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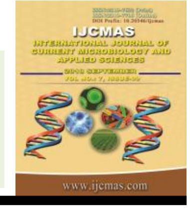

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Optimum Cropping Pattern based on Alternative Price Scenarios in Semi-Arid Eastern Plain Zone of Rajasthan State, India

M.K. Jangid*, Latika Sharma, S.S. Burark and D.C. Pant

Department of Agricultural Economics and Management, RCA, MPUAT, Udaipur, India

**Corresponding author*

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A B S T R A C T

The present study has analyzed the Optimum Cropping Patterin Semi-Arid Eastern Plain Agro-climatic Zone of Rajasthan state by using alternative three price scenarios namely market prices, economic prices (net out effect of subsidy) and natural resource valuation (NRV) considering environmental benefits like biological nitrogen fixation and greenhouse gas costs. In this study, unit-level cost of cultivation data for the triennium ending 2013-14 which were collected from Cost of Cultivation Scheme, MPUAT, Udaipur (Raj.) has been used. It has analyzed crop-wise use of fertilizers, groundwater, surface water, subsidies and optimum crop plan by using linear programming with the help of GAMS. Results from the present study indicated that even after netting out the input subsidies and effect on environment and natural resources, clusterbean-vegetable crop sequence produced the higher net return of ` 215187 per hectare followed by clusterbean-chillies (` 108590/ha) crop sequence under the set of marketing infrastructure, minimum support prices, agricultural technological know-how, climatic conditions and available irrigation facilities existed in this semi-arid eastern plain. Optimum crop plan model of this zone indicated that area shifted from sorghum, maize, cowpea and mothbean towards blackgram, greengram and clusterbean in kharif season whereas in rabi season, area shifted from cumin and onion towards the chillies, vegetables, gram and fenugreek and towards the rapeseed and mustard and wheat to some extent. Therefore, existing gross cropped area has increased at all the three price scenario by 13.49 per cent from 2719.13 thousand hectares to 3086.00 thousand hectares in optimal crop plan.

Introduction

Rajasthan with its huge geographical area of 342.7 lakh hectares is the largest state of India. The state is predominantly an agriculture state with 75 per cent population living in rural areas. Agriculture and allied activities contributed 21.71 per cent of Net State Domestic Product at constant price 2004-05 while its share in Gross State Domestic Product is 20.27 per cent during 2013-14. Agriculture is the single largest sector of the state economy employing 70 per cent labour force directly and indirectly. Rajasthan state has witnessed an extreme level of groundwater over-exploitation. Total annual groundwater draft in the state is 15.71 billion cubic meter which is higher than the sustainable limit of 11.26 billion cubic meter. Central ground water board has categorized 164 blocks out of

248 blocks as over-exploited which is 68.33 per cent of total assessment unit. Only 17.74 per cent (44 blocks) of the total blocks were categorized in safe category. Gross area irrigated by all sources during 2013-14 was 98.65 lakh hectares against 94.55 lakh hectares during 2012-13 registering an increase of 4.10 lakh hectare i.e. 4.34 per cent in Rajasthan.

Semi-arid eastern plain agro-climatic zone comprises four districts of Rajasthan state namely Ajmer, Dausa, Jaipur and Tonk. One third (33.82%) of gross cropped area is irrigated in this zone. Average annual rainfall is 500-700 mm. The depth of ground water level is on an average 21 meter below ground level (mbgl) and out of 31 block, 27 block in this zone have been classified as over exploited by the Central Ground Water Board (CGWB). The area produces bajra, sorghum and clusterbean in the *kharif* season. In the *rabi* season, wheat, barley and rapeseed & mustard are the dominant crops, especially in irrigated areas. Cropping pattern is inefficient in terms of resource use and unsustainable from natural resource use point of view. This leads to serious misallocation of resources, efficiency loss, indiscriminate use of land and water resources, and it adversely affecting long term production prospects. Crop selection at zonal level is one such challenge which can be addressed using optimum crop planning. As such regional crop planning is very crucial that helps to formulate zonal specific crop planning which would optimize the level of each activity of different crops, level of input use and output produced under different resource endowments and price scenarios. It involves area allocation for each of these crops, the sequencing of crops, and the irrigation plans. Best suitable crops and other enterprises should be selected so as to achieve some set of goals particular to the region. Typically, these goals involve the maximization of net income, the minimization of cost, the maximization of total area cultivated, and/or the minimization of irrigation water. Keeping in view the above considerations, a research study entitled "Optimum Cropping Pattern based on Alternative Price Scenarios in Semi-Arid Eastern Plain Zone of Rajasthan state" was conducted.

Materials and Methods

The study was conducted based on plot level secondary data. The data were collected from the 600 representative households of 60 cluster villages during each year of the block period (2011-12 to 2013-14) from the Cost of Cultivation Scheme, Rajasthan.

The comparative performance of different crops was assessed by comparing net returns under alternative price scenarios. These are: (i) Market Price (ii) Economic Price and (iii) Natural Resource Valuation Technique (Raju *et al.*, 2015).

Net Returns at Market Prices (NR_{MP})

Net returns at market price was defined as the gross return (value of main product and by product) less variable costs (Cost A1 + imputed value of family labour) at market price actually paid and received by the farmer or imputed in some cases.

$NR_{MP} = GR – VC$ (i)

Where,

NR_{MP} – Net return at market price,
GR- Gross Returns and
VC- Variable Cost.

Cost A_1 as defined in Manual on Cost of Cultivation Scheme, DES, New Delhi includes all actual expenses in cash and kind in production by the farmer. Some of the components of cost A_1 directly retrieved from the unit level data set of cost of cultivation scheme, while few are estimated for example: depreciation of implements and farm building, interest on working capital has been computed by using the method elaborated in the manual on CCS.

The imputed value of family labour has been calculated as:

Imputed Value of Family Labour = Working Hours of Family Labour × Labour Wage Rate per Hour

Net Returns at Economic Price (NR_{EP})

Net return at economic price was defined as the difference between net return or income at market price and subsidies on inputs like fertilizers and irrigation used in crop production.

i.e. $NR_{EP} = NR_{MP} – Subsidy$ (ii)

Thus, subsidy component has internalized into the model, by covering two aspects viz., fertilizer subsidy and irrigation subsidy. Fertilizer subsidy consisted subsidy on nitrogen (N) and combination of Phosphorous (P) and Potassium (K). The total irrigation subsidy included canal, electricity and diesel subsidy and has been distributed over selected crops based on area under irrigation of each crop. Crop wise irrigation subsidy has two components: Ground water subsidy and Surface water subsidy. Ground water subsidy was estimated by initially calculating the crop-wise ground water use, i.e.

Groundwater use (cubic metre) = Irrigation hours (hrs/ha) × Groundwater draft (cum/hr)

The irrigation hours (hrs/ha) for each crop were taken from plot-wise CCS data. CCS does not collect information of ground water draft. Therefore, the groundwater draft was estimated using the following formula:

$$\text{Ground water draft (lit/sec)} = \frac{\text{HP} \times 75 \times \text{Pump Efficiency}}{\text{Total Head (m)}}$$

The information on horse power (HP) of the pumps owned by the farmers was available in CCS data set. For the households purchasing groundwater, average HP of the pumps (estimated separately for electric and diesel) in respective tehsil can be taken as proxy. Pump efficiency was assumed to be 40 per cent. The total head was obtained as per below equation:

Total head =Water level (mbgl) + Draw down (m) + Friction loss (10% of water level+ Draw down)

Net Returns based on Natural Resource Valuation (NR_{NRV})

Net return based on Natural Resource Valuation (NRV) technique has taken care of nitrogen fixation by legume crops and Green House Gas (GHG) emission from crop production. As such NR_{NRV} was computed by adding value of nitrogen fixation by legume crops at economic price of nitrogen (Value of N) and deducting the imputed value of increase in GHG emission cost to the atmosphere

i.e. $NR_{NRV} = NR_{EP}$ + (Value of N– cost of GHG) (iii)

Thus, legumes are environment-friendly crops and are different from other food plants because of the property of synthesizing atmospheric nitrogen into plant nutrients.

As such, the economic valuation has been done by taking into account the positive externality of legume crops by biological nitrogen fixation and the negative externality of GHG emissions.

Optimization of crop model

The Mathematical Programming was used for developing optimum crop or land use planning. The present study attempted to develop different crop planning strategies by using linear programming (LP). The above linear programming model has been executed under General Algebraic Modeling System (GAMS, Version: 12/2016). It develops the crop model which increases the productivity with minimum input cost under the constraints of available resources like water usage and also labour, fertilizers, seeds, etc., and ultimately getting maximum net benefits. Multi-crop model for two seasons are formulated in LP for maximizing the net returns, minimizing the cost and minimizing the water usage by keeping all other available resources (such as cultivable land, seeds, fertilizers, human labour, pesticides, capital etc.) as constraints (Appendix I and II).

Theoretical formulation of the LP model

The present study made an attempt to develop different crop planning strategies by using linear programming (LP). Multi-crop model for two seasons were formulated in LP for maximizing the net returns by keeping cultivable land and available ground water.

Mathematical specifications of the model

Mathematically, model specification for semi-arid eastern plain agro-climatic zone of Rajasthan state were presented by Equations 1-6 followed by equation wise description.

$$\text{Max } Z = \sum_{c=1}^{n} Y_c P_c — C_c)\, A_c \qquad (1)$$

$$\sum_{T} \sum_{c} a_{tc} A_c \quad < \quad NS_t — OA_t \qquad (2)$$

$$A_c \quad > \quad A\ \text{min}_c \qquad (3)$$

$$A_c \quad < \quad A\ \text{max}_c \qquad (4)$$

$$\sum_{C} w_c A_c \quad < \quad RGWAA \qquad (5)$$

$$A_c \quad > \quad 0 \qquad (6)$$

Objective function: Maximization of net income (Equation 1)

$$\sum_{c=1}^{n} (Y_c P_c - C_c) A_c$$

Let,

Y_c: denotes yield of a crop *c* in one hectare of land,

P: the price received for the output from crop c,

C_c: refers to the cost incurred to cultivate crop c in one hectare of land and

A_c: is the area under cultivation of crop c

Then the RHS of the Equation 1 represents sum of net revenue obtained from all the crops considered for the optimum model development. The objective was to maximize the net revenue (z) based on the optimum crop plan.

Land constraint

Optimum use of land for each month is required. This has achieved by having separate constraint equation (Equation 2 is a compact form of 12 equations one for each month as shown below). This helps to have separate sown area for each month and ensures that total cultivated area under selected crops in each month should be less than net sown area (NS_t) minus area under orchard (OA_t) crops. Further crop calendar has to be maintained as per format (Crop Calendar for Semi-Arid Eatern Plain). Thus, a_{tc} in equation 2 refers to the coefficient of crop calendar matrix for t^{th} month and c^{th} crop.

$$\sum^{C} a_{Jan\,c} A_c \qquad NS_{Jan} - OA_{Jan}$$

$$\sum^{C} a_{Feb\,c} A_c \qquad NS_{Feb} - OA_{Feb}$$

$$\sum^{C} a_{Mar\,c} A_c \qquad NS_{Mar} - OA_{Mar}$$

$$\sum^{C} a_{Apr\,c} A_c \qquad NS_{Apr} - OA_{Apr}$$

$$\sum^{C} a_{May\,c} A_c \qquad NS_{May} - OA_{May}$$

$$\sum^{C} a_{Jun\,c} A_c \qquad NS_{Jun} - OA_{Jun}$$

$$\sum^{C} a_{Jul\,c} A_c \qquad NS_{Jul} - OA_{Jul}$$

$$\sum^{C} a_{Aug\,c} A_c \qquad NS_{Aug} - OA_{Aug}$$

$$\sum^{C} a_{Sep\,c} A_c \qquad NS_{Sep} - OA_{Sep}$$

$$\sum^{C} a_{Oct\,c} A_c \qquad NS_{Oct} - OA_{Oct}$$

$$\sum^{C} a_{Nov\,c} A_c \qquad NS_{Nov} - OA_{Nov}$$

$$\sum^{C} a_{Dec\,c} A_c \qquad NS_{Dec} - OA_{Dec}$$

$$\sum \sum^{C} a_{tc} A_c \qquad NS_t - OA_t$$

Minimum and maximum constraints (Equation 3-4)

Crop planning model using LP primarily captures the supply side behavior specifically area response based on net returns and resource constraints ignoring the demand aspect. Such models tend to over-estimate or under-estimate the area allocations for some crops. As consequences, a single crop may cover infeasible larger area (over-estimation) or null/negligible area (under-estimation).

In some modelling solutions, some major crops may drastically lose their relevance and the corresponding area allocations may become negligible. Then, even though estimates are robust and mathematically proven, such allocations may not be desirable and practically possible from the view point of food security of the country and livelihood security of the farmer because appropriate changes are required in policy framework of the country to adopt the optimum sustainable model. Similarly, area allocations for some crops may be over-estimated ignoring the demand. Such an area allocation is again undesirable as it may lead to glut in the market. To avoid such undesirable over-estimation or under estimation, assigning values to minimum and maximum area of the selected crops become essential in the model. To eliminate such practically undesirable solutions, concept of min, max constraints was used in the model as specified by equation 3-4.

Groundwater constraints

Water is a scarce natural resource. The ground water usage should be less than or equal to replenishable ground water available for agriculture (RGWAA) for making the agriculture sustainable. Data of RGWAA was published by Central Ground Water Board. RGWAA was estimated by deducting water consumed by industries and other non-farm sectors from total replenishable ground water.

Ground water constraint to be used in linear programming (LP) model for Semi-Arid Eastern Plain Zone of Rajasthanian agriculture was as follows:

$$\sum w_c A_c < RGWAA$$

Where,

w_c: actual water drafted for a crop c in recent years based on Cost of Cultivation data.

A_c: refers to the area allocation for a crop c.

Existing land area allocations under different crops are useful to make comparison with optimum crop plan model. The data is available from statistical abstracts of Rajasthan. This data is further useful for defining minimum and maximum area allocation limits for the selected crops. Existing area is based on the three years average land use under the crops. Minimum and maximum area has been determined based on expert elicitation method.

Results and Discussion

Cost and returns of various crops in semi-arid eastern plain zone of Rajasthan state during TE 2013-14

The cost and returns of various crops on alternative price scenario *i.e.* based on market price, based on economic price and based on natural resource valuation are estimated and presented separately for Semi-Arid Eastern Plain Zone of Rajasthan state during TE 2013-14:

Comparative cost and returns based on Market Price (MP)

The comparative returns at market price along with variable cost for various crops in Semi-Arid Eastern Plain during TE 2013-14 were analyzed and presented in Table 1. The cost structure varied across various crops. Among the *kharif* crops, cotton cultivation was at the higher end with variable cost of ` 48332 per hectare followed by groundnut (` 27086/ha), maize (` 25361/ha), mothbean (` 25353/ha) and it was lowest in cowpea *i.e.*` 10009 per hectare while variable cost among the *rabi* crops was found highest in onion *i.e.*` 71541 per hectare followed by chillies (` 51879/ha), vegetables (` 45023/ha), barley (` 42955/ha), wheat (` 41732/ha) and it was seen lowest in gram (` 15440/ha).Among the *kharif* crops, cotton has shown the highest gross return (` 60991/ha) followed by clusterbean (` 60022/ha), groundnut (` 44486/ha) and it was lowest in cowpea (` 5156/ha) whereas among the *rabi* crops, vegetables has shown the highest gross return (` 220113/ha) followed by chillies (` 121316/ha) and it was lowest in cumin (` 22516/ha). The return depends on the cost of cultivation as well as on productivity of crop and its prices existed in the market during the harvesting period. Among the *kharif* crops, the net return over variable cost was found highest in clusterbean cultivation *i.e.*` 40054 per hectare because of lesser the variable cost as per competing crops like cotton (` 12659/ha) and groundnut (` 17400/ha) and lowest in blackgram (` 1127/ha) while in *rabi* crops, the net return over variable cost was highest in vegetable cultivation of ` 175090 per hectare followed by chillies (` 69437/ha) and it was lowest found in cumin (` 3246/ha). The crops like mothbean, cowpea and maize have shown the negative net return over the variable cost.

Net returns based on Economic Price (EP)

The results presented in table 2 indicated that the NPK subsidy was use highest in wheat cultivation of ` 2815 per hectare followed by chillies (` 2214/ha), barley (` 2154/ha) and it was lowest in sesamum cultivation (` 47/ha). Electricity subsidy was found highest in chillies cultivation of (` 1711/ha) followed by vegetables (` 1286/ha) and lowest in clusterbean (` 16/ha). Cultivation of sorghum has shown the highest use of diesel subsidy of ` 459 per hectare followed by onion (` 459/ha). Thus, overall total subsidy was used highest in wheat of ` 4019 per hectare followed by chillies (3925/ha) and barley (` 3661/ha) because of the higher use of fertilizer component in the cultivation of these crops. Among the all crops, the minimum subsidy was used in cultivation of sesamum of ` 64 per hectare because of lesser use of fertilizers and irrigation facilities. The table 2 revealed that among the *kharif* crops, the net returns at economic prices was highest in clusterbean cultivation which remains the most remunerative crop in *kharif* season with net return of ` 39780 per hectare followed by groundnut (` 15374/ha) and lowest in blackgram (` 729/ha) while among the *rabi* crops, the highest net return based on economic prices was observed in vegetable cultivation with ` 172109 per hectare which remains the most superior crops in financial aspects in *rabi* season followed by chillies (` 65512/ha) and lowest in cumin (` 336/ha).

Net returns based on Natural Resource Valuation (NRV)

Results from the table 3 revealed that groundnut cultivation has shown the highest nitrogen fixation equivalent to the economic contribution with ` 4560 per hectare while greengram and mothbean fixed the nitrogen worth ` 2235 per hectare. Chillies and vegetables caused the highest negative externalities by producing GHGs costing ` 235 per hectare whereas the minimum GHG cost incurred by the crops like cowpea, blackgram, greengram, mothbean and gram worth ` 97 per hectare. The results from the table 3 indicated that the net return among the *kharif* crops to be highest in clusterbean with ` 43313 per hectare and lowest in sorghum (` 2054/ha) whereas among the *rabi* crops, the highest net return was found in vegetable cultivation with ` 171874 per hectare followed by chillies (` 65277/ha), barley (` 27678/ha) and it was seen lowest in cumin (` 336/ha) on adding the benefit of nitrogen fixation and deducting the GHG costs from the net returns based on economic prices.

The crops like mothbean, maize and cowpea has also shown the negative return based on natural resource valuation.

Table.1 Comparative Cost and Returns of Various Crops based on Market Price in Semi-Arid Eastern Plain during TE 2013-14 (`/ha)

S. No.	Crops	Variable Cost (A1+FL)	Gross Return	Net Return at Market Price
A	**Kharif Crops**			
1	Bajra	22553	30964	8411
2	Sorghum	14122	17497	3375
3	Maize	25361	22215	-3146
4	Cowpea	10009	5156	-4853
5	Blackgram	16307	17433	1127
6	Greengram	15520	21984	6464
7	Mothbean	25353	10483	-14869
8	Sesamum	11188	17373	6185
9	Groundnut	27086	44486	17400
10	Cotton	48332	60991	12659
11	Clusterbean	19968	60022	40054
B	**Rabi Crops**			
1	Wheat	41732	68361	26629
2	Barley	42955	74406	31451
3	Gram	15440	34301	18861
4	Rapeseed & Mustard	24022	52717	28694
5	Cumin	19270	22516	3246
6	Fenugreek	18346	46093	27747
7	Onion	71541	75053	3511
8	Chillies	51879	121316	69437
9	Vegetable	45023	220113	175090

Source: Plot Level Cost of Cultivation Data of Rajasthan (TE 2013-14)

Table.2 Crop-wise net returns based on economic price in semi-arid eastern plain during TE 2013-14 (`/ha)

S. No.	Crops	NPK Subsidy	Electricity Subsidy	Diesel Subsidy	Total Subsidy	Net Return at Economic Price
A	**Kharif Crops**					
1	Bajra	991	82	80	1152	7259
2	Sorghum	467	---	742	1209	2166
3	Maize	718	165	73	956	-4102
4	Cowpea	92	---	---	92	-4945
5	Blackgram	398	---	---	398	729
6	Greengram	497	---	---	497	5967
7	Mothbean	---	---	---	---	-14869
8	Sesamum	47	17	---	64	6121
9	Groundnut	1092	712	222	2026	15374
10	Cotton	1699	854	382	2935	9724
11	Clusterbean	258	16	---	274	39780
B	**Rabi Crops**					
1	Wheat	2815	1204	---	4019	22611
2	Barley	2154	1202	305	3661	27790
3	Gram	622	130	---	753	18109
4	Rapeseed & Mustard	1623	440	---	2063	26632
5	Cumin	1448	1092	370	2910	336
6	Fenugreek	364	78	240	681	27066
7	Onion	1917	301	459	2677	835
8	Chillies	2214	1711	---	3925	65512
9	Vegetable	1696	1286	---	2982	172109

Source: Estimated using Plot Level Cost of Cultivation Data of Rajasthan (TE 2013-14)
Note: Subsidy @ ` 24.00/kg of N, ` 24.27/kg of P and ` 23.19/kg of K for TE 2013-14, Diesel Subsidy @ ` 12.95 per litre, Electricity subsidy @ ` 3.03 per unit during TE 2013-14

Table.3 Crop-wise net returns based on natural resource variation in semi-arid Eastern plain during TE 2013-14 (`/ha)

S. No.	Crops	Value of Nitrogen	Value of GHG	Net Return based NRV
A	**Kharif**			
1	Bajra	0	112	7147
2	Sorghum	0	112	2054
3	Maize	0	159	-4261
4	Cowpea	3110	97	-1932
5	Blackgram	2506	97	3138
6	Greengram	2235	97	8105
7	Mothbean	2235	97	-12731
8	Sesamum	0	115	6006
9	Groundnut	4560	115	19819
10	Cotton	0	NA	9724
11	Clusterbean	3533	NA	43313
B	**Rabi**			
1	Wheat	0	183	22428
2	Barley	0	112	27678
3	Gram	3140	97	21152
4	Rapeseed & Mustard	0	115	26517
5	Cumin	0	NA	336
6	Fenugreek	0	NA	27066
7	Onion	0	NA	835
8	Chillies	0	235	65277
9	Vegetable	0	235	171874

Source: Estimated by using Plot Level Cost of Cultivation data for TE 2013-14 and based on Peoples *et al.*, (1995), IIPR (2003) and IARI (2014).

Table.4 Net returns from different crops using various approaches of valuation in semi-arid Eastern plain during TE 2013-14 (`/ha)

S. No.	Crops	Net Return at Market Price	Net Return at Economic Price	Net Return at Natural Resource Valuation
A	**Kharif Crops**			
1	Bajra	8411	7259	7147
2	Sorghum	3375	2166	2054
3	Maize	-3146	-4102	-4261
4	Cowpea	-4853	-4945	-1932
5	Blackgram	1127	729	3138
6	Greengram	6464	5967	8105
7	Mothbean	-14869	-14869	-12731
8	Sesamum	6185	6121	6006
9	Groundnut	17400	15374	19819
10	Cotton	12659	9724	9724
11	Clusterbean	40054	39780	43313
B	**Rabi Crops**			
1	Wheat	26629	22611	22428
2	Barley	31451	27790	27678
3	Gram	18861	18109	21152
4	Rapeseed & Mustard	28694	26632	26517
5	Cumin	3246	336	336
6	Fenugreek	27747	27066	27066
7	Onion	3511	835	835
8	Chillies	69437	65512	65277
9	Vegetable	175090	172109	171874

Source: Plot Level Cost of Cultivation Data of Rajasthan (TE 2013-14)

Table.5 Optimum crop models during TE 2013-14

S. No.	Crops	Existing Area (000 ha)	Optimum Area (000 ha)			Direction of Change
			At Market Price	At Economic Price	At Natural Resource Valuation	
A	**Kharif Crops**					
1	Bajra	556.70	567.83	567.83	567.83	+ + +
2	Sorghum	215.95	118.77	118.77	118.77	– – –
3	Maize	45.29	11.32	11.32	11.32	– – –
4	Cowpea	11.74	0.59	0.59	0.59	– – –
5	Blackgram	47.25	92.13	92.13	92.13	+ + +
6	Greengram	248.46	484.50	484.50	484.50	+ + +
7	Mothbean	1.67	0.08	0.08	0.08	– – –
8	Sesamum	64.74	67.98	67.98	67.98	+ + +
9	Groundnut	82.12	86.23	86.23	86.23	+ + +
10	Cotton	16.21	17.02	17.02	17.02	+ + +
11	Clusterbean	95.40	138.33	138.33	138.33	+ + +
B	**Rabi Crops**					
1	Wheat	361.29	379.35	379.35	379.35	+ + +
2	Barley	99.01	103.96	103.96	103.96	+ + +
3	Gram	305.42	381.77	381.77	381.77	+ + +
4	Rapeseed & Mustard	502.28	552.51	552.51	552.51	+ + +
5	Cumin	17.71	0.89	0.89	0.89	– – –
6	Fenugreek	3.35	4.19	4.19	4.19	+ + +
7	Onion	4.38	0.22	0.22	0.22	– – –
8	Chillies	1.74	3.39	3.39	3.39	+ + +
9	Vegetables	38.43	74.94	74.94	74.94	+ + +
C	**Gross Cropped Area**	**2719.13**	**3086.00**	**3086.00**	**3086.00**	+ + +

Table.6 Gains due to optimum crop model over existing scenario during TE 2013-14

S. No.	Optimum Scenario	Change in GCA (%)	Existing Revenue (` in Lacs)	Optimum Net Return (` in Lacs)	Change in Farmers Revenue (Optimal-Existing MP	Gains to Society (` in Lacs)	Net Gain (` in Lacs)
1	Market Price	13.49	526.25	659.52	133.27	0.00	133.27
2	Economic Price	13.49	480.25	610.24	83.99	46.01	130.00
3	Natural Resource Valuation	13.49	500.95	640.68	114.43	25.31	139.74

Appendix-I Coefficients used in development of optimal crop plan in semi-arid Eastern plain agro-climatic zone of Rajasthan state during TE 2013-14

Crops	Existing Area ('000 ha)	Minimum Area ('000 ha)	Maximum Area ('000 ha)	Net Return at Market Price (Rs./ha)	Ground Water Draft (cum/ha)	Net Return at Economic Price (Rs./ha)	Net Return at NRV (Rs./ha)	Subsidy (Rs./ha)	Total Subsidy (Rs.)
Rapeseed & Mustard	502.28	452.05	552.51	28694.45	1139.87	26631.63	26516.63	2062.82	1036113.12
Bajra	556.70	501.03	612.37	8411.30	297.73	7259.13	7147.13	1152.17	641411.65
Barley	99.01	89.11	108.91	31450.94	2962.79	27789.95	27677.95	3660.99	362485.74
Cotton	16.21	14.59	17.83	12659.22	3562.69	9723.93	9723.93	2935.29	47586.90
Gram	305.42	274.88	335.96	18861.29	268.46	18108.74	21151.74	752.56	229843.95
Groundnut	82.12	73.91	90.34	17399.50	2160.53	15373.95	19818.95	2025.55	166345.55
Clusterbean	95.40	85.86	104.94	40053.60	46.09	39779.59	43312.59	274.02	26140.34
Sorghum	215.95	194.35	237.54	3375.17	1195.16	2166.49	2054.49	1208.68	261012.01
Fenugreek	3.35	3.01	3.68	27746.92	445.24	27065.73	27065.73	681.19	2281.07
Greengram	248.46	223.61	273.31	6463.84	0.00	5967.07	8105.07	496.77	123426.70
Mothbean	1.67	1.50	1.83	-14869.44	0.00	-14869.44	-12731.44	0.00	0.00
Onion	4.38	3.94	4.82	3511.49	1617.96	834.61	834.61	2676.88	11730.99
Sesamum	64.74	58.27	71.22	6185.43	49.01	6121.09	6006.09	64.34	4165.28
Vegetables	38.43	34.59	42.27	175090.33	2653.03	172108.62	171873.62	2981.71	114587.20
Wheat	361.29	325.16	397.42	26629.32	3177.38	22610.55	22427.55	4018.77	1451938.46
Cumin	17.71	15.94	19.48	3245.90	2842.30	336.12	336.12	2909.78	51529.29
Blackgram	47.25	42.52	51.97	1126.87	0.00	728.80	3137.80	398.07	18807.82
Chillies	1.74	1.56	1.91	69437.17	4000.32	65512.16	65277.16	3925.00	6822.97
Cowpea	11.74	10.56	12.91	-4852.57	0.00	-4944.77	-1931.77	92.20	1082.15
Maize	45.29	40.76	49.82	-3145.96	457.89	-4101.86	-4260.86	955.90	43292.52

Appendix-II Crop calendar matrix for semi-arid Eastern plain agro-climatic zone of Rajasthan state

Crop	Rapeseed & Mustard	Bajra	Barley	Cotton	Gram	Groundnut	Clusterbean	Sorghum	Fenugreek	Greengram	Mothbean	Onion	Sesamum	Vegetables	Wheat	Cumin	Blackgram	Chillies	Cowpea	Maize
Jan	1	0	1	0	1	0	0	0	1	0	0	1	0	0	1	1	0	1	0	0
Feb	1	0	1	0	1	0	0	0	1	0	0	1	0	0	1	1	0	1	0	0
Mar	0.5	0	0.5	0	0.5	0	0	0	0.5	0	0	1	0	0.5	1	0.5	0	0.5	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0.5	0	1	0.5	0	0	0	0	0
May	0	0	0	0.5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Jun	0	0.5	0	1	0	0.5	1	0.5	0	0.5	0.5	0	0.5	1	0	0	0.5	0	0	0.5
Jul	0	1	0	1	0	1	1	1	0	1	1	0	1	0.5	0	0	1	0	1	1
Aug	0	1	0	1	0	1	1	1	0	1	1	0	1	0	0	0	1	0	1	1
Sep	0	1	0	1	0	1	1	1	0	1	1	0	0.5	0	0	0	1	0	1	1
Oct	0.5	0.5	0.5	1	0	0	0	0.5	0	0	0	0.5	0	0	0	0	0	0.5	0.5	0.5
Nov	1	0	1	0.5	0.5	0	0	0	0.5	0	0	1	0	0	0.5	0.5	0	1	0	0
Dec	1	0	1	0	1	0	0	0	1	0	0	1	0	0	1	1	0	1	0	0

Comparative returns of crops using various approaches of valuation

Table 4 indicated that there was moderate to high decline in net return from the various crops after subtracting the subsidies on fertilize, electricity and diesel. The impact of subsidy was so large in the cultivation of wheat, chillies, barley, cotton and groundnut. The withdrawal of the subsidies has reduced the net income. Due to the high rate of profitability in cultivation of vegetables, chillies, clusterbean, the removal of subsidies reduced the net income marginally. The positive impact of biological nitrogen fixation through the legume crops, the profitability in legume crops has increased and the deduction of GHG costing reduced the net income of various crops. After netting out the subsidies, adding the positive benefits to environment by legume crops and deducting the GHG costing from various crops, the clusterbean-vegetable cropping pattern was found the most superior, stable and produces the higher financial net return of ` 215187 per hectare followed by clusterbean-chillies (` 108590/ha) cropping pattern under the set of marketing infrastructure, irrigation facilities, higher the productivity, minimum support prices and available modern technologies for the cultivation of these crops.

Optimum crop model

The optimum crop plan during TE 2013-14 at existing ground water scenario are presented in Table 5. The gross cropped area was 2719.13 thousand hectares during TE 2013-14. In *kharif* season, bajra (556.70 thousand hectares), greengram (248.46 thousand hectares), sorghum (215.95 thousand hectares), clusterbean (95.40 thousand hectares) and groundnut (82.12 thousand hectares) were the major crops during the study period. Area under blackgram and greengram has been increased by 95 per cent followed by clusterbean (45%), sesamum, groundnut and cotton by 5 per cent and bajra by 2 per cent while the area share in mothbean and cowpea has declined by 95 per cent followed by maize (75%) and sorghum (45%). It was observed that area in optimum crop plan at all three price scenario shifted from mothbean, cowpea, maize and sorghum towards blackgram, greengram and clusterbean. In *rabi* season, rapeseed & mustard (18.47 per cent of GCA), wheat (13.29 per cent of GCA), gram (11.23 per cent of GCA) and barley (3.64 per cent of GCA) were the major crops in the zone during the study period. The optimal plan has allocated about 95 per cent more area to chillies and vegetables followed by gram (25%), fenugreek (25%), rapeseed & mustard (10%) and wheat by 5 per cent whereas area under cumin and onion have declined by almost 95 per cent. Under the optimal crop plan, the area from cumin and onion has been shifted towards chillies and vegetables.

Gain due to optimum crop plan at existing ground water scenario during TE 2013-14 is presented in Table 6. The gross cropped area has increased at all the three price scenario by 13.49 per cent from 2719.13 thousand hectares to 3086.00 thousand hectares in optimal crop plan. The farmer's revenue has increased at market price, economic price and natural resource valuation of ` 133.27 lakh, ` 83.99 lakh and ` 114.43 lakh, respectively. Estimated net gains to the farmer's perspective amounted to ` 133.27 lakh which went up to 139.74 lakh at natural resource valuation. At economic prices and natural resource evaluation, the society has gained by 46.01 lakh and 25.31 lakh, respectively.

Finally, it can be concluded that even after netting out the input subsidies and effect on environment and natural resources, clusterbean-vegetable crop sequence produced the higher net return of ` 215187 per hectare followed by clusterbean-chillies (` 108590/ha) crop sequence under the set of marketing infrastructure, minimum support prices, agricultural technological know-how, climatic conditions and available irrigation facilities existed in the zone. Optimum crop plan model of this zone indicated that area shifted from sorghum, maize, cowpea and mothbean towards blackgram, greengram and clusterbean in *kharif* season whereas in *rabi* season, area shifted from cumin and onion towards the chillies, vegetables, gram and fenugreek and towards the rapeseed and mustard and wheat to some extent. Therefore, existing gross cropped area has increased at all the three price scenario by 13.49 per cent from 2719.13 thousand hectares to 3086.00 thousand hectares in optimal crop plan. The factors that are not captured by the market like subsidies is the direct cost to the society, factors affecting the natural resources and environment as nitrogen fixation and greenhouse gas costs, need to be considered and should be internalized through appropriate policies. Reckoning such costs and return alters the level of net income from various crops.

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