Linear Programming Model For Optimal Cropping Pattern For Economic Benefits Of Mrbc Command Area

Mahek Giri Aparnathi
L.D Engineering college Ahmedabad

Prof. Divya k Bhatt
L.D Engineering college Ahmedabad

Abstract

Optimal cropping pattern optimization model is formulated in which the surface and ground water as decision variables. Linear programming is used for multiple crop models and dynamic programming for single crop model. In irrigated agriculture, where various crops are competing for a limited quantity of land and water resources, linear programming is one of the best tools for optimal allocation of land and water resources (smith, 1973; mAji and heady, 1980; loucks et al., 1981. Salman et al (2001) present a linear programming model to derive regional water demands based on optimized regional cropping pattern with variable water prices based on quality.

Keywords: Horizontal Pressure Vessel, Design using PVElite, Local stress analysis using PVElite.

I. INTRODUCTION

In this study, developed a crop allocation model that maximizes agricultural profits constrained by land by and water availability. The decision making unit on at the level of a single ditch, which maximizes net income by choosing the optimal cropping pattern, land and water usage, given input and output prices. Ey. The model finds the optimal cropping pattern and land usage for the Nadiad branch canal command of mahi command (Gujarat (India), given water availability.

Linear programming (LP) has been used extensively in the analysis of water resource systems and irrigation planning. Some examples are now presented. Mathematical models in irrigation planning and water pricing policies mathematical programming models can be used to determine optimal activity and resource input levels.

II. OBJECTIVE OF STUDY:

- Integration of remote sensing based crop acreage in optimization model (linear programming model)
- Using LP model to maximize net benefit from optimal cropping pattern with different extent of allocation of water from canal and tube wells.

III. MATHEMATICAL MODEL FORMULATION

Objective function: the objective function is to maximize net benefit from irrigated area which includes returns from the irrigated area and the operations costs for canals and tube wells.

A. Benefits from agriculture returns:

Evaluation of benefits from system is tough task for the system analyst, the benefits from agriculture can be computed after deducting expenses incurred in growing crops like seeds, pesticides, fertilizer and labour and surface and ground water cost for cultivation of crops.

The net benefits are obtained by:


Cost-1 = the expenditure on seeds, pesticides, fertilizers and labour.

Cost-2= irrigation cost = net annual capital cost.

Here we are concerned about the cost 2 from the department of agriculture: the amount for cost 1 for each crop was obtained and deducted from the market value product.

So the above equation is simplified to:

Net profit= benefit –cost 2.

\[ \text{Benefits} = \sum_{j} A_j \times \text{YP}_j \times \text{VPP}_j \]

\[ j = 1 \]
Where,  
\( A_j \) = irrigation area of jth crop.  
\( Y_{PAj} \) = yield per acre of jth crop.  
\( VPP_j \) = value per Rs. of jth crop

**B. Operation cost from canals tube wells**

Annual capital cost of canal is calculated by

\[
\text{Cost of surface water} = \sum_{i=1}^{i} C_i Y_i
\]

Where, \( C_i \) = operation cost for canal system  
\( Y_i \) = flow diverted into canal during ith season.

\[
\text{Cost of ground water} = \sum_{i=1}^{i} C_i T_i
\]

In which \( C_i \) = operation cost for tube well system  
\( T_i \) = pumpage from tube well in ith season.

**C. Objective Function Subjected to Constraints:**

Water diverted to canals in any season cannot exceed the canal capacity.

\[
\frac{\gamma Y_i}{\eta} \leq Y
\]

In which,  
\( \gamma \) = ration of peak to average demand = 1.1  
\( Y \) = canal capacity in cumecs = 16.56 Cumecs  
\( \eta \) = canal efficiency = 0.70  
\( D \) = canal running days, In Rabi = 85  
\( C_i \leq 7740 \)

Seasonal diverted to canal cannot exceed seasonal river flow at the canal head-works.

\( C_i \leq x_i \)

In which, \( C_i \) = flow diverted into canal in ha m during ith season.  
\( x_i \) = available water at head of canal in ha m in ith season.

\( C_i \leq 2855 \)

Water pumped from tube wells in any season cannot exceed the tube well capacity.

\[
\frac{\gamma T_i}{\eta} \leq G
\]

In which, \( \gamma \) = ration of peak to average demand  
\( G \) = max capacity of well system.  
\( \eta \) = tube well efficiency  
\( D \) = no. of days canal running.  
No. of open well = 1380  
No. of tube well = 237

Average yield of tube well = 1500 lpm = 0.0250 cumec  
Average yield of open well = 935 lpm = 0.0157 cumec

There fore quantum of water available for pumping.

Open well = 0.0157 \times 1380 = 21.66 cumec  
Tube well = 0.025 \times 237 = 5.925 cumec  
Total = 27.59 cumec

Consider the efficiency of as 70% and assuming that tube well is operated for 65 days in rabi season.  
Therefore, total discharge capacity of tubewell and open well in ha m.

\[
= \frac{27.59 \times 0.7 \times 65 \times 8.64}{1.1} = 9860 \text{ ha m.}
\]

\( T_i \leq 9860 \)

Water requirement for crops is met in each season.

\[
\sum_{j=1}^{j} A_j W_{R_j} - \Theta_3 (\Theta_2 Y_i + T_i) \leq 0
\]

In which, \( W_{R_j} \) = irrigation water requirement of jth crop in ith season  
\( A_j \) = irrigated area for jth crop.  
\( \Theta_3 = 1 - SR_3 - AR_3 - ET_2 \)  
\( \Theta_1 = 1 - SR_1 - AR_1 - ET_1 \)

<table>
<thead>
<tr>
<th>ZONE</th>
<th>SR(surface runoff)</th>
<th>AR(Artificial recharge)</th>
<th>ET(evapotranspiration)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal zone</td>
<td>0.05</td>
<td>0.1</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Irrigated zone | 0.1 | 0.2 | 0.1
---|---|---|---

Table 1: Percentage of abstractions in the canal zone, irrigated zone.

\[
0.4A_1+0.36A_2+0.70A_3-0.6(0.8 C_1+T_1) \leq 0
\]

SR\_1 = fraction of water diverted to canals that is lost as surface runoff = 5%  
AR\_1 = fraction of water diverted to canals that is lost as aquifer recharge = 10%  
ET\_1 = fraction of water diverted to canals that is lost as non-beneficial evapotranspiration = 5%  
SR\_2 = fraction of water diverted to canals that is lost as surface runoff = 10%  
AR\_2 = fraction of water diverted to canals that is lost as aquifer recharge = 20%  
ET\_2 = fraction of water diverted to canals that is lost as non-beneficial evapotranspiration = 10%

Case-a. Restricts maximum value for irrigation under each crop.

\[
A_j \leq T_{IA}
\]

In which  
\(A_j\) = irrigation area of jth crop  
\(T_{IA}\) = total available area for irrigation.

\[
A_1 \leq 9643  
A_2 \leq 2594  
A_3 \leq 2088
\]

Case-b. Allow 25% variation in maximum value for irrigation under each crop without change in seasonal irrigation intensity.

\[
0.75T_{IA} \leq A_j \leq 1.25T_{IA}
\]

In which  
\(A_j\) = irrigation area of jth crop  
\(T_{IA}\) = total available area for irrigation

\[
7232 \leq A_1 \leq 12053  
1946 \leq A_2 \leq 3566  
1566 \leq A_3 \leq 2610
\]

Total area of various crops cannot exceed the total available area of irrigation.

\[
\sum_{j=1}^{3} A_j \leq T_{IA}
\]

IV. EXECUTION OF MATHEMATICAL MODEL WITH DIFFERENT INTENSITIES FOR DIFFERENT RELEASE POLICIES.

The aim of the present study is to determine optimal cropping pattern and optimal utility of ground water instead of existing cropping pattern considering socio-economic point of view.

Water release from canal may vary every year according to reservoir status as determined by rain in monsoon rain, so in place of actual water release policies of canal release. On the basis of past four years release.

Policy.1 - 2500 ha m, policy.2 - 2750 ha m, policy.3 - 3000 ha m, policy.4 - 3250 ha m of canal water for rabi season. Ground water resources can be utilized up to safe limit to satisfy with different proposed seasonal irrigation intensity of 30%, 50%, 70%, 80%, and 100%.

<table>
<thead>
<tr>
<th>Year/season</th>
<th>Release in day cusec</th>
<th>Release in M.C.F.T</th>
<th>Release in M.C.M</th>
<th>Release in ha m</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-12/rabi seasons</td>
<td>11666</td>
<td>1079.94</td>
<td>28.54</td>
<td>2855.81</td>
</tr>
<tr>
<td>2012-13/rabi seasons</td>
<td>9878</td>
<td>853.46</td>
<td>24.16</td>
<td>2420</td>
</tr>
</tbody>
</table>

Table 2: ACTUAL RELEASE FROM CANAL IN RABI SEASON

<table>
<thead>
<tr>
<th>Year/season</th>
<th>Release policy-1(ha m)</th>
<th>Release policy-2(ha m)</th>
<th>Release policy-3(ha m)</th>
<th>Release policy-4(ha m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13/rabi season</td>
<td>2500</td>
<td>2750</td>
<td>3000</td>
<td>3250</td>
</tr>
</tbody>
</table>

Table 3: PROPOSED RELEASE POLICY BASE OF ON PAST RELEASES RABI SEASON IN (ha m)

Table show that area to be irrigated foe each crop for 2 cases of constraints 5, respectively, under different irrigation intensities.

<table>
<thead>
<tr>
<th>Rabi crops</th>
<th>Actual area irrigated (ha)</th>
<th>Seasonal irrigation intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>9643</td>
<td>30% 50% 70% 80% 100%</td>
</tr>
<tr>
<td>Tobacco</td>
<td>2594</td>
<td>4133 6888 9644 11021 13776</td>
</tr>
<tr>
<td>Other</td>
<td>2088</td>
<td>895 1492 2089 2387 2983</td>
</tr>
</tbody>
</table>
Table 4: AREA TO BE IRRIGATED FOR EACH CROP (in ha) FOR DIFFERENT SEASONAL, IRRIGATION INTENSITY BASED EXISTING CROPPING PATTERN.

<table>
<thead>
<tr>
<th>Rabi crops</th>
<th>Actual area irrigated (ha)</th>
<th>Seasonal irrigation intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>30%</td>
</tr>
<tr>
<td>Wheat</td>
<td>9643</td>
<td>4000-5166</td>
</tr>
<tr>
<td>Tobacco</td>
<td>2594</td>
<td>834-1390</td>
</tr>
<tr>
<td>Other</td>
<td>2088</td>
<td>672-1119</td>
</tr>
</tbody>
</table>

Table 5: AREA TO BE IRRIGATED FOR EACH CROP (in ha) FOR DIFFERENT SEASONAL, IRRIGATION INTENSITY BASED EXISTING CROPPING PATTERN UNDER THE CONSTRAINTS OF MAXIMUM VARIATION 25 %

V. THE MATHEMATICAL MODEL IS DEVELOPED IN PREVIOUS TOPIC IS EXECUTED FOR FOLLOWING CASES.

CASE-I. Existing and suggested cropping pattern for rabi season with different intensities for actual release of canal water.
CASE-II. Allow 25% variation in area under each crop for existing and suggested cropping pattern for rabi season with different intensities for actual release of canal water.
CASE-III. Suggested cropping pattern for rabi season with different intensities for different release of canal water.
CASE-IV. Allow 25% variation in area under each crop for existing and suggested cropping pattern for rabi season with different intensities for different release of canal water.
VI. RESULT

The net benefit of the irrigation system under different scenarios as discussed earlier are presented in ...., in case of actual release policy, tables and table show net benefit for different seasonal irrigation intensity for case (a) and case (b) of constraint 5.

A. CASE-I

Existing and suggested cropping pattern for rabi season with different intensities for actual release of canal water.

<table>
<thead>
<tr>
<th>Release policy</th>
<th>Seasonal irrigation intensity</th>
<th>Cost of S.W. Rs.(10^5)</th>
<th>Cost of G.W Rs.(10^6)</th>
<th>Net benefit(10^7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Release Policy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td>3.8542</td>
<td>1.8443</td>
<td>7.9452</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>3.8542</td>
<td>4.3605</td>
<td>13.1387</td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td>3.8542</td>
<td>6.8778</td>
<td>18.3351</td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>3.8542</td>
<td>8.1349</td>
<td>20.9296</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>3.8542</td>
<td>8.3317</td>
<td>22.0527</td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Net Benefit For Different Seasonal Irrigation Intensity For Actual Release (In Case-A A_j<=Tia)

B. CASE-II

Allow 25% variation in existing and suggested cropping pattern for rabi season with different intensities for actual release of canal water.

<table>
<thead>
<tr>
<th>Release policy</th>
<th>Seasonal irrigation intensity</th>
<th>Cost of S.W. Rs.(10^5)</th>
<th>Cost of G.W Rs.(10^6)</th>
<th>Net benefit(10^7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Release Policy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td>3.8542</td>
<td>2.7880</td>
<td>9.8931</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>3.8542</td>
<td>5.5659</td>
<td>15.720</td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td>3.8542</td>
<td>8.3317</td>
<td>21.5677</td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>3.8542</td>
<td>8.3317</td>
<td>22.0538</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>3.8542</td>
<td>8.3317</td>
<td>22.7180</td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Net Benefit For Different Seasonal Irrigation Intensity For Actual Release (In Case-B 0.75Tia ≤ A_j ≤ 1.25Tia)

C. CASE-III

Suggested cropping pattern for rabi season with different intensities for different release of canal water.

D. CASE-IV

Allow 25% variation in area under each crop for existing and suggested cropping pattern for rabi season with different intensities for different release of canal water.

In case of different release policy, table shows net benefit for different seasonal irrigation intensity for case a and case b of constraints 5.
Table. 8: Net Benefit For Different Release Under Different Seasonal Irrigation Intensity(Case-iii, \( A_j \leq T_{ia} \) & Case-iv \( 0.75T_{ia} \leq A_j \leq 1.25T_{ia} \))

<table>
<thead>
<tr>
<th>Release policy-4</th>
<th>80%</th>
<th>20.9374</th>
<th>22.2336</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100%</td>
<td>22.0612</td>
<td>23.0923</td>
</tr>
<tr>
<td>30%</td>
<td>7.9666</td>
<td>9.9145</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>13.1601</td>
<td>15.7418</td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td>18.3565</td>
<td>22.0577</td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>20.9509</td>
<td>22.5437</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>22.0747</td>
<td>23.4424</td>
<td></td>
</tr>
</tbody>
</table>

VII. DISCUSSION OF RESULT

Fig 1 shows the net benefit for actual release policies under different irrigation intensity (30%, 50%, 70%, 80% and 100% etc.) for both the case of constraint 5. As intensity of irrigation net benefit also increased. For same irrigation intensity the case II had higher benefit than the case I. in case I benefits ranged from 7.94 to 22.05 and case II benefits ranged from 9.89 to 22.77. release 4 had highest benefit in both the cases. As intensity of irrigation is utilization of ground water is also increase so cost of ground water is increase. Result of case-I and case-ii as shown in table.

![Net Benefits for actual release with different level of intensity](image1)

Fig. 1: Net Benefits For Actual With Different Level Of Intensity

- IN CASE OF \( A_j \leq T_{ia} \)
- IN CASE OF \( 0.75T_{ia} \leq A_j \leq 1.25T_{ia} \)

Fig show 2 the net benefits for different release policies under 30% seasonal irrigation intensity the case IV had higher benefits than the case-III. In case-III benefits ranged from 7.92 to 7.96 and case IV benefits ranged from 9.87 to 9.91. release 4 had highest benefits in both the cases.

![Net benefits for 30% seasonal irrigation intensity](image2)

Fig. 2: Net Benefits For 30% Seasonal Irrigation Intensity

Fig show 3 the net benefits for different release policies under 50% seasonal irrigation intensity the case IV had higher benefits than the case-III. In case-III benefits ranged from 13.01 to 13.16 and case IV benefits ranged from 15.70 to 15.74. release 4 had highest benefits in both the cases.
Fig. 3: Net Benefits For 50% Seasonal Irrigation Intensity

Fig show 4 the net benefits for different release policies under 70% seasonal irrigation intensity the case IV had higher benefits than the case-III. In case-III benefits ranged from 18.31 to 13.35 and case IV benefits ranged from 21.12 to 22.05. release 4 had highest benefits in both the cases.

Fig. 4: Net Benefits For 70% Seasonal Irrigation Intensity

Fig show 5 the net benefits for different release policies under 80% seasonal irrigation intensity the case IV had higher benefits than the case-III. In case-III benefits ranged from 20.83 to 20.95 and case IV benefits ranged from 21.61 to 22.54. release 4 had highest benefits in both the cases.

Fig. 5: Net Benefits For 80% Seasonal Irrigation Intensity

Fig show 6 the net benefits for different release policies under 100% seasonal irrigation intensity the case IV had higher benefits than the case-III. In case-III benefits ranged from 21.61 to 22.07 and case IV benefits ranged from 21.80 to 23.44. release 4 had highest benefits in both the cases.
VIII. SUMMARY AND CONCLUSION

The linear programming model was formulated for maximization of net return from optimal cropping pattern with conjunctive water use, considering various release policies and intensities of irrigation. It was found to be an effective tool for land and water resources allocation. The existing cropping pattern and its acreage in nadiad branch canal command area was estimated using multi-date remote sensing data of IRS P6/1D LISS-III. Based in this acreage the intensity of irrigation was suggested under each crop. The release policies canal was based on previous year’s taken from actual situation. Following specific conclusions could be drawn using with regard to optimization of net return from optimal cropping pattern with conjunctive water use.

- The comparison of case –I and case-ii for actual release policy and existing cropping pattern. Showed that the net return in case-ii was higher as compared to case –I for same intensity of irrigation. This showed the existing cropping pattern was non–optimal.
- Comparison of results of case-iii and case-iv showed that the for different release policies under same intensity of irrigation the change in benefits is nominal. Hence the average of four release policies could be considered as the best scope of surface water and ground water utilization.
- For same intensity and same release policy, comparing case-iii and case-iv, the net return was higher in case-iv in which 25% variation was allowed in area under each crop.

REFERENCE