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Sustainable irrigation planning for JOBAT Command Area using Multi Objective Fuzzy Linear Programming approach

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ABSTRACT

In this study, an irrigation planning model is developed and applied in form of Multi-Objective Fuzzy Linear Programming (MOFLP) approach for crop planning in the command area of the Shahid Chandra Shekhar Azad Sagar (Jobat) in Dhar District of Madhya Pradesh, India. The formation of the MOFLP model is based on different Linear Programming (LP) models and Multi-Objective Fuzzy Linear Programming (MOFLP) models. Here models are used to maximize the Net Benefits (NB) and Crop Production (CP). The cropping patterns giving the best result for the Crop Production and Net-Benefit are different. The Area Under Irrigation is 0 for gram when just Crop Production is optimised. Similarly, when only the Net Benefit is optimised, the Area under irrigation is 0 for sugarcane because of the low value of the benefit coefficient. So, we find Optimal Cropping Pattern for the Crop Production and Net-Benefit by LP and MOFLP at different live reservoir storage.

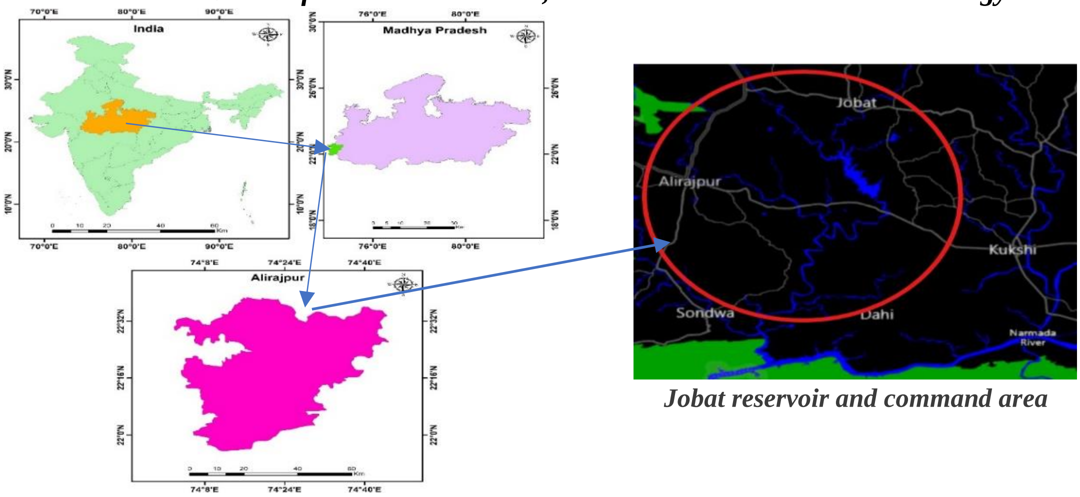
Keywords: *Fuzzy Linear Programming, Water requirement, Crop Production*

1. INTRODUCTION

India is mostly a farming country. Agriculture employs over 70% of the population. In other words, agriculture plays a vital role in the Indian economy. Overall development of the country depends on agriculture, but Water and Land are the resources on which agriculture depends, and management of these limited resources is essential. These issues of land allocation for various crops, crop output maximization, profit maximization, and production cost reduction are all related to agriculture planning. At first, these issues of the agricultural sector were modelled as single objective Linear Programming problems that deal with a single problem at one time. However, with changing scenarios, several objectives need to be solved simultaneously. In this study, it has been attempted to use the multi-Objective fuzzy linear programming (MOFLP) Model to decide conflicting situations while simultaneously planning for different conflicting objectives.

2. STUDY AREA AND DATA

In the present study, the Shahid Chandra Shekhar Azad Sagar (Jobat) irrigation project has been considered for irrigation planning to get optimal cropping patterns using the MOFLP model. The Jobat irrigation project is a medium irrigation project situated in village Waskal, district Alirajpur, about 24 km from Kukshi town. The Jobat Irrigation Project is planned to benefit the drought-prone Area declared by the Government of India and tribal areas of Kukshi Tehsil in Dhar District of Madhya pradesh. The beneficiaries constitute 85% of the tribal population. The Project was started in the year 1989 and completed in the year 2007. The Jobat Command falls in 27 villages of District Dhar. The dam is in Alirajpur District, while the command area is in Dhar District. Jobat irrigation project Geographically, the Area is bounded by the latitude 22'16'50" and longitude 74'35'10". Fig.1 shows the command area of Jobat Dam.



Jobat reservoir and command area

Fig. 1: Study Area Map

The Jobat Dam in Madhya Pradesh is located on Narmada's Hathni tributary. It is one of the Narmada River's 30 dams. It is a composite dam with a height of 34.6 meters. The reservoir has a gross storage capacity of 77.84 million cubic meters (MCM), a live storage capacity of 70.04 MCM, and a dead storage capacity of 7.80 MCM. Dam's catchment area is 792 Km2. The Gross command area is 14122 ha, and the Culturable command area (CCA) is 9848 ha. The Maximum Potential has been achieved as 12507 ha with 127% irrigation intensity. Figure 1 shows the location of Jobat Dam.

2.1 Agricultural Condition

Paddy, soybean, cotton, maize, and peanuts are the major crops in the Kharif season in the Area., and Wheat, gramme, chilli, and vegetables are among the crops grown during the Rabi season. The water has been utilized from the Project for irrigation, primarily in the Rabi season. Cultivation in Kharif season is done majorly on rainwater. Irrigation has been done in the 9848-ha area by the left bank canal of the Project. The designed potential in Kharif season is 5613 ha, and in Rabi season, it is 5909 ha and other perennial 985 ha. So, the total potential is 12507 ha.

2.2 Existing Cropping Pattern

The cropping pattern in the year 2015-16 of the Jobat irrigation project is given in Table 1

Table 1: Crop Pattern and irrigable area (2015-16)

S. No.	Crops Pattern	Percentage	Irrigable Area(ha)
1	Wheat	70	8802
2	Gram	5	629
3	Chilli	15	1886
4	Vegetables/Fruits	10	1258
	Total	100	12575

The cropping pattern in the year 2017-18 of the Jobat irrigation project is given in Table 2

Table 2: Crop Pattern and irrigable area (2017-18)

S. No.	Crops	Percentage	Irrigable Area(ha)
1	Wheat	25	1228
2	Gram	50	2455
3	Chilli	15	736
4	Vegetables/Fruits	10	491
	Total	100	4910

2.3 Average Yield

The average yield of different crops has been considered in the present study from taking yield data from 2011 to 2018 shown in Table-3.

Table 3: Average yield for different crops

S. No.	Name of Crop	Average Yield (Kg/ha)
1	Wheat	3090
2	Gram	1176
3	Chilli	9667
4	Vegetables/Fruits	9667
5	Cotton	1830
6	Sugarcane	3000
7	Maize	3266

2.4 Return per Hectare

Return per hectare has been found by taking the current market price for different crops. For calculating Return per hectare, the value of input cost has been considered 20% of Gross Benefit for each crop. Return per hectare for each crop is shown in Table 4.

$$Net - Benefit = Gross\ benefit - input\ cost\ (20\%\ of\ gross\ benefit) \quad (1)$$

Table 4: Net-Benefit for different crops

S. No.	Name of Crop	Net-Benefit (Rs/Ha)
1	Wheat	54384
2	Gram	37632
3	Chilli	154672
4	Vegetables/Fruits	116004
5	Cotton	67344
6	Sugarcane	9600
7	Maize	44418

2.5 Standard Value of Delta

The Rabi crops considered the standard value of delta value taken in the present study for different crops is shown in Table 5.

Table-5: Average delta for different crops

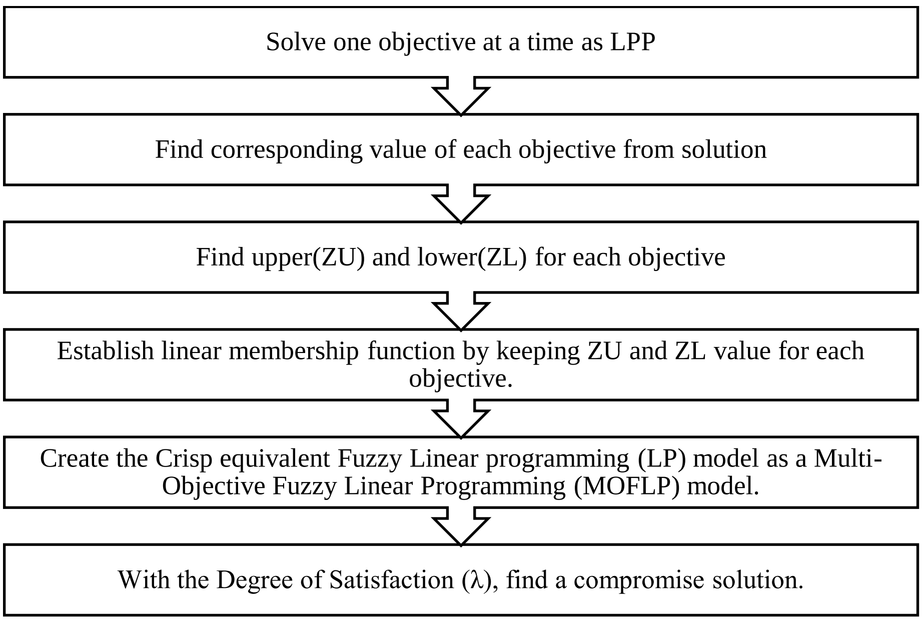
S. No.	Name of Crop	Average Delta(m)
1	Wheat	0.495
2	Gram	0.394
3	Chilli	0.4235
4	Vegetables/Fruits	0.501
5	Cotton	0.45
6	Sugarcane	0.9
7	Maize	0.45

The crop planning for the study area has been done considering the Rabi season (November-March). As under the existing cropping pattern, it is found that water is under-utilized, and we can add some additional crops. To carry out the study, some crops like cotton, sugarcane, and maize are considered in the proposed cropping pattern to develop an irrigation planning model to get the optimum value of crop production and Net -benefit.

3. METHODOLOGY

3.1 Algorithm for Fuzzy Linear Programming

The following Algorithm has been adopted in the present study-



A fuzzy membership function describes fuzzy input data in the Multi-Objective Fuzzy Linear Programming (MOFLP) problem. It is possible to maximise or minimise the fuzzy objective function. The membership function over the tolerance range characterizes the fuzziness of available resources in FLP. In this work, objective functions are treated as fuzzy sets, whereas inflows are treated as deterministic.

3.2 Objective Function and Constraints

In this study, the following two irrigation planning objectives were considered:

1. Maximisation of crop production (CP)

For making crop production function Average Yield of different crops is used.

$$Max\ z1 = \sum Ai * Xi \tag{2}$$

Where Ai = Average Yield of ith crop, and Xi = Area under the i^{th} crop

2. Maximisation of Net Benefit (NB)

For making the Net Benefit function, the Net-Benefit Coefficient for different crops is used.

$$Max\ z2 = \sum NBi * Xi \tag{3}$$

Where, NBi = Net -Benefit coefficient for the ith crop, and Xi = Area under the ith crop

Subject to following constraints as follows:

1. Area
2. Water requirement
3. Affinity constraints
4. Non-negativity

The maximization of CP i.e., maintaining food sufficiency in the region has been thought of in the case of the second objective. At the very least, the region's population can only hope to survive provided enough food is available. Sustainability has been linked to the second objective as a result of this consideration.

The following Table-6 represents the data used for making the Crop production function and Net-benefit function.

Table 6: Crop production function and Net-benefit function

S. no.	Name of Crops	Average Yield (Kg/ha)	Market Price (RS/kg)	Gross- Benefit (Rs/ha) (GB)	Net-benefit (Rs/ha)
1	Wheat	3090	22	67980	54384
2	Gram	1176	40	47040	37632
3	Chilli	9667	20	193340	154672
4	Vegetables/Fruits	9667	15	145005	116004
5	Cotton	1830	46	84180	67344
6	Sugarcane	3000	4	12000	9600
7	Maize	3266	17	55522	44417.6

Based on the above methodology and data, an analysis has been performed using LP and MOFLP Model for different live storage conditions, i.e.,100%, 90%, 80%, 70%, and 60% of live storage, and the result obtained is shown in Fig.2 to Fig.6

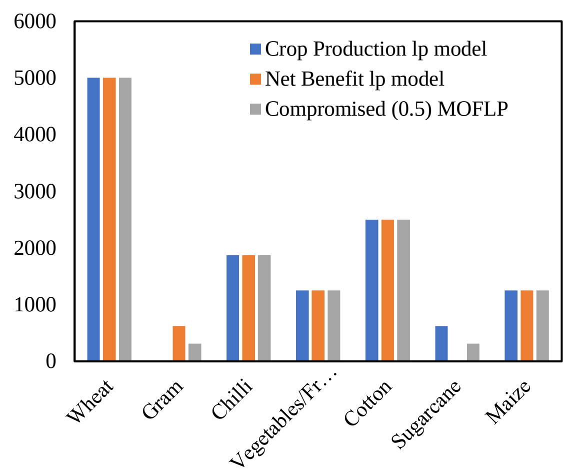


Fig. 2: Bar Chart for 100% Live Storage

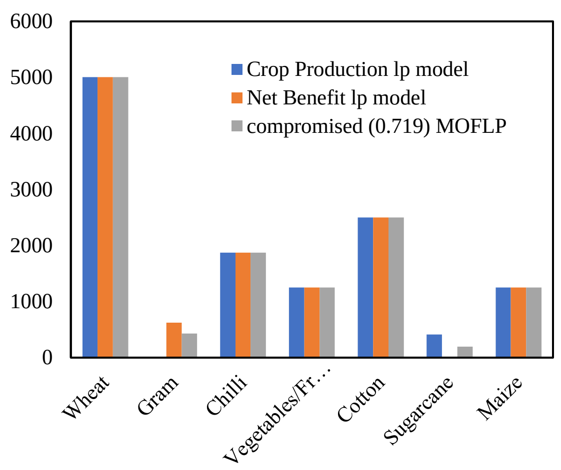


Fig. 3: Bar Chart for 90% Live Storage

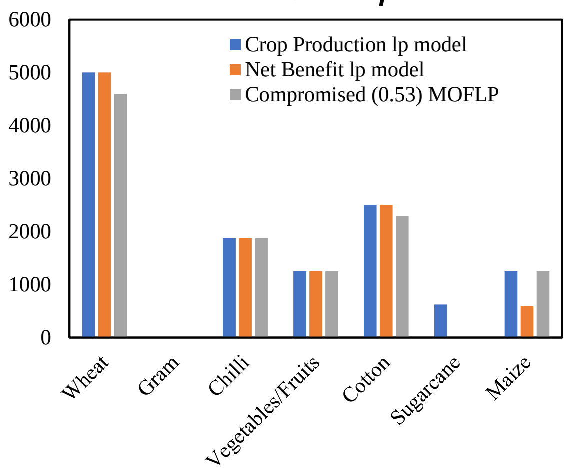


Fig. 4: Bar Chart for 80% Live Storage

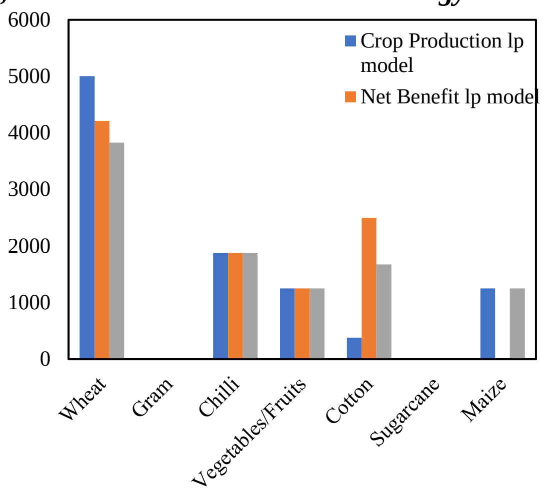


Fig. 5: Bar Chart for 70% Live Storage

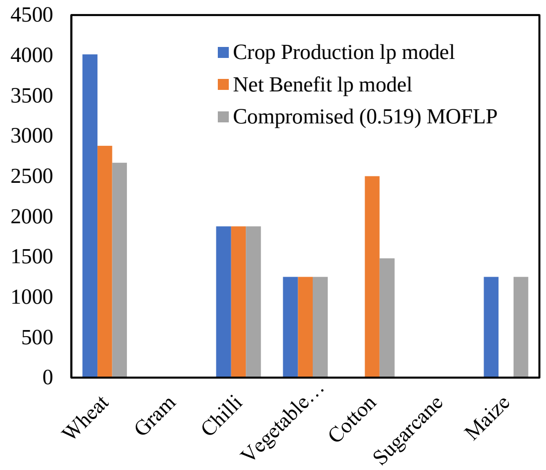


Fig. 6: Bar Chart for 50% Live Storage

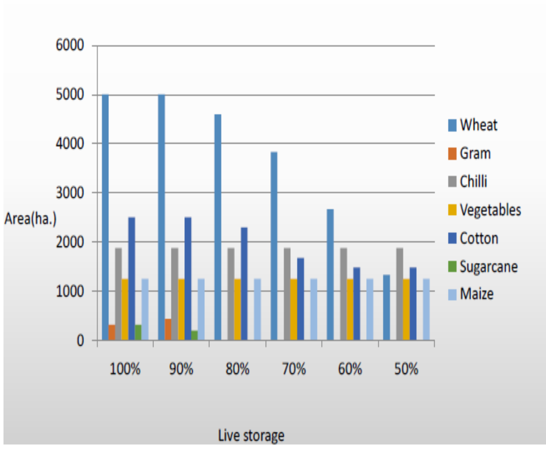


Fig. 7: Optimal Cropping Pattern for various Live Storage

4. DISCUSSION ON RESULTS

The MOFLP models were created for Irrigation Planning in this study to provide an Optimal Cropping Pattern that maximizes two objectives: Crop–Production, and Net-Benefit. The created models were applied to the Jobat Irrigation Project case study. It is observed that at 100% live storage in the LP model and MOFLP model solutions, the irrigated area is constant for Wheat, Chilly, Cotton, Vegetables, and Maize. When crop yield is to be maximised, the area under irrigation is zero for gram. Similarly, because of the low value of the benefit coefficient, the Area under irrigation for sugarcane is 0 when the NB is to be maximised. However, we obtained The Area under irrigation for both crops in a compromised solution. Hence, we can deal with the conflicting situation using the MOFLP model. Fig.7 represents Optimal Cropping Pattern for different Live-Storage.

5. CONCLUSIONS

Based on the analysis performed and the results obtained, it is concluded that This is an integrated approach for irrigation planning. It is found that under the existing cropping pattern, the water has been underutilized. Thus, a revised cropping pattern has been used by considering crops, i.e., cotton, sugarcane, and maize. This study and generated model will aid decision-makers in making judgments in conflicting scenarios when working for many objectives at the same time.

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