TS_2 was designed at 10 per cent decrease in the water availability in both the seasons. In this plan, there was a marginal decline in the area for groundnut production, which was offset by increase in the area of paddy to the same extent. Paddy and groundnut occupied 0.23 and 0.30 ha respectively. Brinjal maintained the same area as in Model TS_1 on *kharif*-irrigated land. The allocation of land for *Rabi* paddy declined from 0.23 and 0.17 ha while that of green gram increased from 0.30and0.36 ha between models TS_1 and TS_2. Cotton occupied one acre of *Rabi* irrigated land. The intensity of cropping remained the same as in model TS_1. The net farm returns increased from Rs. 28, 054.68 in the existing plan to Rs. 41, 406.22.

The optimum model TS_3 suggested crop activities like that of model TS_2 with slight decrease (0.05 ha) in the area for paddy and by the same extent of increase for the production of groundnut over the model TS_2 during *kharif*. Green gram, a predominant pulse crop of the study area occupied about 65 per cent of *Rabi* irrigated area followed by paddy (23.66 per cent) and cotton (11.83 per cent). It is important to note that cotton area declined by 72.50 per cent over the previous optimum models. The plan did not exhibit any change in the intensity of cropping. The net farm returns were increased from Rs. 28, 054.68 in the existing plan to Rs. 39, 820.15.

The results of normative plan TS_4 recommended for the complete elimination of brinjal during *kharif* and cotton during *Rabi* which were found not only in the existing plan but also in all the previous optimum plans. This might be due to scarcity of irrigation water. There was not much variation in the allotment of land resource for other crop activities except a significant increase in the area of groundnut from 0.35 ha in model TS_3 to 0.63 ha during *kharif* and an increase of 0.12 ha for the production of green gram during *rabi* over the model TS_3.The cropping intensity declined from 200 per cent in the previous optimum model to 188.17 per cent due to underutilization of *kharif* irrigated land 0.11 ha. However, the small farmers of tail region realized Rs. 35, 229.73 as net farm returns.

Large farms. The optimum model TL_1 recommended to increase the area under paddy (1009), groundnut and brinjal from 0.52, 0.28 and 0.11 ha in the current production programme to 1.11, 0.60 and 0.30 ha respectively by eliminating paddy (1001) and sunflower during *kharif* season. On *rabi* irrigated land, paddy, cotton, and green gram occupied 0.40 and 0.88 and 0.73 ha respectively indicating a decrease of 0.10 ha in the case of paddy and an increase of 0.52 and 0.35 ha under cotton and green gram respectively over the existing plan. The plan did not favour the inclusion of less remunerative gingelly crop. The process of optimization led to complete utilization of land in both the seasons, and this resulted in the increase of cropping intensity from the 176.12 and 200 per cent. The production programme indicated by the model TL_1 helped the large farmers of tail region to realize Rs. 70, 713.59 as net farm returns exhibiting an increase of Rs. 21,187.30 over the existing plan.

Model TL_2 suggested a different crop mix from that of model TL_1 by including sunflower (Hybrid) on 0.23 ha. As a result, the area under paddy declined by 20.72 per cent over the model TL_1. Groundnut and brinjal occupied the same area as in model TL_1 during the *kharif*. Green gram occupied more than 50 percent of *rabi* land followed by cotton (28.36 %) and paddy (19.90 %). The cropping intensity remained the same as in model TL_1. The net farm returns were increased by 36.56 per cent over the existing plan.

The normative plan TL_3 suggested allocating the same extent of land resource as in the previous optimal plans to produce groundnut and brinjal during *kharif* and paddy during *Rabi*. However, it recommended increase in sunflower area (hybrid) by 0.23 ha while reducing the area of paddy by the same extent over the model TL_2 during *kharif*. Similarly, during *Rabi*, the area under cotton declined by 0.31 ha leading to increase in the area of green gram by the same magnitude over model TL_2. The cropping intensity was 200 per cent. The net farm returns increased from Rs. 49,526.29 in the current plan to Rs. 64,556.52 an increase of Rs. 15,030.23.

The optimum model TL_4 indicated to keep 0.31 ha of *kharif* land and 0.09 ha of *Rabi* land as fallow and this resulted in decline in the cropping intensity by 20 per cent over models TL_1, TL_2 and TL_3. This was due to shortage of water supply to the extent of 30 per cent over the existing water availability.

The model did not favour any alteration in the level of production of groundnut and brinjal during *Kharif* and paddy during *Rabi*. The area under paddy and sunflower declined from 0.65 ha and 0.46 ha in model TL_3 to 0.60 ha and 0.20 ha in model TL_4 respectively during *kharif*. Due to paucity of irrigation water, green gram a less water consuming crop occupied 75 per cent of the *rabi* land. The crop mix suggested by the model enabled the large farmers of tail region to realize Rs. 57, 897.70 as net farm returns.

The entire study related to cropping pattern in existing and optimum plans is in tune with (Nadda *et al.,*1978; Nagaraja and Venkatraman 1983; Parasurama Reddy *et al.,* 1989; Tilekar and Nimbalkar 2000).

Table 3: Cropping pattern of different optimum plans under middle region – small farmers and Large Farmers.

Crop	Existing Plan		MS1	ML1	MS2	ML2	MS3	ML3	MS4	ML4
	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
***Kharif* irrigated land Area (ha)**										
Paddy (1001)	0.32	0.63	-	-	-	-	-	-	-	-
Paddy (1009)	0.18	0.53	0.48	0.67	0.37	0.66	0.34	0.55	0.38	0.50
Sunflower (morden)	0.12	0.20	0.06	-	0.17	-	0.32	-	0.09	-
Sunflower (Hybrid)	-	0.28		0.22		0.23		0.54		0.88
Groundnut	0.08	0.19	0.20	0.60	0.20	0.60	0.20	0.60	0.20	0.60
Bajra	0.09	-	-	-	-	-	-	-	-	-
Sugarcane	0.15	0.26	0.20	0.60	0.20	0.60	0.08	0.40	0.04	0.11
Fallow	-	-	-	-	-	-	-	-	0.23	-
Total	0.94	2.09	0.94	2.09	0.94	2.09	0.94	2.09	0.94	2.09
***Rabi* irrigated land Area (ha)**										
Paddy (Molagulakulu)	0.32	0.53	0.18	0.13	0.23	0.14	0.27	0.25	0.22	0.30
Cotton	0.15	0.38	0.41	0.60	-	0.34	-	-	-	-
Chillies	0.05	0.12	0.15	0.40	0.15	0.40	0.15	0.40	0.15	0.40
Cowpea	0.04	0.09	-	0.36	0.26	-	-	-	-	-
Greengram	0.04	0.11	-	-	0.10	0.61	0.44	1.04	0.53	1.28
Gingelly	0.05	0.13	-	-	-	-	-	-	-	-
Sugarcane	0.15	0.26	0.20	0.60	0.20	0.60	0.08	0.40	0.04	0.11
Fallow	0.14	0.47	-	-	-	-	-	-	-	-
Total	0.94	2.09	0.94	2.09	0.94	2.09	0.94	2.09	0.94	2.09
Cropping intensity (%)	158.11	177.51	200	200.00	200	200.00	200	200.00	175.53	200.00
Net Farm Returns (Rs.)	31716.76	71489.29	46868.55	99199.60	45933.67	96404.00	40658.21	87284.00	34881.88	76873.03
Net Farm Returns per hectare of cultivated area (Rs.)	33741.23	34205.40	49860.16	47463.92	48865.61	46126.32	43253.41	41762.68	37108.38	36781.35
Irrigation water available (ha-cm)	177	360.00	177	360.00	159.3	324.00	141.6	288.00	123.9	252.00
Water used (ha-cm)	175	360.00	177	340.58	159.3	324.00	141.6	288.00	123.9	252.00
Cash used (Rs.)	17832.67	45369.88	15311.68	54429.33	14659.44	53018.53	12806.25	49341.30	11035.65	44216.63

Table 4: Cropping pattern of different optimum plans under tail region – small farmers and large farmers.

Crop	Existing Plan		TS1	TL1	TS2	TL2	TS3	Tl3	TS4	TL4
	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
***Kharif* irrigated land** Area (ha)										
Paddy (1001)	0.58	0.62	0.17	-	0.23	-	0.18	-	0.19	-
Paddy (1009)	-	0.52	-	1.11	-	0.88	-	0.65	-	0.60
Sunflower (Hybrid)	-	0.27	-	-	-	0.23	-	0.46	-	0.20
Sunflower (morden)	0.18	0.21	-	-	-	-	-	-	-	-
Groundnut	0.12	0.28	0.36	0.60	0.30	0.60	0.35	0.60	0.63	0.60
Brinjal	0.05	0.11	0.40	0.30	0.40	0.30	0.40	0.30	-	0.30
Fallow	-	-	-	-	-	-	-	-	0.11	0.31
Total	0.93	2.01	0.93	2.01	0.93	2.01	0.93	2.01	0.93	2.01
***Rabi* irrigated land Area (ha)**										
Paddy (Molagulakulu)	0.42	0.50	0.23	0.40	0.17	0.40	0.22	0.40	0.21	0.40
Cotton	0.11	0.36	0.40	0.88	0.40	0.57	0.11	0.26	-	-
Greengram	0.18	0.38	0.30	0.73	0.36	1.04	0.60	1.35	0.72	1.52
Gingelly	0.15	0.29	-	-	-	-	-	-	-	-
Fallow	0.07	0.48	-	-	-	-	-	-	-	0.09
Total	0.93	2.01	0.93	2.01	0.93	2.01	0.93	2.01	0.93	2.01
Cropping intensity (%)	192.47	176.12	200	200.00	200	200.00	200	200.00	188.17	180.09
Net Farm Returns (Rs.)	28054.68	49526.29	41728.96	70713.59	41406.22	67635.05	39820.15	64556.52	35229.73	57897.70
Net Farm Returns per hectare of cultivated area (Rs.)	30166.32	24639.95	44869.85	35180.89	44522.82	33649.28	42817.37	32117.67	37881.43	28804.83
Irrigation water available (ha-cm)	145	322.00	145	322.00	130.5	289.80	116	257.60	101.5	225.40
Water used (ha-cm)	145	322.00	129.45	322.00	126.93	289.80	116	257.60	101.5	225.40
Cash used (Rs.)	17609.93	41869.95	14099.17	52998.41	13674.16	49916.91	12826.91	46834.47	11873.33	41599.27

SHADOW PRICES

This section presents the shadow prices of selected resources in optimum solution of different models. Shadow prices refer to the marginal value products of the resources. They indicate quantum of change in the net farm returns due to a unit change of that resource ceteris paribus. They are of interest to the decision makers and planners because they indicate the most profitable resources to alter and the maximum amount of each resource that can be used in a particular production process. The shadow prices with positive sign mean that a unit increase in the quantity of resource used would increase the objective function by the amount shown.

Shadow prices would be zero when a resource is not completely utilized because there is no return added for the marginal use of resource, all other conditions remaining the same. However, the marginal value product of resource change if one or more of other conditions change. The shadow prices of selected resources on the small and large farms of head, middle and tail regions are presented in Tables 5-7.

Head Region. The optimization models of small and large farms (except HS4) showed shadow prices for both kharif and rabi irrigated land. This reflected complete use of land resource.

The results of optimal plans designed at 30 per cent reduction in water availability indicated lower shadow prices for kharif and rabi irrigated land as compared to the shadow prices in other optimal plans. This clearly reveals that the profitability of farm business could be increased if the farmers are provided with adequate irrigation of water.

The marginal value productivity of irrigation water was higher during kharif compared to rabi season. The shadow prices of irrigation water in kharif and rabi were the highest in the optimum plan developed with 30 per cent decrease in water availability. The shadow price of irrigation water was higher on small farms compared to large farms and thus reflected higher profitability among small farms for each additional hectare centimeter of irrigation water if it could be made available. It can be inferred that the scarcity of irrigation water was more on the small farms.

Middle Region. The Table 6 showed that, except MS4, all other programming models indicated shadow prices for land resource. The normative plan MS4 showed zero shadow price for kharif irrigated land. The plausible reason for the underutilization of kharif land was shortage irrigation water. The profitability of irrigation water in kharif and rabi was indicated by all the optimal plans.

Table 5: Shadow prices of selected resources on small and large farms under different optimum models - Head Region (Rs.).

Land Resource	Model – HS_1	Model – HL_1	Model – HS_2	Model – HL_2	Model – HS_3	Model – HL_3	Model – HS_4	Model – HL_4
Kharif irrigated land	12064.12	19131.12	12064.12	19131.12	10231.18	19131.12	-	4875.38
Rabi irrigated land	14366.20	13588.00	14366.20	13588.00	13560.22	13588.00	10686.21	8519.29
Kharif Irrigation water	79.14	8.98	79.14	8.98	144.14	8.98	371.50	325.78
Rabi Irrigation water	32.67	1.48	32.67	1.48	64.91	1.48	227.87	204.23

Table 6: Shadow prices of selected resources on small and large farms under different optimum models - Middle Region (Rs.).

Land Resource	Model – MS1	Model – ML1	Model – MS2	Model – ML2	Model – MS3	Model – ML3	Model – MS4	Model – ML4
Kharif irrigated land	16345.93	17674.96	5261.12	9969.32	1193.29	4106.40	--	4106.40
Rabi irrigated land	16498.88	8972.49	8068.33	5322.44	6621.99	3237.85	5910.21	3237.85
Kharif Irrigation water	33.10	-	279.43	171.23	369.83	301.52	396.34	301.52
Rabi Irrigation water	1.09	74.76	188.66	190.42	246.52	273.81	274.99	273.81

Table 7: Shadow prices of selected resources on small and large farms under different optimum models - Tail Region (Rs.)

Land Resource	Model – TS_1	Model – TL_1	Model – TS_2	Model – TL_2	Model – TS_3	Model – TL_3	Model – TS_4	Model – TL_4
Kharif irrigated land	20950.64	8559.61	20950.64	8559.61	14190.81	8559.61	--	--
Rabi irrigated land	13907.38	10086.67	13907.38	10086.67	11503.89	10086.67	6458.26	--
Kharif Irrigation water	-	37.51	-	37.51	150.22	37.51	465.57	227.12
Rabi Irrigation water	46.10	171.13	46.10	171.13	142.24	171.13	344.07	574.60

Tail Region. From the Table 7, it is observed that the shadow prices were indicated by all the optimum models for kharif and rabi irrigated land except TL4 and TS4 for kharif irrigated land. The profitability of additional unit of irrigation was indicated by all the models (except TS1 and TS2) (Shareef and Murthy 2001; Selvarajan and Subramanian 1981).

CONCLUSIONS

In sum the present study revealed that farmers were operating their farms under conditions of sub-optimality. But the extent of mal allocation of resources was relatively higher on the small farms compared to the large farms. The optimum cropping pattern involved fewer crops, thereby indicating the trend towards specialization. The process of optimization led to increase in the area under high valued crops and thus reducing the number of crops. There is greater scope for increasing the net farm returns and the use of resource services and resources through systematic farm planning under the existing water supply and resource base on the farms of the three regions. The sensitivity analysis with reduced availability of water by 10, 20 and 30 per cent level revealed that the farmer's income could be increased over the existing plan if the normative plans are adopted. The optimum plans developed at 30 per cent reduction in water availability indicated substantial decrease in net farm income. The shadow price of irrigation water was higher on small farms compared to large farms. This implies that additional hectare centimeter of irrigation water for small farmers would be more remunerative.

FUTURE SCOPE

The findings of the study would be very useful to the farmers of the study area to identify the irrationality in existing production patterns and resource use and to suggest appropriate production plans for efficient utilization of scarce resources resulting in increasing net farm income and employment. The study also throws light on future potentialities of increasing net farm income and employment under different levels of water availability.

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