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CUSTOMIZED OPTIMAL SALINE RESISTANT CROPPING POLICY: A CASE STUDY

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ABSTRACT

The study area, Nuh is one of the backward regions of Mewat district of Haryana state, India. Agriculture and agro-based dairy & poultry business are back bone of the region's economy. The people of this area are natural agriculturists deprived of proper irrigation. Irrigation canal system of the area depends on Gurgaon canal. This region has the history of salinity and scarcity of potable drinking water. In the present study existing scenario of the study area was analysed in terms of cropping pattern, water use, and net benefits from agriculture. MATLAB based optimization model being proposed to evolve customized optimal saline resistant cropping policy with laying emphasis on maximizing the net benefits, human labour employment generation, and proper utilization of land & water resources. While evolving the cropping policy, saline resistant crops and soil health constraints are also considered. It was concluded that suggested cropping policy proposed to irrigate 37.97 % more area than existing condition. Further it is able to generate 8.62 % more net benefits, 40.15 % higher labour employment (in man days) than that of existing condition.

KEYWORDS: Human Labour, Maximization, Optimization, Salinity, MATLAB

INTRODUCTION

The Nuh region (27° 59′ 30.4″ to 28° 13′ 40.3″ North Latitude and 76° 57′ 20.5″ to 77° 10′ 58.38″ East Longitude) of Mewat district is one of the backward districts of Haryana state, India with inadequate irrigation development, brackish groundwater and low crop productivity. Agriculture and agro-based dairy & poultry business are back bone of the region's economy. The study area has specific characters with a long history of salinity and scarcity of potable drinking water. In this study, an effort has been made to develop an approach based on an optimization model for sustainable management of water resources using technological tool – MATLAB. The proposed model is applied to a region primarily dependent on agriculture that has been striving to compete with others, to evolve sustainable saline resistant optimal cropping policies.

METHODOLOGY

The proposed methodology comprises of a) Identification of requirements of the study area, b) Data acquisition and analysis, c) Development of the model and d) Application of the model to a case study. In the present study MATLAB based optimization model being developed to evolve sustainable saline resisting cropping policy. The developed model is subjected to constraints based on water, land and human resources of the region & agriculture, population and water resources sectors. Nuh region has a long history of salinity and long way back farmers were advised to opt for saline resistant crops. They were also suggested for judicious use of groundwater to safeguard yield of crops and preserve cultivable area of the region. Further it was observed that the optimum yields of crops were obtained from poor quality irrigated soils in the past by adopting better water management policies followed by strict adherence to saline resistant crops and their cropping sequences. The recommended cropping sequences as reported by various researchers (Sharma, 2008; Singh, 2008) for saline soils were pearl millet- barley, pearl millet- wheat, pearl millet-mustard, sorghum-wheat or barley; also paddy-berseem. It was further assessed that this will be helpful in gradual reclamation of soil health as it is a continuous process. Also, it was witnessed that burning mustard residue for local brick kilns of the study area was a serious threat to soil and environment. Awareness needs to be developed to use byproduct of mustard crop for restoration of soil health. Accordingly, constraints based on saline resistant cropping are introduced the model. These details are discussed subsequent sections.

Optimization Model

Linear programming model based on simplex method being used and analyzed through MATLAB. Dantzig et al (1955) rightly asserted that the tremendous power of the simplex method is a constant surprise to me and is till date successfully used by various researchers (Smith, 1973; Sritharan et al, 1988; Rao, 1996; Adibe & Ogbo, 2012; Rao et al, 2013a, 2013b).

Objective Function

The objective function has been formulated for maximizing net benefits and can be written as

$$\textbf{Max (Z)} = \sum_{i=1}^{nc} NR_{j,i} \times A_{j,i} \qquad \text{...(1)}$$

Where

nc = number of crops (=12)

$NR_{j,i}$ = net return from i^{th} crop of j^{th} division

$A_{j,i}$ = area of i^{th} crop of j^{th} division

i.e.

$Z= NR_{1,1}.A_{1,1}+ NR_{1,2}\cdot A_{1,2}+ NR_{1,3}\cdot A_{1,3}+ NR_{1,4}\cdot A_{1,4}+\cdots\cdots\cdots+ NR_{1,12}\cdot A_{1,12}$

$NR_{1,1}$: Net return from 1^{st} crop

$A_{1,1}$: Area of 1^{st} crop

Constraints

- Total water required by all crops shall be less than are equal to total available water in that year
- Total water required by all crops in a particular month shall be less than or equal to total water available in that particular month
- Groundwater draft is always less than groundwater available
- Total irrigated area in Kharif season shall be less than or equal to cultivable area in kharif season
- Total irrigated area in Rabi season shall be less than or equal to cultivable area in Rabi season

- Total available human labour required shall be less than or equal to total human labour available.
- Maximum area under each crop should be such that it shall satisfy storage and marketing requirements of the area
- Total domestic water required (*DWR*) for the population of the region should be less than or equal to total water allocated for domestic water use consumption
- Total water required for livestock water use should be less than or equal to total water allotted for livestock water use consumption
- Total water required for Industrial water use should be less than or equal to total water allotted for Industrial water use consumption
- Sum of cropping areas of Pearl Millet and Sorghum crops are equal to sum of cropping areas of Barley, Wheat and Mustard. i.e.

$$0 \cdot A_1 + 1 \cdot A_2 + 1 \cdot A_3 + 0 \cdot A_4 + 0 \cdot A_5 + 0 \cdot A_6 + 0 \cdot A_7 + 0 \cdot A_8 + 0 \cdot A_9 + 0 \cdot A_{10} + 0 \cdot A_{11} + 0 \cdot A_{12} =$$

$$0 \cdot A_1 + 0 \cdot A_2 + 0 \cdot A_3 + 0 \cdot A_4 + 0 \cdot A_5 + 0 \cdot A_6 + 1 \cdot A_7 + 1 \cdot A_8 + 0 \cdot A_9 + 1 \cdot A_{10} + 0 \cdot A_{11} + 0 \cdot A_{12} \quad \cdots(2)$$

- Cropping area of Paddy equals to cropping area of Berseem i.e.

$$1 \cdot A_1 + 0 \cdot A_2 + 0 \cdot A_3 + 0 \cdot A_4 + 0 \cdot A_5 + 0 \cdot A_6 + 0 \cdot A_7 + 0 \cdot A_8 + 0 \cdot A_9 + 0 \cdot A_{10} + 0 \cdot A_{11} + 0 \cdot A_{12} =$$

$$0 \cdot A_1 + 0 \cdot A_2 + 0 \cdot A_3 + 0 \cdot A_4 + 0 \cdot A_5 + 0 \cdot A_6 + 0 \cdot A_7 + 0 \cdot A_8 + 0 \cdot A_9 + 0 \cdot A_{10} + 1 \cdot A_{11} + 0 \cdot A_{12} \quad \cdots(3)$$

Lower bound of mustard crop is as per food and manure requirement and upper bound has no bounds.

Optimization toolbox of MATLAB provides a function **linprog (**linprog.m) (Mathworks, 2012), which has been used, for analysing the developed optimization LP model. Syntax of LP model (linprog) discussed subsequently (refer table 1).

Linprog

It solves linear programming problems specified by

$$\min_x f^T \cdot x \qquad such\ that \begin{cases} A \cdot x \leq b \\ Aeq \cdot x = beq \\ lb \leq x \leq ub \end{cases} \qquad \ldots(4)$$

Table 1: Details of "Linprog"

A	The matrix of coefficients of linear inequality constraints: $A \cdot x \leq b$
b	Vector of coefficients of corresponding right-side vector: $A \cdot x \leq b$
Aeq	The matrix of coefficients of linear equality constraints: $Aeq \cdot x = beq$
Beq	Vector of coefficients of corresponding right-side vector: $Aeq \cdot x = beq$
f	The vector of coefficients for the linear term in the linear equation $f^T \cdot x$
x	Vector of design variables
lb, ub	Lower and upper bound vectors (or matrices).

ANALYSIS OF EXISTING SCENARIO

FAO (FAO CDR- Training Manual No.3) methodology used for estimating water requirements of crops and thus water required in ha.m computed. Also net returns from each crop and human labour requirements (in man-days) are tabulated in table 3. Two principal crop seasons, K*harif* (monsoon, June-July to October) and *Rabi* (winter, November-March) are practiced in a year. Details of crops of both seasons are also compiled in table 3. An adult labour was assumed to work eight hours a day and twenty-five days a month. One female labour unit was assumed to be equivalent to 0.75 times of male labour unit (Kaur et al, 2010; Kothari, 1999). Existing scenario of the study area in terms of cropping area, corresponding water requirements, net benefits and human labour requirements are computed and tabulated (table 2)

Table 2: Existing Cropping Scenario

Name of Crop	Area (ha)	Water Required (ha.m)	Net Benefits (Million ▪)	Labour (in man-days)	
Paddy	4868	5817.26	133.140	929788	KHARIF
Pearl Millet	4189	1219.00	31.501	502680	
Sorghum	3464	176.66	21.408	439928	
Fodder	6279	678.13	26.937	797433	
Dhaincha	939	206.58	2.797	76998	
Pulses	94	49.35	1.880	7708	
Total	**19833**	**8146.99**	**217.663**	**2754535**	
Barley	349	139.25	7.633	66659	RABI
Mustard	6669	2847.66	103.436	800280	
Tomato	31	21.39	2.668	3937	
Wheat	22873	13723.80	654.854	2904871	
Berseem	611	219.96	2.811	50102	
Rabi Pulses	429	227.37	9.438	35178	
Total	**30962**	**17179.43**	**780.840**	**3861027**	
Grand Total	**50795**	**25326.42**	**998.503**	**6615562**	

ANALYSIS OF MODEL

The proposed MATLAB based optimization model has been subjected to said constraints to evolve customized saline resistant cropping policy. Also sample input details of module 'linprog' has been tabulated (table 3).

Table 3: Input to Optimization Model

$$f = \begin{bmatrix} -27.35 & -7.52 & -6.18 & -4.29 & -2.979 & -20 & -21.87 & -15.51 & -86.08 & -28.63 & -4.6 & -22 \end{bmatrix}$$

$$A = \begin{bmatrix} 1.195 & 0.291 & 0.054 & 0.108 & 0.223 & 0.525 & 0.399 & 0.427 & 0.692 & 0.604 & 0.36 & 0.53 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ 191 & 120 & 127 & 127 & 82 & 82 & 147 & 107 & 228 & 125 & 127 & 72 \end{bmatrix}$$

$$b = \begin{bmatrix} 2565388 & 35927 & 35927 & 20969400 \end{bmatrix}$$

$$lb = [2349;12583;2353;2584;100;1856;279;7000;94;14163;2349;1570];$$

$$ub = \begin{bmatrix} \inf & \inf & \inf & \inf & \inf & \inf & \inf & \inf & 100 & \inf & \inf & \inf \end{bmatrix}$$

$$Aeq = [0\ 1\ 1\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0;\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 0\ 1\ 0\ 0];\ \&\ beq = [30884;30884];$$

lb=[2349;12583;2353;2584;100;1856;279;7000;94;14163;2349;1570];

While running the model optimal solution obtained by varying right-hand side constant (b_{eq}) in such a way so that all inequality and equality constraints are satisfied. Keeping at the same time exitflag (of "linprog" of MATLAB) remained '1' (exitflag=1 means solution optimal). Thus, the proposed policy is customized to suit the needs (in this case saline resistant cropping sequences are incorporated) and accordingly customized cropping pattern is prepared and organized in Table 4.

Table 4: Customized Cropping Pattern Considering Salinity and Soil Health Aspects

Crop Name	Area (ha)	Water Use (ha.m)	Net Benefits (Million ▪)	Labour (man-days)
Paddy	2349	2807.055	64.245	448659
Pearl Millet	12583.00	3661.65	94.624	1509960
Sorghum	15717.00	801.57	97.131	1996059
Fodder	2584.00	279.07	11.085	328168
Dhaincha	100.00	22.00	0.298	8200
Kharif Pulses	1856.00	974.40	37.120	152192
Barley	9721.00	3878.68	212.598	1856711
Mustard	7000.00	2989.00	108.570	840000
Tomato	94.08	64.91	8.098	11948
Wheat	14163.00	8497.80	405.487	1798701
Berseem	2349.00	845.64	10.805	192618
Rabi Pulses	1570.00	832.10	34.540	128740
Total	**70086**	**25653.88**	**1084.601**	**9271956**

RESULTS & DISCUSSIONS

From the analysis of existing scenario it may be estimated that existing condition able to provide employment to 5784 female and 17352 male labourers per day. That is, about 38% female workers were getting employment opportunities from existing cropping pattern. At the same time around 29.7% male workers were able to get employment opportunities from agriculture. Total net benefits from existing cropping pattern are estimated as ▪ 998.503 Million i.e. ▪ 3478 per capita per annum from agriculture by considering the population in 2011. Net benefits from Kharif and Rabi crops are estimated as ▪ 217.663 and ▪ 780.849 Million respectively. With regard to existing water use situation, there exists inconsistency between water required by the crops and water available for the crops affecting dwindling in yields of crops and reduction in actual cropped areas and supplemented salinity. Excess use of groundwater in some months when not required and improper distribution of water when desired were observed. As mentioned earlier, Nuh region has a history of saline groundwater and therefore needs cropping patterns comprising of saline resistant crops. Also, the trend of burning mustard residue in brick kilns is common in the region which in turn has effecting soil health. While comparing the proposed customized saline resistant cropping policy with existing scenario it is observed that suggested policy proposed to irrigate 37.97 % more area than existing condition. Further it is also concluded that it is able to generate 8.62 % more net benefits and 40.15 % higher labour employment (in man days) than that of existing condition. Also it has the ability to negotiate salinity and restoration of soil health aspects of the study area in long-term time horizon. Thus, it is also suggested that residue of mustard shall be used in composting and restoration of soil nutrients.

CONCLUSIONS

It can be concluded from the present study that MATLAB based optimization model is successfully developed and aims at achieving economic development by maximizing net benefits. The model is subjected to different constraints, based on water, land & human resources, to suit the needs and solving problems of the study area. It has the dexterity in analysis and very useful in arriving swift realistic conclusions which shall be helpful to water resources planners and decision makers for different study areas. Thus it can be summarized that the proposed approach has the ability to provide policies that suits the requirements of study areas and accordingly modified policies can be generated.

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