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Natural resource management for doubling farmer's income: An approach for optimization of crop planning in humid Southern plain zone of Rajasthan state (India)

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Abstract
The present study was undertaken to estimate the natural resource management for doubling the farmer's income through the optimization of crop panning approach in the Humid Southern Plain Zone of Rajasthan state. In this study, a cluster-based cost of cultivation data of various crops for the triennium ending year 2013-14 were collected from "Comprehensive Scheme to Study the Cost of Cultivation of Principal Crops in Rajasthan state" MPUAT, Udaipur (Rajasthan). The economic performance of various crops was estimated by analyzing the net returns based on existing market prices, economic prices and natural resource valuation. This research analysis considered the subsidy as a cost to society. Similarly, green-house gas emissions from the crops have been taken as the cost to the society and nitrogen fixation by leguminous crops have been taken as beneficial returns to the society. Major findings from the research study shown that the soybean – rapeseed and mustard crop sequence were produced the highest net return of ₹60123 per hectare followed by soybean – wheat (₹58973/ha), lentil – rapeseed and mustard (₹58541/ha), lentil – wheat (₹57391/ha) in the Humid Southern Plain Zone of Rajasthan state. Under optimum allocation of crop area, more area allocated to maize, soybean and cotton in *kharif* season and wheat, gram and rapeseed and mustard in *rabi* season was suggested to enhancing the farmers income with sustainable use of available ground water. The optimum plans developed in the study suggested that state government as well as district administration/agriculture department should promote cultivation of specific crops in this zone through providing the more incentives or subsidies on inputs like seed, fertilizers, agricultural implements, irrigation facilities, etc. More water intensive but remunerative crops like cotton, soybean, paddy and sugarcane should be promoted where surface water resources are available.

Keywords: Natural resource management, farmer's revenue, optimum cropping pattern and humid Southern plain zone

Introduction
Agriculture sector being the largest user of available groundwater resources (CGWB, 2013) bears the prime responsibility in averting the groundwater crisis. CGWB, a nodal agency for monitoring groundwater resources, carries out periodic assessment of groundwater use for different sectors like irrigation, domestic, industry of the country but such estimates are not available for individual crops within the agriculture sector. Total annual replenishable groundwater potential in Rajasthan has been estimated as 12.51 billion cubic meter (BCM) and rainfall contributes 74.58 per cent in total groundwater recharge. Out of total replenishable, 11.26 billion cubic meters (BCM) can be made available for different uses annually, keeping aside 1.26 billion cubic meters (BCM) for natural discharge. With an annual ground water draft of 15.71 billion cubic meter (irrigation consuming 87.78 per cent of total draft), overall groundwater development in the state is 139.52 per cent. However, groundwater development is not uniform across geographical regions. Rajasthan state has witnessed an extreme level of groundwater over-exploitation. Total annual groundwater draft in the state is 15.71 billion cubic meters which is higher than the sustainable limit of 11.26 billion cubic meters. Central ground water board has categorized 164 blocks of the out of 248 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. This is an alarming situation for the agriculture sector (CGWB, 2013).
Due to unpredictable situation of monsoon mostly during first decade of the present century, the level of water table is going down in different parts of the state as well as this zone.

The area under almost crops except wheat, maize, sugarcane and potato had declined over the period due to inconsistent availability of water under study. The production of major crops like food-grains, pulses, oilseeds, etc. were found to be remaining stagnant. Under these conditions, the major question here arises that 'how to increase the income of the farming community in state out of shrinking net sown area with the use of cheap sources of energy for groundwater extraction, *i.e.* electric or solar energy which are comparatively cheap than diesel energy. Further, repairing and maintenance and expansion of surface irrigation system (canal) are very much essential for augmenting irrigation, recharge of groundwater as well as lessen the dependency on worsening weather situation. To meet the growing needs of nutritional security to an increasing population in present situation, it is imperative to bring more cultivable area under suitable crop cultivation or increase production per unit area of available cultivable land and water resources (Dahiphale *et al.* 2015) [3]. In Rajasthan state, there is a augmenting need to increase the income and employment of the farmers through optimal crop planning (Singh *et al.* 1990) [13]. Overall development scenario of the state as well as zone depends on agriculture as it is the backbone of the state economy (Singh *et al.* 2015) [14]. Agriculture depends on natural resources like land and water. Due to urbanization and a reluctance to disturb environments, there is difficult task to bring the additional land under agricultural uses or cultivation process. Therefore, it is very much important to optimize the utilization of available land and water resources to achieve maximum production with the minimal cost (Rani and Rao 2012) [11]. This requires proper planning and management process of land and water resources and appropriate use of available technologies. Here endeavor is being made to maximize the income of the cultivators from raising the crops, considering the important constraints, *viz*. land constraints and water constraints. Land constraint uses allocation of the minimum and maximum area for each crop grown in the state, assuming the considerable area under major staple food crops (paddy, wheat and maize etc.) from the food security point of view in the state (Singh *et al.* 1990) [13]. An attempt has been made in this paper, to revise the existing crop plan using linear programming considering land and water as constraints.

Data and research methodology

Present research study was based on plot-wise data collected under Comprehensive Scheme for Cost of Cultivation of Principal Crops (CCPC), Ministry of Agriculture and Farmers' Welfare, Government of India, running in MPUAT, Udaipur (Rajasthan). Useful secondary data for area of different crops were collected from various published issues of Directorate of Economics and Statistics, Government of Rajasthan. Data regarding groundwater use were obtained from the Annual Report of Central Groundwater Board, Government of India. The economic valuation of different crops was estimated by analyzing the net returns based on alternative three price scenarios which as follows: (i) Market Price (ii) Economic Price and (iii) Natural Resource Valuation Technique (Raju *et al.* 2015) [10].

Net returns based on market prices (NR_{MP})

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

$$NR_{MP} = GR - VC \;\ldots\ldots\ldots (i)$$

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, Directorate of Economics and Statistics, New Delhi includes all actual expenses in the form of cash and kind during the crop production taken by the farmer. Some of the important 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 various statistical methods 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 based on 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. $NR_{EP} = NR_{MP} - \text{Subsidy} \;\ldots\ldots\ldots (ii)$

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), 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 related to 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 estimating the value of natural resources has taken care about nitrogen fixation by legume crops and

Green House Gas (GHG) emission from crop production. As such NR_{NRV} was computed by adding the 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, legume crops are environment-friendly crops and are different from other food crops 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 by other crops.

Optimum Crop Plan

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 linear planning 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.

Mathematical Specifications of the Model

Mathematically, model specification for Humid Southern Plain Zone of Rajasthan state were presented by Equations 1-6 followed by equation wise description.

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

$$\sum_{T} \sum_{c} a_{tc}\, A_c \leq NS_t - OA_t \qquad (2)$$

$$A_c \geq A\ \min_c \qquad (3)$$

$$A_c \leq A\ \max_c \qquad (4)$$

$$\sum_{c} w_c\, A_c \leq RGWAA \qquad (5)$$

$$A_c \geq 0 \qquad (6)$$

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 right hand side of the equation 1 represents sum of net revenue obtained from all the crops considered for the optimum crop planning model development. The major 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 Rajasthan). Thus, a_{tc} in equation 2 refers to the coefficient of crop calendar matrix for t^th^ month and c^th^ crop.

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

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

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

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

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

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

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

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

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

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

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

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

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

Minimum and Maximum Constraints (Equation 3-4)

Optimization of crop plan model using linear programming approach primarily captures the supply side behavior specifically area response based on net returns and resource constraints ignoring the demand aspect. Such type of models tends to over-utilization or under-utilization the area allocations for some crops. As a consequences, a single crop may cover infeasible larger area (over-utilization) or negligible area (under-utilization).

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 used in linear programming model as follows:

$$\sum w_c A_c \leq RGWAA\ c$$

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 district-wise 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.

Result and Discussion

The structural management in the use of available natural resources brings about changes in the total cost structure to the extent to which these adjustments take place at the farm level. The costs and returns of the individual crop enterprise are also influenced largely depending upon the degree of changes taking place in the resource use structure. The quantum and proportion of out-of-pocket expenses and imputed costs in the total cost structure which, either increase or decrease depending upon changes in the use of different resources and substitution of one form of resource for another. It is a matter of worldwide phenomenon that, in the process of transformation of traditional agriculture into a modernized one, changes usually takes place through increased use of off-farm produced new forms of resources. The variable cost included the cost incurred on different inputs such as seed, fertilizer, manure, insecticides, irrigation, human labour (including family labour) and machine labour *etc.* the comparative return and profitability is affected by the factors like yield level, input use in production and their respective prices and output prices. The net return based on economic prices from various crops were computed by subtracting input subsidies like NPK subsidy, electricity subsidy and diesel subsidy. Agriculture has considerable effect on climate primarily through production and release of greenhouse gases such as carbon dioxide, methane and nitrous oxide. On the contrary, 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 impact of legume crops by biological nitrogen fixation and the negative impact of GHG emission. On adding these benefits and deducting the costs from net return based on economic price, we can get overall returns from cultivation of various crops to society and the natural resource valuation. In this view, the comparative returns at market price along with variable cost, net return based on economic price and net return based on natural resource valuation for various crops grown in the Humid Southern Plain Zone of Rajasthan were estimated and presented below.

The comparative cost and returns at all three price scenarios for various crops in Zone VIII (Humid Southern Plain) during TE 2013-14 showed that among *kharif* crops, the cotton cultivation was at higher end with the inclusion of highest variable cost of ₹38358 per hectare while among *rabi* crops, it was seen highest in garlic cultivation of ₹92207 per hectare. Among *kharif* crops, cotton cultivation has shown the maximum gross return with ₹54163 per hectare followed by lentil (₹40660/ha) whereas among *rabi* crops, the gross return was observed highest in garlic cultivation of ₹114152 per hectare followed by vegetables (₹73500/ha), wheat (₹68274/ha) and rapeseed & mustard (₹68262/ha). Based on market prices over variable cost, the net return was found highest in lentil of ₹20754 per hectare among *kharif* crops followed by soybean (₹20450/ha), paddy (₹18774/ha), maize (₹16620/ha) while it was observed highest in wheat (₹40666/ha) followed by rapeseed & mustard (₹40316/ha), garlic (₹21945/ha) among *rabi* crops. The net return based on economic prices was seen highest in lentil cultivation *i.e.* ₹19120 per hectare followed by soybean (₹18945/ha) among *kharif* crops while among *rabi* crops, it was seen highest in rapeseed & mustard cultivation (₹37543/ha) followed by wheat (₹36461/ha). Based on adding the benefits of nitrogen fixation and deducting the green-house gas emission costs, the net return was seen highest in soybean cultivation of ₹22695 per hectare and lowest in clusterbean cultivation (₹9184/ha) whereas among the *rabi* crops, it was found highest in rapeseed & mustard (₹37428/ha) followed by wheat (₹36278/ha) and fenugreek (₹20313/ha). Thus, over all study has shown that the soybean-rapeseed & mustard cropping pattern produces the higher net return of ₹60123 per hectare followed by soybean-wheat (₹58973/ha), lentil-rapeseed & mustard (₹58541/ha) and lentil-wheat (₹57391/ha) became the most stable and efficient cropping pattern under the given framework of marketing infrastructure, minimum support prices, technological improvement, climatic condition etc. in the Humid Southern Plain Zone. The farmers may not move towards the diversification until incentivized by economically attractive alternative cropping patterns.

Table 1: Comparative Cost and Returns of Various Crops based on Market Price, Economic Price and NRV in Zone VIII (Humid Southern Plain) during TE 2013-14 (₹/ha)

S. No.	Crops	Variable Cost (A1+FL)	Gross Return	Net Return at Market Price	NPK Subsidy	Electricity Subsidy	Diesel Subsidy	Total Subsidy	Net Return at Economic Price	Value of Nitrogen	Cost of GHG	Net Return at NRV
A	Kharif Crops											
1	Maize	24029	40649	16620	2699	265	298	3263	13358	0	159	13199
2	Paddy	21788	40562	18774	2490	---	---	2490	16284	0	1128	15156
3	Blackgram	20944	18223	-2720	1151	---	---	1151	-3872	2506	97	-1463
4	Greengram	24736	19501	-5235	306	228	---	534	-5769	2235	97	-3631
5	Lentil	19906	40660	20754	1634	---	---	1634	19120	1993	NA	21113
6	Soybean	18226	38676	20450	1504	---	---	1504	18945	3865	115	22695
7	Groundnut	33795	13532	-20263	3069	---	---	3069	-23332	4560	115	-18887
8	Cotton	38358	54163	15805	3682	---	---	3682	12123	0	NA	12123
9	Clusterbean	12166	18270	6104	440	13	---	453	5651	3533	NA	9184
B	Rabi Crops											
1	Wheat	27608	68274	40666	3270	936	---	4205	36461	0	183	36278
2	Barley	24539	31197	6657	1345	416	285	2045	4612	0	112	4500
3	Gram	20396	36831	16436	2383	221	42	2647	13789	3140	97	16832
4	Rapeseed & Mustard	27946	68262	40316	2387	350	36	2773	37543	0	115	37428
5	Fenugreek	19026	40727	21701	1388	---	---	1388	20313	0	NA	20313
6	Onion	61500	56186	-5314	5377	3659	---	9036	-14350	0	NA	-14350
7	Garlic	92207	114152	21945	3911	---	---	3911	18033	0	NA	18033
8	Vegetable	81612	73500	-8112	5244	---	---	5244	-13356	0	235	-13591

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 and based on Peoples *et al*. (1995), IIPR (2003) [5] and IARI (2014).

This zone covers the Banswara, Dungarpur, Pratapgarh and some part of Chittorgarh and Udaipur districts of Rajasthan state. It also covers the 5.48 per cent of states' geographical area. 27.50 per cent area under irrigated condition and average annual rainfall of this zone is 900-1000 mm. The depth of ground water level is approximately 2-20 meters below ground level. Two blocks of this zone are critical for ground water level; six blocks are semi-exploited while all the rest blocks are in safe category.

To ensure the sustainable use of groundwater in the zone, it is necessary to revisit the existing cropping pattern and develop optimum crop plan for the zone which maximize net returns not only to the farmers but also to the societies as a whole. Several research studies in the past conducted for development of optimum cropping pattern for maximizing net returns from farmers' perspective (Kaur *et al.* 2010, Husain *et al.* 2007 and Pradhan 2012) [7, 4, 9]. However, the studies ignored the social perspective and hence did not assess any benefits or losses to the society.

The present study attempts to fill this void and develop optimum crop plan for the zone by maximizing net returns based on three alternative approaches *i.e.* market price, economic price (net out effect of subsidies) and natural resource valuation (NRV) considering environmental benefits like biological nitrogen fixation and greenhouse gas costs. These three price scenarios are based on the arguments that the crop profitability should be linked with social cost, *i.e.* input subsidies and effect of environment and natural resources (Raju *et al.* 2015) [10]. Computing net returns at market prices of inputs represents income to the producer but not to the society as it is a direct cost to the society. Thus, while computing the returns to the society, subsidy has been suitably accounted for. Further, positive and negative environmental externalities need to be accounted that has a direct bearing to the society. Linear programming model was formulated to propose optimal cropping pattern for maximizing net returns based on three different price scenarios for given water supply situation. The study also attempts to safeguard savings of groundwater to ensure the sustainable use of groundwater in the zone. The linear programming model has been executed under General Algebraic Modeling System (GAMS).

The optimum crop plan and gain to society for Zone VIII (Humid Southern Plain) at existing groundwater use during TE 2013-14 were analyzed and presented in Table 2 and 3. From the results of Table 2, Maize (40.62 per cent of GCA), soybean (12.93 per cent of GCA) and paddy (5.26 per cent of GCA) were the major crops cultivated in *kharif* season. The area allocated to cotton has increased by 10 per cent from 17.11 thousand hectares to 18.83 thousand hectares in optimal crop plan. Positive change in the acreage of crops like maize, paddy, blackgram, greengram, lentil and soybean by 5 per cent each due to favorable trade-off between water and net returns in these crops while optimal crop plan reduced the groundnut and clusterbean acreage by 95 per cent each *i.e.* from 3.57 thousand hectares to 0.18 thousand hectares in groundnut and from 14.84 thousand hectares to 0.74 thousand hectares in clusterbean. Thus, it was observed that the area from groundnut and clusterbean have shifted towards cotton, maize, paddy *etc.* in *kharif* season under optimum crop plan.

In *rabi* season, wheat (266.02 thousand hectares), gram (59.63 thousand hectares) and rapeseed & mustard (23.73 thousand hectares) were contributed about 32 per cent of gross cropped area as major crops in the zone. As a result, area under gram and rapeseed & mustard have increased by 45 per cent followed by wheat (20%), vegetable (20%) and garlic by 5 per cent while area under onion has decline by 95 per cent followed by fenugreek and barley *i.e.* area declined by 5 per cent in each crop. Thus, it can be concluded that area from barley, fenugreek and onion has been diverted towards wheat, gram, rapeseed & mustard and vegetables. The gross cropped area has increased by 9.08 per cent *i.e.* from 1103.22 thousand hectares to 1203.38 thousand hectares in optimum crop plan situation at all three price scenario. Similar findings were also observed by Rohit (2015) [12], Jain *et al.* (2017), Burark *et al.* (2017) [1] and Yadav *et al.* (2017) [15].

Table 2: Optimum Crop Models for Zone VIII (Humid Southern Plain) 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	Maize	448.16	470.57	470.57	470.57	+ + +
2	Paddy	58.08	60.98	60.98	60.98	+ + +
3	Blackgram	35.72	37.50	37.50	37.50	+ + +
4	Greengram	0.56	0.59	0.59	0.59	+ + +
5	Lentil	6.18	6.48	6.48	6.48	+ + +
6	Soybean	142.67	149.81	149.81	149.81	+ + +
7	Groundnut	3.57	0.18	0.18	0.18	– – –
8	Cotton	17.11	18.83	18.83	18.83	+ + +
9	Clusterbean	14.84	0.74	0.74	0.74	– – –
B	**Rabi Crops**					
1	Wheat	266.02	319.22	319.22	319.22	+ + +
2	Barley	13.52	7.44	7.44	7.44	– – –
3	Gram	59.63	86.47	86.47	86.47	+ + +
4	Rapeseed & Mustard	23.73	34.41	34.41	34.41	+ + +
5	Fenugreek	7.12	3.91	3.91	3.91	– – –
6	Onion	0.58	0.03	0.03	0.03	– – –
7	Garlic	4.33	4.54	4.54	4.54	+ + +
8	Vegetables	1.40	1.68	1.68	1.68	+ + +
C	Gross Cropped Area	1103.22	1203.38	1203.38	1203.38	**+ + +**

Findings from the Table 3 showed the gains to society due to optimum crop plan at existing ground water scenario during triennium ending year 2013-14. This model at existing ground water use revealed that the optimal returns from farmers' perspective had changed by ₹ 35.14 lakh (14.14%) at market price. Thus, there is a potential to increase the net returns by reorienting the existing cropping pattern at prevailing level of ground water use with optimal crop plan recommended by this model. At economic price, farmers' revenue has decreased (₹ -2.36 lakh) due to net effect of subsidies but at natural resource valuation, the farmers' revenue has increased by ₹ 4.89 lakh because of positive impact of legume crops. Gain to society have positive impact at economic prices and natural resource valuation scenario with ₹ 33.63 lakh and ₹ 26.69 lakh, respectively. Net gain at market prices, economic prices and natural resource valuation situation were estimated as ₹ 35.14 lakh, ₹ 31.26 lakh and ₹ 31.58 lakh, respectively. Similar findings were also observed by IIPR (2003) [5], Rohit (2015) [12], Jain *et al.* (2017) [6], Burark *et al.* (2017) [1] and Yadav *et al.* (2017) [15].

Table 3: Gains due to Optimum Crop Model over Existing Scenario in Zone VIII (Humid Southern Plain) during TE 2013-14

S. No.	Optimum Scenario	Change in GCA (%)	Existing Revenue (₹ in Lakh)	Optimum Net Returns (₹ in Lakh)	Change in Farmers Revenue (Optimal–Existing MP)	Gains to Society (₹ in Lakh)	Net Gain (₹ in Lakh)
1	Market Price	9.08	248.53	283.68	35.14	0.00	35.14
2	Economic Price	9.08	214.90	246.17	-2.36	33.63	31.26
3	Natural Resource Valuation	9.08	221.84	253.42	4.89	26.69	31.58

Conclusion
Thus, it can be concluded from the present research that the soybean – rapeseed and mustard crop sequence provide the highest net return on the basis of market price, economics price and natural resource valuation of ₹60123 per hectare to the farmer followed by soybean – wheat (₹58973/ha), lentil – rapeseed and mustard (₹58541/ha), lentil – wheat (₹57391/ha) in the Humid Southern Plain Zone of Rajasthan state. Under optimum allocation of available natural resource including crop area, more area allocated to maize, soybean and cotton in *kharif* season and wheat, gram and rapeseed and mustard in *rabi* season was suggested to maximize farmers income up to the mark with sustainable use of available ground water. The optimum plans developed in the study suggested that State Government as well as district administration/agriculture department should promote the cultivation of specific crops in this zone through incentives. More water intensive but more remunerative crops like soybean, paddy and sugarcane should be promoted in Humid Southern Plain Zone of Rajasthan state where greater extent availability of surface water resources existed. Resource base mapping of the state through satellite is required for development and adoption of location specific optimum crop plans for sustainable agriculture.

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