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Er Gautam Verma
RAEO in Agriculture Department (C.G. Govt.) Raipur, Chhattisgarh, India

Er. AP Mukherjee
Associate Professor I.G.K.V. Raipur, Chhattisgarh, India

Dr. MP Tripathi
Professor and Head (SWE) I.G.K.V. Raipur, Chhattisgarh, India

Correspondence
Er Gautam Verma
RAEO in Agriculture Department (C.G. Govt.) Raipur, Chhattisgarh, India

Optimization of conjunctive use of water resources for maximum crop production in Distributory 5 command of Mandhar branch canal in Chhattisgarh

Er Gautam Verma, Er. AP Mukherjee and Dr. MP Tripathi

Abstract
Conjunctive water use refers to simultaneous use of surface water and groundwater to meet crop demand. The conjunctive use of surface water and groundwater resources is one of the important factors to increase the crop productivity under deficit condition. Its main objective is to use available water resources in the best possible manner.

The study was conducted in the command area of distributory no-5 of Mandhar branch canal in Raipur (Chhattisgarh). This area comes under Chhattisgarh plain. Paddy and soybean was the main crops during *kharif* season. But Arhar and urd was also considered in the study as per the livelihood crops for the farmers that are used in their daily food routine. Conjunctive use of water resource had been optimized by using LP problem. The decision regarding the selection of the crop in *kharif* season indicates that to achieve maximum profit under the constraints, paddy should be grown on 3208.36 ha of land out of which 17% for broadcasting and 83% for transplanting method. About 2.82, 0.70, 24 and 3.52% of net sown area would be used for arhar, urd and soybean production respectively to get maximum net profit.

Keywords: conjunctive use, optimization model

Introduction
It has long been recognized that the quantity and availability of the water resources are the limiting factor in the development of most arid and semi-arid region, particularly where industrial, residential or agricultural expansion causes present and future demand to exceed the natural supply. It may also be true in the case of humid areas previously thought to be immune to water shortage problems due to insufficient infrastructure and lack of management strategies.

The conjunctive use of surface water and ground water offers the solution to a large extent. To optimize conjunctive use of water, the best way forward is to concentrate on capacity building of irrigation system managers to improve system management and reshape hydraulic infrastructure of large and small-surface systems. To sustain groundwater use in tube well irrigated areas, enhancing recharge from precipitation and surface water imports is necessary. The distributory 5 of Mandhar branch in Abhanpur block of Raipur (C.G.) was chosen for research purpose due to shortage of ground water for irrigation.

Materials and Methods
Study Area
The study area, distributory no. 05 of Mandhar branch command canal lies between 81º 35' 00'' to 81º 42' 30'' E longitude and 21º 05' 14'' to 21º 08' 05'' N latitude in Raipur district in Chhattisgarh. Gross commanded area of distributory no.5 was 4610 ha and culturable commanded area was 3833 ha. It is one of the distributaries of Mandhar branch canal. It flows through the six villages of Abhanpur block. The Mandhar branch canal releases from Mahanadi main canal at a distance of about 4 km south from Abhanpur block.

The data regarding water releases from Mandhar branch to distributory no.5 is collected from sub-divisional officer, water resource sub-division, Abhanpur (Raipur) State Water Resource Department, Raipur. These data were interpreted to know the water imported from outside the command area through distributory no. 5. (See Table 1).

Table 1: Volume of water in the distributory no. 5 canal during *kharif* season

Years	Discharge (cumec)	No. of days (in the kharif season)	Water availability/day (m^3/day)	Water availability during kharif season (Mm^3)
2006	2.269	102	196041.6	19.996
2007	2.358	107	203731.2	21.799
2008	2.462	105	212716.8	22.335
2009	2.386	115	206150.4	23.707
2010	2.294	108	198201.6	21.405
Average	2.3538	107.4	203368.32	21.848

***Source*:** water resource sub-division, Abhanpur

Linear Programming Approach

Linear programming is a technique for optimizing the allocation of resources subjected to constraints. Linear programming technique has been used to find the optimal cropping pattern for the project area and it has also been effectively used to solve the allocation of input resources such as acreage of land, water, fertilizer and capital to various crops so as to maximize net return. This has been formulated with the assumption that all the groundwater and surface water that can safely be extracted are used for irrigating the field.

The existing water resources in the study area are of two type i.e. surface water and groundwater. For development of efficient conjunctive use system the availability of surface water and groundwater has to be analyzed in quantity. Depending on the cropping system which could provide maximum return from the available resources has to be worked out. Since the land availability and water availability is constant in the study area therefore linear programming is the best method to find out the optimal solution that will give maximum profit in the limited resource. For present study linear programming technique is used. The technique is formulated with linear objective function subjected to linear constraints viz., surface water availability constraints, groundwater potential constraints, area availability constraints and non- negativity constraints.

Productivity, Net Profit and Cost of Production of Crops

For the present study four crops (i.e. paddy, soybean, arhar and urd) of *kharif* season are taken into account. The data regarding cost, profit and productivity of crops grown at farmer field were gathered through survey of the villages by personal interview with Agriculture Development Officer, Abhanpur and through interaction with farmers. It is very clear from the Table 2 that cost of production of arhar is more and net benefit of arhar is also more which is Rs. 39764 Rs/ha. Similarly transplanting system of paddy cultivation give more profit than the broadcasting system of paddy cultivation in the command. Soybean has least cost of production that is Rs. 12344 Rs/ha. Because of the low cost of cultivation soybean is being cultivating by the farmers.

Table 2: Net profit of different crops of Abhanpur

Crops	Cost of Cultivation (Rs/ha)	Market Price (MSP) (Rs/Qt)	Yield (Qt/ha)	Average Yield (Qt/ha)	Net Profit (Rs/ha)
Broadcast system of paddy	17366	1080	30-35	33.5	18814
Transplant system of paddy	18040	1080	50-55	53.5	39740
Soybean	12344	1690	15-20	17.5	17231
Arhar	21036	3200	18-20	19	39764
Urd	16325	3300	12-15	13.5	28225

***Source*:** Based on Interaction with farmers in the study area. Market price is based on minimum support price of Abhanpur Dhan Mandi (2011).

Objective Function

The objective function is to maximize the net return from the command area subjected to resource constraints. The objective function, for the selection of crop during *kharif* season is:-

$$\text{Max } Z = \sum_{i=1}^{n} P_i A_i \ \ldots (3.2)$$

Where,

A_i = Area to be allocated to i^{th} crop (ha)

P_i = Profit from i^{th} crop (Rs/ha)

Constraints

The irrigation requirement of the crops must be fully satisfied during the season from the available surface and groundwater. The total irrigation water applied depends on the area of each crop and depth of irrigation water required by each crops. Maximization of the objective function is subjected to the following two constraints:

(1) Water constraints

The net irrigation requirement of the crop raised in a particular season should not exceed the available water in that area. Therefore if 'V' is the available water in the *kharif* season then,

$$\sum_{i=1}^{n} D_i A_i \leq V \ \ldots (3.3)$$

Where,

D_i = Depth of irrigation water required by i^{th} crop (cm)

A_i = Area to be allocated for i^{th} crop (ha)

V = Total available water resources (ha-cm)

i = 1, 2, 3……..n

(2) Land availability constraints

The total area to be allocated for different crops in any season should be less than or equal to the total available cultivable area. Hence the constraints is imposed as

$$\sum_{i=1}^{n} A_i \leq A \ldots (3.4)$$

Where,

A = Total available land (ha)

Now different cases have been explored for maximization of net profit for the same available resources. Overall economics of distributory no.5 command area was worked out by considering the net profit of chosen crops. Cost of production, yield and market price of different crops are given in above Table 2. These values were used to determine the net profit of the crops. 9 cases are considered for solving the linear programming problem and for getting the most appropriate result.

Result and Discussion

Assessment of Water Resources in the Command Area

Total groundwater availability in the study area during was found to be as 6.43 Mm^3. The total surface water availability was found to be 22.48 Mm^3. In the command area total available water resource was 28.91 Mm^3. The percentage of surface water was 77.76 % and groundwater was 22.24%. It was recognized that in the command area groundwater availability was very less. Farmers will have to depend mostly on to the distributory no 5 canal for the irrigation during *kharif* season.

Optimization of Water Resource

In the study area 4 crops viz. paddy, soybean, arhar and urd were selected for optimizing the conjunctive use of water resources on the basis of maximum net return. Cumulative water availability was 28.91 Mm^3 (289100 ha-cm). It was concluded that a huge amount of canal water was available in the study area (more than 300% as compare to groundwater) for the irrigation purpose. Under these water resources farmers of command area can get more profit as shown in Table 3 considering different cases.

Table 3: Land allocation for different crops (in %) and maximum benefit

Cases	Broadcasting System of Paddy Cultivation	Transplanting System of Paddy Cultivation	Soybean	Arhar	Urd	Maximum Benefit (crores)
	% of Net Sown Area	% of Net Sown Area	% of Net Sown Area	% of Net Sown Area	% of Net Sown Area	
1.	31.56	61.41	7.04	0	0	10.88
2	18.59	74.37	7.04	0	0	11.83
3	18.59	74.37	0.00	6.66	0.35	12.35
4	18.59	74.37	3.52	2.82	0.70	12.07
5	18.59	74.37	3.52	1.76	1.76	12.03
6	0.00	92.96	3.52	1.76	1.76	13.37
7	0.00	92.96	0.00	5.28	1.76	13.65
8	0.00	92.96	0.00	7.04	0.00	13.72
9	18.59	74.37	3.52	0.70	2.82	11.99

It is evident from the above Table 3 that the benefit is very less (10.88 crores only) in the present scenario (case -1) as compare to the other conditions. Thus it is necessary for the farmers of command area to cover more area under transplanting system of paddy cultivation during kharif season for getting more profit.

Thus the feasible result is given by case 4 where profit is 12.07 crores. This profit is one crore more than the profit incurred with current scenario of crop command area. It is easily acceptable by the farmers of the command area. Thus for getting maximum profit, farmers of distributory no.5 command area will have to grow transplanting system of paddy in more than 74% of net sown area. Arhar crop will have to cover 2.8% of net sown area means 97.2 ha of land. Soybean and urd will have to cover an average of 3.5 and 0.7% of net sown area respectively so that the benefit would be maximum. It is also clear from the above table that to get higher profit from available land and water resources, all the crops must be taken by the farmers. This will also ensure their nutritional security.

Table 4: Comparison between present and suggest pattern

Crops Area (ha)	Broadcasting	Transplanting	Soybean	Arhar	Urd
Present Pattern	1089.15	2119.19	243	0	0
Suggest Pattern	641.7	2566.7	121.5	97.3	24.3

Summary and Conclusions

For getting feasible solution Tora optimization system window version-2 has been used. In the existing pattern total profit from these two crops were 10.88 crores. After calculation it was found that for optimum profit, broadcasting method, transplanting method of paddy cultivation, soybean, arhar and urd should be grown on an average of 18.59%, 74.37%, 3.5%, 2.8% and 0.7% of the net sown area respectively. The profit in the suggested pattern was 12.07 crore. Thus profit will rise to 10.9%, showing an increase of Rs. 1.19 crores. Thus 1.19 crores will be the additional income in the same available land and water resources.

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