Watershed Management in arid and semiarid region by Utility Factor in Fuzzy Environment for deficit Irrigation

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ABSTRACT - The resources planners usually aim at identification or development of possible resources system, design or management plans and evaluation of their economic, ecological, environmental and social impacts. In this, single or combined decisions are sought on selection, sizing, target fixing, operation, capacity expansion, and financial planning etc in respect of a system. Since the late 1950s, system methodology has been successfully used to develop various techniques for solving classical systems planning problems and their extensions and as such many techniques namely, linear programming, nonlinear programming, mixed integer programming, dynamic programming, simulation etc. are being widely used nowadays.

The purpose of present paper is to study the use of modern technology for more and more practical applications in the field of water resources. In the present study a model is developed for maximizing the returns with the associated utilities assigned to each crop by fuzzifying the cost coefficients of each crop. Then optimal cropping pattern which gives maximum returns from the command area under specified constraints, namely Irrigation Intensity and Land is selected. By using, a model optimal cropping pattern is developed for different quantity of available water and farmars will be suggested to cultivate same crops suggested by model to have Maximize Net benefit.

***Keywords**: Optimization, fuzzy Linear Programming, Cropping pattern, Cost coefficient, Utilities, Maximum yield, Membership function, LINGO.*

1.0 INTRODUCTION

The rainfall distribution in India varies over time to time as well as place to place. For any region of country 70% of annual rainfall is received during the monsoon month, June to September and for the rest of period there may be slight rain. The National Water Policy (NWP-1987) suggests that the water resource development projects should be planned and developed. As far as possible, objective project (i.e., multi objective project) with drinking water supply as top priority followed by irrigation, hydropower etc. Application of system engineering techniques to water resources management problems appears to have good potential since it is possible to consider the complex issues with system approach. This methods are not only deals with the engineering aspects of water resources planning and management, but also covers a multi disciplinary approach to consider other relevant factors such as physical, social, economic, political, biological. K.S Raju and D.N Kumar have introduced Multicriterion decision making in irrigation planning. [1]. P. Anand Raj and D. Nagesh[2] Kumar have introduced Ranking alternatives with fuzzy weights for maximizing set and minimizing set. Philippe Debaekea,∗, AbdellahAboudrare, have combined various crop management strategies to cope with water deficit resulting from soil, weather or limited irrigation: drought escape, avoidance or tolerance, crop rationing, irrigation (supplemental, deficit). Simple soil and plant indicators associated with real-time decision support systems is developed to revise the initial management plan by integrating in-season weather information. [3]. S. S. Valunjkar[4]has Optimized water resources for cropping pattern under sustainable conditions through fuzzy logic system by making most efficient use of surface water resources at different reliable flow conditions. D. K. Sharma et al[5]have presented a fuzzy goal programming (FGP) approach for optimal allocation of land under cultivation and proposes an annual agricultural plan for different crops .S. A. Mohaddes and M. Ghazali Mohayidin, developed fuzzy goal programming model [6]. K. P. Gore and R. K. Panda, worked out multi-objective allocation model using fuzzy technique to obtain a compromise alternate plan for better return[7]. J. Soltani et al determined optimum cropping pattern by using Fuzzy Goal Programming (FGP) model and compared with goal programming (GP) and linear programming (LP) models. The cropping pattern of FGP is found to be the best and gave maximum net return.[8].Gomaa et al have done initial investigation of the recent work published in this field involving the mathematical formulation and the computational methods used to solve the resulting models.[9]. Majeke et al [10] have developed a linear programming model to determine the optimal crop combination for a rural farmer. Crop planning involved choices about varieties, planting dates, fertilizer and pesticide treatments. L. Kumari et al have provided a procedure for handling the volatility in profits of vegetable crops using Fuzzy Multi objective Linear Programming (FMOLP) model solved by MS-Excel tool [11] J. Otoo et al[12]have formulated mathematical models like the

LP Model for planning and management of limited resources to have more benefit. R. Shreedhar et al, [13]have formulated multi crop model using LP for maximizing the net benefits, by keeping all other available resources (such as cultivable land, seeds, fertilizers, human power, pesticides, cash etc) as constraints. Osama et al[14] have developed model which proposes a change in the cropping pattern in the old lands of Egypt to increase the gross net return without adding further any other expenses V. Kumar[15]has developed fuzzy linear planning model for optimization of land and water resources. D. Zingaro et al[16]have developed models which pointed out the decoupled payment scheme as the most important driver of change in the crop pattern. M. T. Mellaku et alhave suggested that linear programming-based cropland allocation modeling might be applied to enhance the profit performance of smallholder crop production.[17] M. T. Mellaku et al[18] promoted sustainable utilization of natural and environmental resources. A. K. Karimov et al,have studied a change in cropping patterns produce water savings and social gains. used hydrological modeling with the HYDRUS-1D software package. [19]. R. Sanchis et al have given different solution approaches for the management of the water resources in irrigation water systems with fuzzy costs.[20]. A comparison between different methods was applied in a real water network, reaching a 20% total cost reduction for the best solution. F. Mohammadian and M. Heydari,have appliedfuzzy goal programming to determine the optimal cultivation crops model.[21]. A. Alotaibi and F. Nadeem, [22] have reviewedapplications of linear programming to optimize agricultural solutions. Quantitative methods help farmers plan and make decisions. In LP applications included feed mix, crop pattern and rotation plan, irrigation water, and product transformation. It also highlight the various tools that are central to analyzing LP model results. The review will culminate in a discussion on the different approaches that help optimize agricultural solutions.

2.0 MODEL DEVELOPMENT

The objective of any water resources system is to distribute the water for different purpose optimally. Optimization methods are necessary for planning, design and management of the complex water resource system. Fuzzy set theory is a concept; deals to minimize the uncertainty, vagueness of naturally occurring things. Application of fuzzy set theory in linear programming is an advanced optimization method and is called as fuzzy linear programming.

2.1 Objectives and Assumptions:

The objective of present study is to evolve suitable planning strategy and methodology to achieve optimal utilization of the available resources by Fuzzy linear programming method

1. Modeling for optimal operation plan for a reservoir system under specified constraints namely Irrigation Intensity, Land availability, Socio-economy etc.
2. Modeling for maximizing the associated utilities assigned to each crop by fuzzifying the costs.
3. Modeling for the selection of optimal cropping pattern which gives maximum returns from the command area as well as for obtaining maximum area under cultivation.

In the formulation of the problem the following assumptions have been made.

- Crops are considered to be grown throughout the year. There are three seasons for growing crops i.e., Kharif, Rabi, Summer Rabi.
- The irrigation intensity adopted is 22% in Kharif season, 45% in Rabi season and 28% in Summer Rabi season, H.W. crop 3%, Perennial 4.5% and that becomes a total irrigation intensity of 102.5%.
- Ground water usage is not considered in the command area. Only surface water is used for irrigation.

The Jayakwadi project, Maharashtra is taken as case study to maximize the revenue from the available constraint, i.e., available land, water for irrigation and socio economic constraint. The Jayakwadi project region is suitable for growing 10 crop varieties, recommended by Government of Maharashtra comity appointed in 1976.

2.2 Formulation of the Model

The problem has been formulated as a monthly operational model based on inflows and the operating horizon has been taken as twelve monthly periods from June to May which is generally considered as the water year. The Fuzzy Linear Programming Model (FLPM) has been formulated with all the known quantities on the right hand side of the constraint equations.

Before proceeding with the development of the model, it is necessary to establish a framework within which the goals and priorities of reservoir operations can be represented systematically. For each of the decision variable (crop) two cost coefficients have been found. One is with maximum returns and other is with minimum returns. The cost coefficients have been found as,

$C_{M,i} = a_i\, y_{M,i}\, r_{M,i}$ for I = 1 to 10 ... ... (2.1)

$C_{m,i} = a_i\, y_{m,i}\, r_{m,i}$ for I = 1 to 10 ... ... (2.2)

Where $C_{M,i}$ = maximum cost coefficient of the crop Xi, a_i = maximum area that can be allocated to the crop Xi, $y_{M,i}$ =maximum yielding of the crop Xi (in quintals/hectare), $r_{M,i}$ = high farm gate prices for the grain of Xi th crop (Rs/ quintal), $C_{m,i}$ = minimum cost coefficient of the crop Xi, $y_{m,i}$ =minimum yielding of the crop Xi (in quintals/hectare), $r_{m,i}$ = low farm gate prices for the grain of Xi th crop (Rs/ quintal).

In this model cost coefficients of the objective function are considered to be fuzzy. By fuzzification utilities of all crops can be determined. The utilities of each crop are found by fuzzifying cost coefficients. With these maximizing and minimizing sets, we can define the right utility value, $U_M(X)$, left utility value, $U_m(X)$, and the total $U_T(X)$, of each of fuzzy numbers. They are given by

$U_M(X) = \sup x \{\{ \mu_{ai}(X) \cap \mu_m(X) \}\}$ ... ... (2.3)

$U_m(X) = \sup x \{\{ \mu_{ai}(X) \cup \mu_m(X) \}\}$ ... ... (2.4)

$U_T(Xi) = (U_M(Xi) + \nu - U_m(Xi)) / 2$ ... ... (2.5)

The greater the value of Um (x), the smaller Xi becomes. Therefore, we use (ν-Um (x)) to count the order of membership function. Hence we divide by 2, in order to find the total utility value by means of right and left side order of membership function. In the present study cost coefficients of objective function are considered to be fuzzy. The fuzzified cost coefficients (from utilities) can be found by drawing a line (utility line) parallel to x-axis for corresponding utility value. The value on x-axis corresponding to the intersection point of left limb of member ship function μ_{ai} (X) and the utility line will give minimum value (XiF-min) and corresponding to the intersection point of right limb of membership function and the utility line will give the maximum value (XiF-max).

The objective function of the FLPM is to maximize the gross utility of the crops. The objective function may be stated as,

$$Max \underset{i=1}{\overset{10}{Z}} = UiXi \quad \text{... ....} \quad (2.6)$$

Where Ui = Utility of crop Xi, Xi = Area of i^{th} crop.

Instead of formatting an objective function to maximize gross returns, i.e., instead of taking cost coefficients, utilities of each crop have been taken. The objective value here is overall utility of all crops which have been selected by the model.

2.3 Constraints

The objective function is subjected to the following constraints.

Area allocation constraints

The total area allocated among all the crops should not exceed the culturable land available in the system

$$\sum_{i=1}^{n} Xi \leq A \quad \text{... ....} \quad (2.7)$$

Where Xi = Area in ha of i^{th} crop.

Water allocation constraints

The total water allocated among all crops should not exceed the water availability for irrigation.

$$\sum_{i=1}^{n} \Delta i X i \leq W \quad \ldots \quad \ldots \quad \ldots \quad (2.8)$$

Where Δ i = Water depth in m required for ith crop.

Water availability (continuity) constraints

Table 2.1: **Cost coefficients and Utility of different crops from Crop Water Requirement and Net Value of Agriculture Produce**

Sr. No	Variable	Crop	Season	Max. Allowable area In Ha. From CADA	Min.cost coefficient (million Rs)	Max.cost coefficient (million Rs)	Right Utility	Left Utility	Total Utility
1	X1	Paddy	Kharif	17888	1341.60	2146.56	0.19	0.89	0.15
2	X2	Jowar	Kharif	21458	686.65	1888.30	0.16	0.95	0.11
3	X3	Wheat	Rabi	45717	1645.81	4205.96	0.38	0.86	0.26
4	X4	Jowar	Rabi	26823	858.336	1770.31	0.15	0.93	0.11
5	X5	Gram	Rabi	9022	541.32	1172.86	0.10	0.96	0.06
6	X6	Cotton	T.S.	44717	6707.55	10866.23	1.00	0.39	0.80
7	X7	Chillie	T.S.	5365	150.22	354.09	0.02	1.00	0.01
8	X8	Groundnut	H.W.	5365	354.09	804.75	0.06	0.98	0.04
9	X9	Sugarcane	Perennial	5365	1180.30	1952.86	0.17	0.90	0.13
10	X10	Banana	Perennial	2682	1115.712	2360.01	0.20	0.91	0.15

The minimum, maximum cost coefficients before fuzzification have also been presented in column 1 and 2, right, left, and total utilities are presented in column 3 to 5 and maximum, minimum utilities after fuzzification are presented in column 8 and 9. The maximum utility is found to the crop X6 (0.80) because of highest right utility (1). This is due to highest cost coefficient (10866.23) among maximum cost coefficients. The minimum utility is found to the crop X7 (0.01) because of low right utility of 0.02 and highest left utility of 1.00. To get maximum total utility, right utility should be high and left utility should be low. The total utilities of all crops are very low (<0.25) except the crops X3 and X6 which are having considerably high utilities.

3.0 Result of Fuzzification

In the present study fuzzification is considered in the objective function, i.e., the values of C, cost coefficient have been fuzzified. In the minimizing and maximizing sets the minimum and maximum values of C are 150.22 and 10866.23 respectively Crops which have been selected by the model are presented in table 3.1.

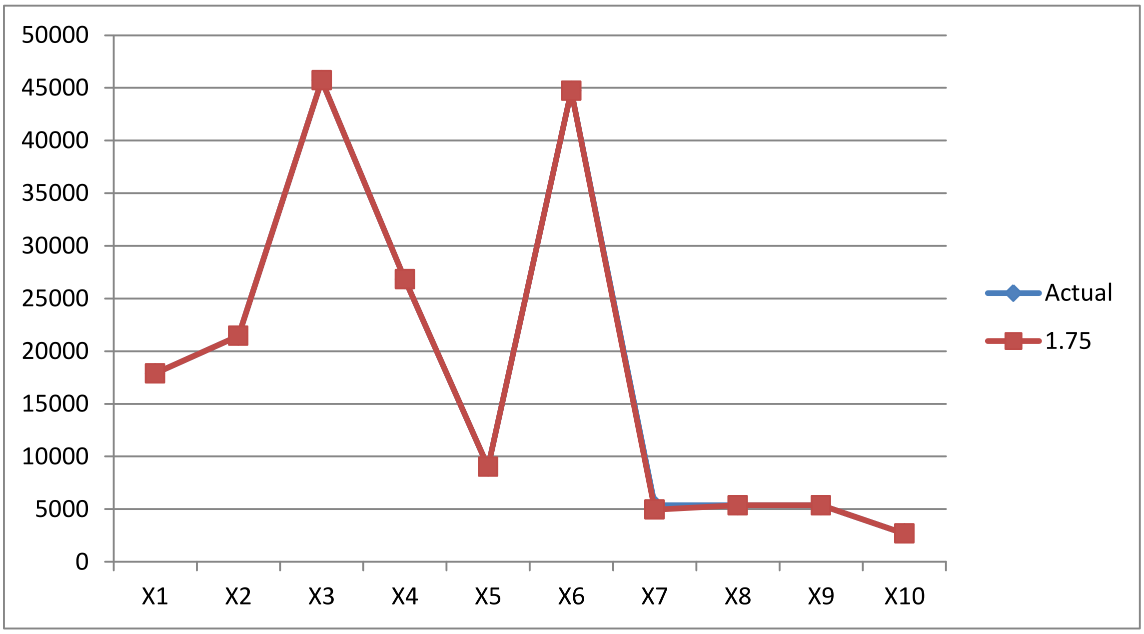
Table 3.1 Cost coefficients and utilities of the crops selected by FLPM

Crop	Min. cost Coeff. (M Rs)	Max cost coeff. (M Rs)	Total Utility	Area Allocated Ha.	Min.cost coeff. (MRs) After Fuzzification	Max.cost coeff. (MRs) After Fuzzification
X1	1341.60	2146.56	0.15	17888	1341.6	2146.56
X2	686.65	1888.30	0.11	21458	686.656	1888.304
X3	1645.81	4205.96	0.26	45717	1645.812	4205.964
X4	858.33	1770.31	0.11	26823	858.336	1770.318
X5	541.32	1172.86	0.06	9022	541.32	1172.86
X6	6707.55	10866.23	0.80	44717	6707	10866.23
X7	150.22	354.09	0.01	4963	138.964	327.558
X8	354.09	804.75	0.04	5365	354.09	804.75
X9	1180.30	1952.86	0.13	5365	1180.3	1952.86
X10	1115.712	2360.01	0.15	2682	1115.712	2360.16
Net Benefit in (Million Rs)				57559		

Table 3.2 Area allocated to crops with Land & Water constaint

water available(MHa Liter)			1.75	1.5	1.3937	1.0	0.75	0.5	0.25	0.10
Variable	**Crop**	Actual area allocated	Area allocated	Area allocated	Area allocated	Area allocated	Area allocated	Area allocated	Area allocated	Area allocated
X1	Paddy	17888	17888	17888	17888	15980	0	0	0	0
X2	Jowar	21458	21458	21458	21458	21458	21458	21458	0	0
X3	Wheat	45717	45717	45717	45717	45717	36410	16879	0	0
X4	Jowar	26823	26823	26823	26823	0	0	0	0	0
X5	Gram	9022	9022	9022	9022	0	0	0	0	0
X6	Cotton	44717	44717	44717	44717	44717	44717	44717	43478	17391
X7	Chillie	5365	4963	0	0	0	0	0	0	0
X8	Grndnut	5365	5365	0	0	0	0	0	0	0
X9	Sugarcan	5365	5365	3091	612	0	0	0	0	0
X10	Banana	2682	2682	2682	2682	0	0	0	0	0
Net Benifit			57559	56999.4	56677.	52417	47600	42522	34782	13913

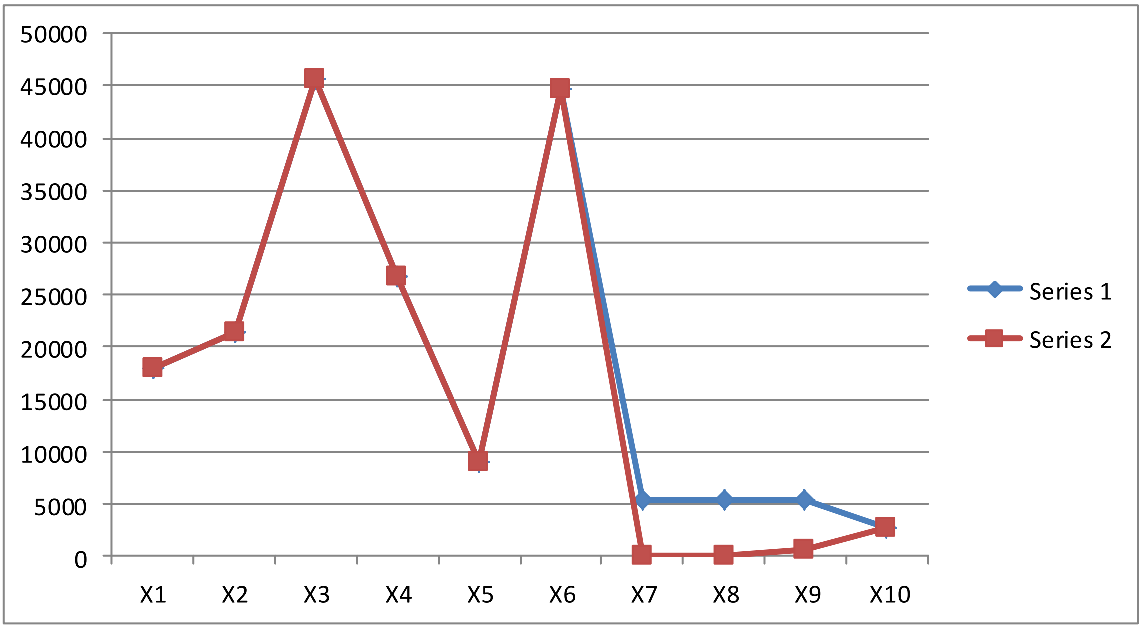
Graph- 3.1 Area Allocated to Crops in record of CADA, Aurangabad and when ample quantity of water is available i. e. 1.75 MHa Liter.



It is found that when ample quantity of water is available i. e. 1.75 MHa Liter the results of Programme run by LINGO software are matching 100% with actual results of Command Area of Development Authority, (CADA), Aurangabad. It is giving only 7 % variation in area for crop X7, so the code which we have written by using LINGO as software Langauge is Justified.

Now we can run the Programme for different quantity of available water.

Graph- 3.1 Area Allocated to Crops in record of CADA, Aurangabad and when water available is1.39 MHa Liter.



Actual surface water available in Jayakwadi Project due to Paithan Left Bank Canal (PLBC) and Paithan Right Bank Canal (PRBC) is 1.39MHa Liter. Which we can call Deficit irrigation . Area allocated due to availability of this water is as shown in graph.

Due to deficit irrigation, to get Maximum benefit from available resourses that is water farmers should not cultivate X7-Chillie, x8- Groundnut and, X9-Sugarcane area get affected.

Net Benefit in (Million Rs) is 56677.40.

CONCLUSIONS

Fuzzy linear programming model is developed for maximizing gross returns from the irrigation project. The approach is applied to Jayakwadi stage I, Maharashtra, India.

1) Gross returns are maximized by FLP. Utility values of fuzzy numbers are determined by using maximizing and minimizing sets (cost coefficients).

- Fuzzy numbers have triangular membership functions. Utility factor of each crop is determined.
- The high utility is 0.80 found to the crop X6 (Cotton) and lowest utility is 0.01 found to the crop X8 (Groundnut).
- To get maximum total utility right utility should be high and left utility should be low.
- The total utilities of all crops are very low (<0.25) except Cotton and wheat.

2) Cropping pattern is maximized using LINGO subjected to the constraints given in the model. With this, maximized cropping pattern is evaluated and gross return is 56677.40 Million Rs.

3) To increase the returns, irrigation intensity should be increased. The availability of water can be increased by diverting water from other sources such as ground water or recycling of water or by using water efficiently with drip, sprinkler or new methods of irrigation.

Acknowledgements

The authors would like to express their sincere thanks to Command Area Development Authority, Aurangabad, Maharashtra State, India for providing necessary data for analysis.

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