DROUGHT PROOFING MECHANISM IN MAHI COMMAND AREA THROUGH LINEAR PROGRAMMING MODEL - A CASE STUDY

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ABSTRACT

A linear programming (LP) model was developed to formulate optimal cropping pattern for producing minimum food requirement in relation to minimum investment during drought years in Mahi command area. The study revealed that by judiciously using minimum quantum (58.7% of normal usage) of irrigation water in drought years feeding 58% of area grown with optimal cropping pattern incurring minimum investment (less by 40.9%), it would be possible to achieve food security. The investment, although made in drought condition, has not involved any financial risk and also provided considerable employment (10% of total man days). Further, the model envisages strengthening of cooperative societies promoting sharing of benefits, creditors like SHG (Self Help Groups) and voluntary regulatory bodies for water distributaries for the success of proposed activities.

INTRODUCTION

Water resources management represents one of the most fundamental challenges going to be faced by India in 21st century. Over the last century, increase in irrigated area provided foundation on which agricultural growth, poverty alleviation and ultimately the growth of Indian economy have rested. Progress has been substantial but much to it may prove unsustainable in many areas of the country due to ground water over draft, water scarcity, siltation of reservoirs and the unanticipated impacts of human actions on complex water systems threaten both the environment and economic foundations of society (Anonymous, 2000). This calls for that all these resources should be used judiciously in such a way that basic needs of the people of the area should be fulfilled during the scarcity with minimum investment. Thus problems like distress migration, starvation death etc., in the command area should not occur during drought years.

Objective of this case study was to prepare drought-proofing mechanism during the drought year by better crop husbandry management at command level and better resource sharing at community level. In the process of optimal crop planning it is assumed that availability of input resources are uniformly distributed across all the land holding in the command areas' inhabitant.

MATERIAL AND METHODS

The present study was undertaken in Banswara District of Rajasthan, which falls under Badiya command (Badiya distributory from right main canal of Mahi Bajaj Sagar Project). The gross command area and culturable command area under Badiya command area are deep, alluvial deposits carried by Mahi River. The field slope varies from 3 to 10 per cent. Average minimum temperature ranges from 17.5 to 20.0°C and average maximum temperature ranges from 29.0 to 30.0°C. The annual rainfall in the district is 882 mm most of which is received between July and September. Drought occurrence is once in a 6 years on the basis of probability analysis. The data pertaining to cultivated rabi season crops irrigated through Badiya distributory from right main canal of Mahi river were collected from various secondary sources. Maize and rice are major crops grown during kharif (monsoon) season.

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and wheat \((Triticum aestivum)\) and maize \((Zea mays)\) in rabi (winter) season. It was assumed that the rabi season is from 44th to 12th meteorological (met.) week.

**Linear programme model:**

A LP model was developed for Badiiya distributory command of Mahi Bajaj Sagar Project for integrated resource planning, which can be stated in the following form:

\[
Z = \sum_{i=1}^{n} C_i X_i
\]

Where,
\[
Z = X_1, X_2, X_3, \ldots, X_n
\]

\(X_1, X_2, X_3, \ldots, X_n\) are area variables

Subject to

\[
\sum_{i=1}^{n} a_{ij} X_j \leq b_i, \quad i = 1, 2, 3, \ldots, m
\]

Where,
\[
C_i = \text{Cost coefficient of } X_i
\]
\[
X_i = \text{Decision variable}
\]
\[
a_{ij} = \text{Technical coefficient}
\]
\[
b_i = \text{Constraint}
\]
\[(*) = >, =, \text{or} < \text{for each constraint.}
\]

The subscripts used 'j' in the model presents: 1= maize, 2= Bengal gram, 3= mustard, 4= wheat, 5= vegetables.

Objective was sought with a view of minimizing investment considering the interest of the command area as well as the national goals. The main objective was as given below:

**Investment minimization based on minimum food requirement.**

\[
\text{Mini. } Z_{fb} = \sum_{i=1}^{5} I_i X_i
\]

Where
\[
X_i = \text{Area of land cultivated under ith crop (ha)}
\]
\[
I_i = \text{Investment required for ith crop (Rs./ha)}
\]
\[
Z_{fb} = \text{Net value of investment based on minimum food requirement (Rs.)}
\]

The various constraints within which the system should operate to achieve the desired objective are:

a) **Area constraints**: The summation of area allocated for different crops in a rabi season should be less than or equal to the total available cultivated area.

\[
\sum_{i=1}^{5} X_i \leq A
\]

b) **Labour constraint**: The total requirement of the labour in season should not exceed the labour available in that season in order to prevent the import of labour from outside.

\[
\sum_{i=1}^{5} L_i X_i \leq L
\]

Where,
\[
I_i = \text{Labour required for ith crop (Mandays/ha)}
\]
\[
L = \text{Total labour available (Mandays)}
\]

C) **Water constraint**: The water requirements of the crops should be fully met during the entire crop period. Hence, mathematically the equation for a particular season is:

\[
\sum_{i=1}^{5} w_i X_i \leq W
\]

Where,
\[
w_i = \text{Depth of water required in a particular season by ith crop (cm)}
\]
\[
W = \text{Total water available in that season (ha/cm)}
\]

d) **Food constraint**: Cereals, pulses, oilseeds and vegetables are considered under food requirement constraint. Total production of cereals (maize and wheat), pulses, oilseed and vegetables should meet actual requirement of the total population, which is based on minimum per capita requirement recommended by ICMR (per capita per day.
requirement of maize, wheat, pulse, oil and vegetables are 205gms, 320gms, 45.5gms, 34gms and 340gms respectively. These are the social constraints and mathematically can be expressed as:

i. Cereals constraint
\[
\sum_{i=0}^{1} P_i X_i + \sum_{i=4}^{4} P_i X_i \geq C_c
\]

ii. Pulse
\[
\sum_{i=1}^{2} P_i X_i \geq P_u
\]

iii. Oilseed
\[
\sum_{i=2}^{3} P_i X_i \geq O_s
\]

iv. Vegetables
\[
\sum_{i=1}^{5} P_i X_i \geq V_e
\]

Where, Cc, Pu, Os and Ve are total estimates of requirement of cereals, pulse, oilseed and vegetables for population of the block, qtl/year.

e) Affinity constraint: Due to strong affinity of the local people for wheat it was expected that at least 40 per cent of the total cultivable area in rabi season is a must under wheat crop.
\[
\sum_{i=1}^{4} X_i \geq 0.4 A
\]

Where, A = Total culturable area (ha)

f) Capital constraint: In a developing country like India, capital is the biggest constraint for any planning. The capital available from the entire source should not be less than the total expenditure involved in planning. Hence,
\[
\sum_{i=1}^{5} I_i X_i \leq (M_a + M_b)
\]

Where,
- \( M_a \) = Total money available from own resources of villagers (Rs.)
- \( M_b \) = Total money available from borrowing capacity of villages (Rs.)

g) Benefit constraint: For comparable benefits to existing system
\[
\sum_{i=1}^{5} B_i X_i \geq B_e
\]

Where, Be = Net value of benefits in existing system (Rs.)

RESULTS AND DISCUSSION

Considering the objective of investment minimization on the basis of minimum food requirement in the command area, an effort was made to allocate the land to different crop activities using LP model. Keeping in view the objective of investment minimization, it is proposed to allocate land areas, viz., 96.81, 42.97, 42.81, 676.00 and 30.58 ha to raise different crops i.e. maize, gram, mustard, wheat and rabi vegetables respectively. Such proposed land allocation (Table 1) based on optimal cropping pattern works out to a reduction by 41.55% as compared to area (1521.33 ha under existing cropping pattern. Inspite of this decrease in area allocation as necessitated by inadequate irrigation water in drought year/years, LP model so ensures as to produce minimum food requirements of the command area. Further, the model also takes care of the affinity towards wheat by allocating as much as 40% of cultivable area.

It is interesting to note that a minimal quantity of irrigation water (i.e. only 58.7% of the water resource required for existing cropping pattern in normal years) is sufficient enough to produce the minimum food requirement (Table 2).

In the command area, a total of 50,578 labour maydays during rabi season are available,
Table 1. Cultivated area allocation at existing and optimal cropping pattern under different crops

<table>
<thead>
<tr>
<th>Crops</th>
<th>Area under existing cropping pattern (ha)</th>
<th>Area under proposed optimal cropping pattern based on benefit maximization (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>118.32</td>
<td>96.81</td>
</tr>
<tr>
<td>Bengal gram</td>
<td>84.52</td>
<td>42.97</td>
</tr>
<tr>
<td>Mustard</td>
<td>152.13</td>
<td>42.82</td>
</tr>
<tr>
<td>Wheat</td>
<td>1098.76</td>
<td>676.00</td>
</tr>
<tr>
<td>Rabi/Vegetables</td>
<td>67.60</td>
<td>30.58</td>
</tr>
<tr>
<td>Total</td>
<td>1521.33</td>
<td>889.19</td>
</tr>
<tr>
<td>% usages to existing cropping pattern</td>
<td></td>
<td>58.45</td>
</tr>
</tbody>
</table>

Table 2. Irrigation water allocation at existing and optimal cropping pattern under different crops weekly basis

<table>
<thead>
<tr>
<th>Crops</th>
<th>Water used under existing cropping pattern (ha-cm)</th>
<th>Water used under optimal cropping pattern based on benefit maximization (ha-cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>248.47</td>
<td>203.39</td>
</tr>
<tr>
<td>Bengal gram</td>
<td>92.13</td>
<td>46.84</td>
</tr>
<tr>
<td>Mustard</td>
<td>266.22</td>
<td>74.93</td>
</tr>
<tr>
<td>Wheat</td>
<td>1692.09</td>
<td>1041.04</td>
</tr>
<tr>
<td>Rabi/Vegetables</td>
<td>119.65</td>
<td>54.13</td>
</tr>
<tr>
<td>Total</td>
<td>2418.56</td>
<td>1420.32</td>
</tr>
<tr>
<td>% usages to existing cropping pattern</td>
<td></td>
<td>58.73</td>
</tr>
</tbody>
</table>

Total water available in the command area = 3545.60 ha-cm

Table 3. Labour requirement at existing and optimal cropping pattern under different crops on weekly basis

<table>
<thead>
<tr>
<th>Crops</th>
<th>Labour used under existing cropping pattern (Mandays)</th>
<th>Labour utilization under optimal cropping pattern based on benefit maximization (Mandays)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>748.96</td>
<td>612.79</td>
</tr>
<tr>
<td>Bengal gram</td>
<td>399.77</td>
<td>203.26</td>
</tr>
<tr>
<td>Mustard</td>
<td>678.49</td>
<td>190.95</td>
</tr>
<tr>
<td>Wheat</td>
<td>5746.51</td>
<td>3535.38</td>
</tr>
<tr>
<td>Rabi/Vegetables</td>
<td>1393.23</td>
<td>630.31</td>
</tr>
<tr>
<td>Total</td>
<td>8966.99</td>
<td>5172.79</td>
</tr>
<tr>
<td>% usages to existing cropping pattern</td>
<td></td>
<td>57.69</td>
</tr>
</tbody>
</table>

Total man days available in the command area = 50578
Total man days employed during drought = 5172.79 (10.22 %)

of which 17.7% are employed during normal years. As a result of optimal cropping pattern in drought years an employment 10.2% of mandays could be created which otherwise, find no employment in drought years (Table 3). However, the rest of the labour mandays in excess of 10% are required to be provided employment by way of off farm income generating activities/Agro-hort. based processing units/cottage handicrafts etc., which could hopefully compensate for the loss (47.27%) (Table 6) in income due to drought conditions.

During the lean years with water
resource constraint, the investment minimization (Table 4) could be achieved with the suggested LP model, yet ensuring the minimum food requirements. In other words, the financial risk is reduced to 40.9% while protecting food security. Generally the Indian farmers does not indulge in financial risk. From the farmers point of view also, the model with investment minimization, almost get over financial risk by contemplating an optimum input out-put ratio. Simultaneously the model pools financial resource, which are within reach of community without involving external finance from government or non-government agencies.

In the final analysis, it implies during the drought years the model shows the possibility to produce minimum food (Table 5) requirement out of reduced land allocation (41.5%) with optimal cropping pattern requiring only 59% of normal usage of water apart from investment minimization (Less by 40.9%).

### Table 4. Investment at existing and optimal cropping pattern under different crops

<table>
<thead>
<tr>
<th>Crops</th>
<th>Investment under existing cropping pattern (Rs. in lac)</th>
<th>Investment under optimal cropping pattern based on benefit maximization (Rs.in lac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>5.27</td>
<td>4.31</td>
</tr>
<tr>
<td>Bengal gram</td>
<td>2.68</td>
<td>1.36</td>
</tr>
<tr>
<td>Mustard</td>
<td>5.10</td>
<td>1.44</td>
</tr>
<tr>
<td>Wheat</td>
<td>59.68</td>
<td>36.72</td>
</tr>
<tr>
<td>Rabi Vegetables</td>
<td>6.22</td>
<td>2.82</td>
</tr>
<tr>
<td>Total</td>
<td>78.95</td>
<td>46.65</td>
</tr>
<tr>
<td>% Less</td>
<td></td>
<td>40.91</td>
</tr>
</tbody>
</table>

### Table 5. Production at existing and optimal cropping pattern under different crops

<table>
<thead>
<tr>
<th>Crops</th>
<th>Production under existing cropping pattern (qtl.)</th>
<th>Production under optimal cropping pattern based on benefit maximization (qtl.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>4732.80</td>
<td>3872.28</td>
</tr>
<tr>
<td>Bengal gram</td>
<td>1690.40</td>
<td>859.42</td>
</tr>
<tr>
<td>Mustard</td>
<td>2281.95</td>
<td>642.23</td>
</tr>
<tr>
<td>Wheat</td>
<td>49444.20</td>
<td>30420.00</td>
</tr>
<tr>
<td>Rabi Vegetables</td>
<td>14196.00</td>
<td>6422.43</td>
</tr>
<tr>
<td>Total</td>
<td>72345.35</td>
<td>42216.39</td>
</tr>
<tr>
<td>% Production to that of existing cropping pattern</td>
<td></td>
<td>58.35</td>
</tr>
</tbody>
</table>

### Table 6. Income at existing and optimal cropping pattern under different crops

<table>
<thead>
<tr>
<th>Crops</th>
<th>Income under existing cropping pattern (Rs. in lac)</th>
<th>Income under optimal cropping pattern based on benefit maximization (Rs. in lac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>3.72</td>
<td>3.05</td>
</tr>
<tr>
<td>Bengal gram</td>
<td>3.16</td>
<td>1.60</td>
</tr>
<tr>
<td>Mustard</td>
<td>4.03</td>
<td>1.13</td>
</tr>
<tr>
<td>Wheat</td>
<td>54.04</td>
<td>33.25</td>
</tr>
<tr>
<td>Rabi Vegetables</td>
<td>6.62</td>
<td>2.99</td>
</tr>
<tr>
<td>Total</td>
<td>71.57</td>
<td>42.02</td>
</tr>
<tr>
<td>% Less</td>
<td></td>
<td>41.29</td>
</tr>
</tbody>
</table>
CONCLUSION

This case study of Mahi command area establishes that minimum food requirement can be achieved with investment minimization adopting optimal cropping pattern in relation to scarce water in drought condition. Nevertheless, for successful implementation of any such optimal crop-planning scheme during scarcity years, establishment of cooperative societies will be prerequisite which can effectively promote the equal sharing of the benefits and other crucial resources among the community. At the same time local credit institution like self help groups and income generation group etc. should be strengthened in command area for better results in normal monsoon years. It is also suggested to establish regulatory bodies at distributary/water course level in command area.

REFERENCES