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

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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:

Net profit = market value product - cost1 – cost 2.

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.

$$\text{Benefits} = \sum_{j=1}^{j} Aj \ \ YPAj \ \ VPP_j$$

Where, Aj = irrigation area of jth crop. YPAj = 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 calculates by

$$\text{Cost of surface water} = \sum_{i=1}^{i} C\ Y_i$$

Where, C = operation cost for canal system

Yi = flow diverted into canal during ith season.

$$\text{Cost of ground water} = \sum_{i=1}^{i} C\ T_i$$

In-which C = operation cost for tube well system. T_i = pumpage from tube well in ith season.

C. OBJECTIVE FUNCION SUBJECTED TO CONSTRAINTS:

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

$$\frac{\gamma}{D}\ \frac{Y_i}{\eta} \leq Y$$

In which, γ = ration of peak to average demand=1.1

Y = canal capacity in cumecs=16.56 Cumecs

η = 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.

$$\frac{\gamma}{D}\ \frac{ti}{\eta} \leq g$$

In which, γ = ration of peak to average demand

G= max capacity of well system.

η = 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 × 1380=21.66 cumec

Tube well 0.025 × 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 ha m.

$T_1 \leq 9860$

Water requirement for crops is met in each season.

$$\sum_{j=1}^{j} Aj\ WR_{ij} - \Theta_2 (\Theta_1 Y_i + T_i) \leq 0$$

In which, WR_{ij} = irrigation water requirement of jth crop in ith season

Aj = irrigated area for jth crop.

$\Theta_2 = 1 - SR_2 - AR_2 - ET_2$

$\Theta_1 = 1 - SR_1 - AR_1 - ET_1$

ZONE	SR(surface runoff)	AR(Artificialrecharge)	ET(evapotranspiration)
Canal zone	0.05	0.1	0.05

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 canal 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 canal 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.

$$Aj \leq TIA$$

In which Aj = irrigation area of jth crop
TIA= 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.

$0.75TIA \leq Aj \leq 1.25TIA$

In which Aj = irrigation area of jth crop TIA= 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.

$$\sum_{j=1}^{j} Aj \leq TIA$$

$$A1+A2+A3 \leq 14325$$

In which Aj = irrigation area of jth crop
TIA= total available area for irrigation

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%.

Year/season	Release in day cusec	Release in M.C.F.T	Release in M.C.M	Release in ha m
2011-12/rabi seasons	11666	1079.94	28.54	2855.81
2012-13/rabi seasons	9878	853.46	24.16	2420

Table. 2: ACTUAL RELEASE FROM CANAL IN RABI SEASON

Year/season	Release policy-1(ha m)	Release policy-2(ha m)	Release policy-3(ha m)	Release policy-4(ha m)
2012-13/rabi season	2500	2750	3000	3250

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.

Rabi crops	Actual area irrigated (ha)	Seasonal irrigation intensity				
		30%	50%	70%	80%	100%
Wheat	9643	4133	6888	9644	11021	13776
Tobacco	2594	1112	1853	2595	2965	3706
Other	2088	895	1492	2089	2387	2983

Table. 4: AREA TO BE IRRIGATED FOR EACH CROP (in ha) FOR DIFFERENT SEASONAL, IRRIGATION INTENSITY BASED EXISTING CROPPING PATTERN.

Rabi crops	Actual area irrigated (ha)	Seasonal irrigation intensity				
		30%	50%	70%	80%	100%
Wheat	9643	4000-5166	5166-8610	7233-12055	8266-13777	10332-17220
Tobacco	2594	834-1390	1390-2317	1947-3244	2224-3707	2780-4633
Other	2088	672-1119	1119-1492	1567-2612	1791-2984	2238-3729

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.

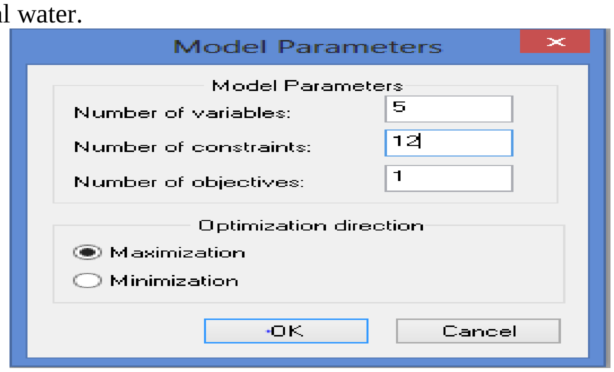

Fig. 1 : Model Parameters In Lips Software

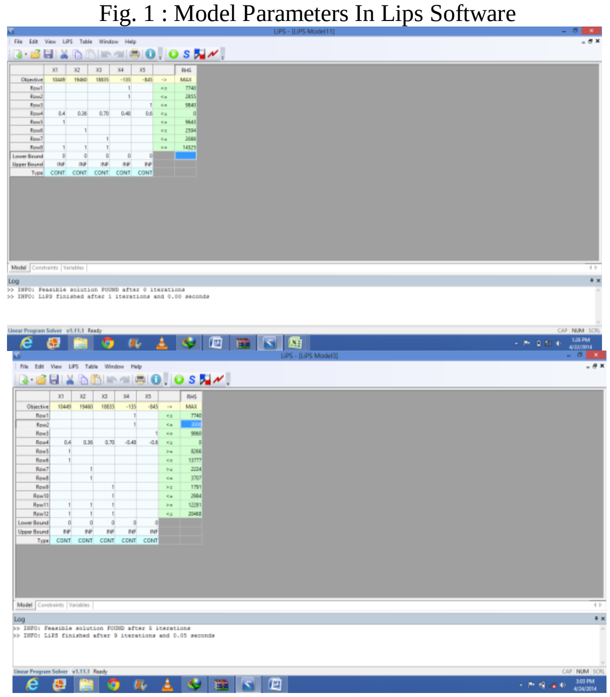
Fig. 2 : Normal / Matrix Formulation Of Lp Problem

VI. RESULT

The net benefit of the irrigation system under different scenarios as discussed earlier are presented in …., in case of actual release policy, table 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.

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

Table. 6: Net Benefit For Different Seasonal Irrigation Intensity For Actual Release (In Case-A .Aj<=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.

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

Table. 7: Net Benefit For Different Seasonal Irrigation Intensity For Actual Release(In Case-B. 0.75tia ≤ Aj ≤ 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.

Release policy	Seasonal irrigation intensity	Net benefit in Rs.(10^7)	
		Case-iii Aj ≤ TIA	Case-iv 0.75TIA ≤ Aj ≤ 1.25TIA
Release policy-1	30%	7.9260	9.8739
	50%	13.0119	15.7013
	70%	18.3159	21.1274
	80%	20.8345	21.6134
	100%	21.6124	21.8017
Release policy-2	30%	7.9395	9.8874
	50%	13.1331	15.7148
	70%	18.3295	21.4375
	80%	20.9239	21.9235
	100%	21.9225	22.4470
Release policy-3	30%	7.9531	9.9010
	50%	13.1466	15.7283
	70%	18.3430	21.7476

	80%	20.9374	22.2336
	100%	22.0612	23.0923
Release policy-4	30%	7.9666	9.9145
	50%	13.1601	15.7418
	70%	18.3565	22.0577
	80%	20.9509	22.5437
	100%	22.0747	23.4424

Table. 8: Net Benefit For Different Release Under Different Seasonal Irrigation Intensity(Case-Iii, Aj ≤ Tia & Case-Iv 0.75tia ≤ Aj ≤ 1.25tia)

VII. DISCUSSION OF RESULT

Fig 1 shows the net benefit for actual releasease 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.

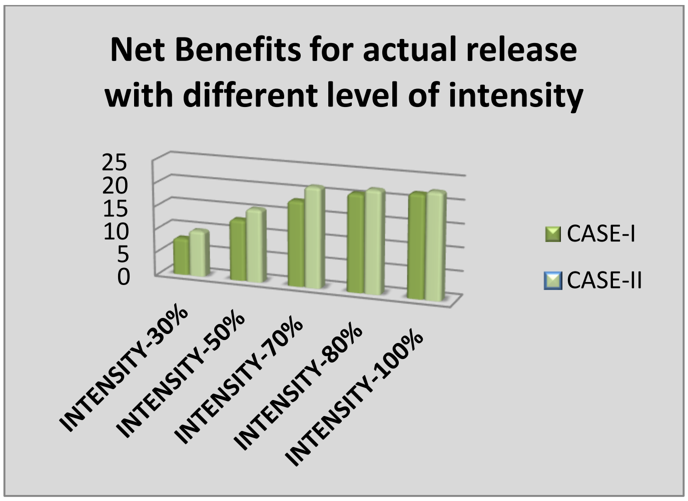

Fig. 1: Net Benefits For Actual With Different Level Of Intensity

- IN CASE OF Aj ≤ TIA
- IN CASE OF 0.75TIA ≤ Aj ≤ 1.25TIA

  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

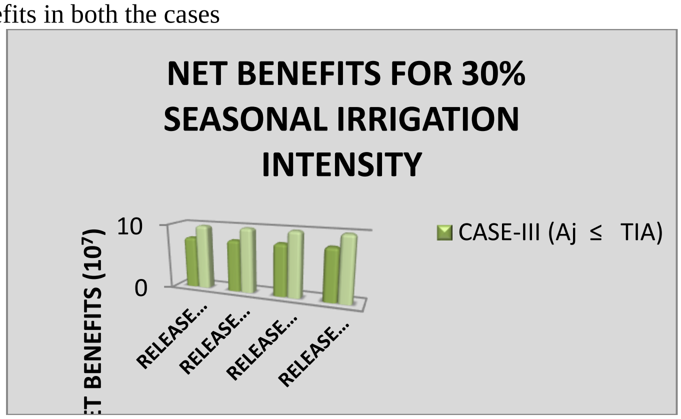

Fig. 2: Net Benefits For 30% Seasonal Irrigation Intensity

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

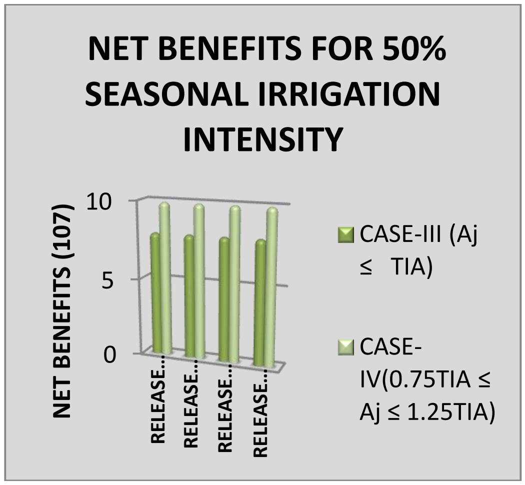

Fig. 3: Net Benefits For 50% Seasonal Irrigation Intensity

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.

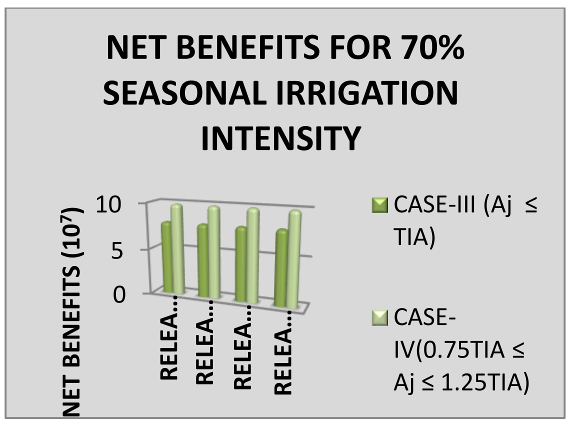

Fig. 4: Net Benefits For 70% Seasonal Irrigation Intensity

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.

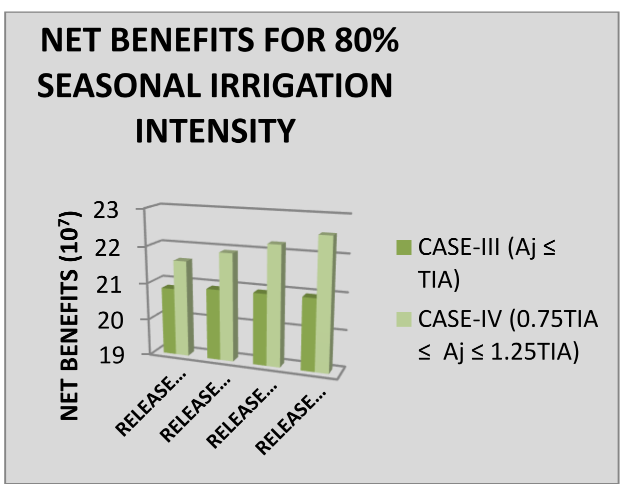

Fig. 5: Net Benefits For 80% Seasonal Irrigation Intensity

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.

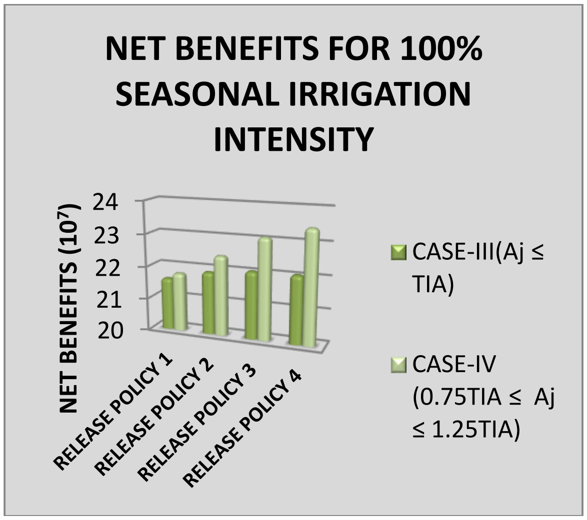

Fig. 6: Net Benefits For 100% Seasonal Irrigation Intensity

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.

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