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Resource Use Efficiency in Saline Irrigated Environment

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INTRODUCTION

Aquifers surveyed in different states have indicated that about 32-84 per cent of the ground water is of poor quality in nature. Minhas and Gupta (1992) reported that the area under saline ground water in Haryana, Punjab, Rajasthan, Gujarat and Uttar Pradesh was about 4, 3, 82, 10 and 1 per cent, respectively. In North West India, irrigation development has taken place without the parallel development of an adequate drainage system. As a result, water and salt have been accumulating steadily over the years in various irrigated basins of the area. While the ground waters are usually alkaline in semi-arid parts of the states lying in north-west part in India, a two to three per cent mixing with seawater renders fresh water unsuitable for human consumption and for irrigation, while a 4 per cent mixing is enough to completely destroy a freshwater resource. Contamination of groundwater with pathogens, heavy metals and trace elements due to disposal of domestic sewage and industrial effluents and associated hazardous/toxic impact on human health add another dimension to the problem. Not only that but the indiscriminate use of poor quality water in the absence of proper soil-water-crop management practices pose grave risks to soil health and environment. Development of salinity, alkalinity/sodicity and toxicity problems in soils, not only deteriorate the quality of the produce and limit the choice of cultivable crops, but sometimes the effects become so severe that lands eventually go out of cultivation.

To sustain or restore the productivity in the saline environment, the interface between the fresh and saline water layers vis-à-vis groundwater recharge in the area is essential. To establish this interface to a better position than at present, either the abstractions should be reduced/optimised through skimming structures or the recharge should be increased or both. Similarly in the highly saline ground water zone, sub-surface drainage is a must. Keeping in view the seriousness of the problem, consistent efforts made at research centres of Indian Council of Agricultural Research (ICAR) in different agro-ecological regions have yielded valuable concepts and experimentally

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verifiable information for assessing the water quality hazards and methods of sustainable irrigation with saline and alkali groundwater. Basically there are three reasons which call for controlling the salinity and alkalinity problems both from soil as well as from groundwater: (1) for trafficability so that seedbed preparation, planting, harvesting, and other field operations can be conducted in a timely manner, (2) for protection of crops from excessive soil water conditions, and (3) for salinity control.

An attempt is made in the paper to establish the suitable methodology to capture the trends of alkalinity and salinity and to quantify the economic loss especially in agriculture due to poor quality irrigation water (saline and alkaline water) in Northwest India. The study also tries to highlight the issues, strategies and policy options for sustainable crop production in the problem areas where irrigation requirements of crops were met mainly by drawing ground water, which is poor quality in nature.

Magnitude of the Problem

There are no reliable estimates as to the effect of water logging and salinity on agricultural production at farm level, regional level or at global scale. The available estimates show that the production losses as a result of human induced problems of water logging and salinity in arid and semi-arid zones is of the order of the production from 8-10 million hectares (mha) of irrigated lands without problems of land degradation (Dregne and Chou, 1992). From slightly degraded lands, the estimated production losses were of less than 10 per cent, from moderately degraded land between 10-25 per cent, from severely degraded lands between 25-50 per cent and from very severely degraded land production more than 50 per cent. Since land degradation is location-specific and spatial in nature, the magnitude of losses varies from area to area. Worldwide the extent of damaged due to salinisation is ranging between 12 to 36 per cent of production loss. At the global level the annual loss from 45.4 mha salt affected lands in irrigated area has been estimated at US $ 11.4 billion (Ghassemi *et al.*, 1995). In India unfortunately, data on the occurrence and spread of water logging and salinity in the country are varied and sketchy. The existing estimates range from 5.5 million to 13 million ha. It has been reported that an area of 0.7 to 1.0 million ha is already seriously affected with water logging and salinity in Northwest India. The estimated annual economic loss in Haryana is about Rs. 1669 million from its salt affected area (Datta and de. Jong, 2002).

METHODLOGY

Study Area

The study area was located in Agra and Mathura district of Uttar Pradesh. A total of 30 farmers were purposively selected from four villages, namely, Savai (7 farmers), Nagla Hirdaya (17 farmers), Bhojpur (3 farmers) and Karanpur (3 farmers). The basis for purposive selection of farmers was to capture the input-output relationship and various crop management practices followed, specifically under saline conditions, where poor quality of water (with high salt concentration or high alkalinity problem) is used for agricultural operations. The data were collected from field experiments conducted during the years 2000-01 and 2003-04 from sample farmers' field by Sample experimental station of the Central Soil Salinity Research Institute, Karnal (Haryana). Detailed information was collected through pre-structured survey schedule from the sample farmers on input use; returns obtained, input and output prices, irrigation sources, hours of irrigation, crop choice available, crop rotation followed, cropping pattern, cropping intensity and income from agricultural operation and non-agricultural sources. Besides, the different quality parameters of water, such as, salinity level, in terms of electrical conductivity of soil (EC_e in deci-Siemen per meter), salinity level, in terms of Sodium Absorption Ratio (SAR in mili-mohs per liter) and soil pH was estimated during the study period from the collected water and soil (at the *rabi* harvest) sample from the experimental plots.

Analytical Framework

Tabular analysis was used to explain the socio-economic characteristics, extent of salinity problem existing, cropping pattern followed and input-output relationship under saline condition. Instability of cropped area, yield and net returns were analysed through estimating the co-efficient of variation. To estimate the effect of salinity and alkalinity level on crop yield, quadratic type of production function was employed, which is commonly found in the literature for estimating this kind of relationship (Datta *et al.,* 2004; Dayal *et al.,* 1999; Dinar and Knapp, 1986; Dinar *et al.,* 1985; 1990; Letey *et al.*, 1990 and others). The quadratic yield response function form under saline and alkaline condition can be specified as the following:

$$Y_{sal} = a_1 + b_1 (ECe) \pm c_1 (ECe)^2 \qquad ....(1)$$

and, $$Y_{alk} = a_2 + b_2 (SAR) \pm c_2 (SAR)^2 \qquad ....(2)$$

where, Y_{sal} = crop yield (kg/ha) under saline condition, ECe = Electrical Conductivity (dS/m), Y_{alk} = crop yield (kg/ha) under alkaline condition, SAR = Sodium Absorption Ratio (mmo/L), a_1, b_1, c_1, a_2, b_2, and c_2 are different parameters to be estimated.

To estimate the resource use efficiency under saline condition for various resources Cobb-Douglas type of production function was employed (Datta *et al.,* 2004; Sharma and Datta, 1997; Dayal *et al.,* 1999 and others). The Cobb-Douglas production function employed for the present study is specified as below:

$$Y = a.(SR)^{b1}.(IRRI)^{b2}.(OC)^{b3}.(IC)^{b4} \qquad ....(3)$$

$$\text{Or, } Ln\, Y = Ln\, a + b_1 Ln(SR) + b_2 Ln(IRRI) + b_3 Ln(OC) + b_4 Ln(IC) \qquad ....(4)$$

where, Y = Crop yield (kg/ha), SR = Seed rate (kg/ha), OC = operational cost (Rs./ha), includes, human labour, machine labour employed, IC = Input cost (Rs./ha), includes cost of fertiliser and manure used, a, b_1, b_2, b_3 and b_4 are different parameters to be estimated.

The returns to scale was estimated by taking the sum of all b b_i values, i.e., $\sum b_i$. If the value of $\sum b_i$ is >, < or = 1 indicates the increasing, decreasing or constant returns to scale, respectively. Marginal value of productivity (MVP_i) was estimated by multiplying the marginal product (MP_i) of individual inputs with the corresponding output price (Py_i).

The present analysis is focused on three major crops, bajra (*kharif* crop), wheat (*rabi*) and mustard (*rabi*). Together, these three crops accounted for nearly 70 per cent of the gross cropped area (GCA) for the sample farmers in the study area. The effect of salinity and alkalinity on crop yield (through Quadratic form of production function) was estimated separately during 2000-01 and 2003-04 for wheat crop to capture the change in effect over the different time period. However, in case of bajra and mustard, due to non-availability of adequate number of observations, the two years data (2000-01 and 2003-04) was pooled and analysed. Similarly, for resource use efficiency, Cobb-Douglas type of production function was estimated for wheat in two different periods (2000-01 and 2003-04) and for bajra and mustard the pooled data was used due to lack of adequate number of observations.

RESULTS AND DISCUSSION

Socio-Economic Profile

A comprehensive benchmark socio-economic survey was conducted during 2000-01 and 2003-04 on the same households to capture the changes in socio-economic status over the study period. Education level among the sample households remains almost unchanged during the reference period (Table 1). The average land holding was observed to be 1.36 ha. The family size showed marginal increase during 2003-04 (6.37) as compared to 2000-01 (6.07), but the difference was not found to be statistically significant. The average annual income of the sample households was calculated to be Rs. 50,177. It is interesting to see that a major share (Rs. 24,443) of the income was from other sources, (includes service, shop, small business, agricultural labourers and non-agricultural labourers) followed by agriculture (Rs. 15,333) and livestock (Rs. 10,400). This shows that income from agricultural activities is not dominating the total annual income of the farming community, inspite of having almost cent per cent (98-99 per cent precisely) of the net sown area under irrigated conditions perhaps due to poor quality of water. Tubewell is the only source of irrigation in the villages and no canal irrigation was observed. Rental value of land, which reflects the actual profitability status of the agricultural operation, was observed to be moderately high in case of good/normal land (Rs. 2,500/ha and Rs. 3,375/ha during 2000-01 and 2003-04, respectively) as compared to rental value under saline affected land (Rs. 2,250/ha and Rs. 3,000/ha during 2000-01 and 2003-04, respectively). This is a clear indication that farming alone cannot fulfill the nominal needs of the households' food security as their average family size is 6 and their size of landholdings is about 1 ha.

TABLE 1. SOCIO-ECONOMIC PROFILE OF THE SAMPLE FARMERS FROM AGRA AND MATHURA DISTRICTS OF UTTAR PRADESH:

Particulars	No. / Per cent	
	2000-01	2003-04
(1)	(2)	(3)
No. of households	30	30
Educational status		
Illiterate (per cent)	36.81	36.64
Primary level (per cent)	24.18	28.79
Other (per cent)	39.01	34.57
Average land holdings (ha)	1.36	1.37
Average family size (No)	6.07	6.37
Irrigated area (per cent of NSA)	98	99
Irrigation sources		
Tubewell (per cent of farmers)	100	100
Rental value of land		
Saline area (Rs./ha)	2,250.00	3,000.00
Good/Normal area (Rs./ha)	2,500.00	3,375.00
Average rainfall received (mm)	558	518
Major income sources		
Agriculture (Rs./year)	-	15,333.00
Livestock (Rs./year)	-	10,400.00
Others (Rs./year)	-	24,443.00
Total (Rs./year)	-	50,177.00

Extent of Saline Alkaline Problem

It is quite notable to see the extent of change in saline alkaline problem in Table 2, which depicts that the twin problem is increasing (particularly saline problem) at a

TABLE 2. EXTENT OF SALINE PROBLEM AMONG SAMPLE FARMERS

Problems	Percentage of farmers	
	2000-01	2003-04
(1)	(2)	(3)
Salinity*		
Medium (ECe: 2.5-5.0 dS/m)	33	33
High (ECe: 5.0-7.5 dS/m)	30	23
Excessive (ECe: >7.5 dS/m)	37	44
Alkalinity		
Normal (pH 7-7.5)	0	3
Low (pH 7.5-8.0)	13	17
Medium (pH 8.0-8.5)	60	43
High (pH >8.5)	27	37

ECe represents Electrical Conductivity expressed in deci-Siemen per metre.
*Based on USDA classification.

faster pace. Nearly half of the farmers' plot (44 per cent) was affected by saline problem during 2003-04 at very high magnitude (*ECe* > 7.5 dS/m), which was 37 per cent during 2000-01. The table also shows that 100 per cent of the sample farmers were experiencing the salinity problem at some part of their land. Similarly, more than 80 per cent of the farmers' plot was observed to be affected by alkaline problem at varying magnitude, like, high (27-37 per cent), medium (60-43 per cent) and low alkalinity (13-17 per cent) problem during 2000-01 and 2003-04 respectively. The variation of salinity over the years may be explained due to erratic rainfall, which is 558 mm during 2000-01 whereas in 2003-04 it was only 518 mm.

Cropping Pattern

Winter (*rabi*) is the main season for crop production activity when about half of the gross cropped area is cultivated (Table 3). The field is rarely kept fallow during

TABLE 3. CROPPING PATTERN UNDER THE SALINE ENVIRONMENT ON SAMPLE FARMERS

Particulars	Cropping pattern (per cent to GCA)	
	2000-01	2003-04
(1)	(2)	(3)
Kharif		
Bajra	16.33	15.05
Jower	0.48	0.69
Fallow	31.48	32.48
Rabi		
Wheat	44.67	42.03
Potato	2.05	1.69
Mustard	4.26	4.87
Others	0.73	3.19
Net Sown Area (ha)	40.69	41.23
Gross cropped area (ha)	59.19	58.75
Cropping intensity (per cent)	145.47	142.48

this season. During 2003-04 the area under other crops (like barley) has increased over 2000-01, because the farmers tried to improve the net return through some alternative crops. Wheat is the main crop during *rabi* season accounting for nearly half of the GCA, but it showed declining trend during 2003-04 as compared to 2000-01. The different categories of poor quality water have led to changes in cropping pattern where the choice has been restricted either to *bajra* or jowar. The farmers are forced to keep major part of their land, nearly one-third fallow during *kharif* season due to lack of good quality water at the time of sowing or moisture regime does not permit them for sowing in time. Low cropping intensity (145 to 142 per cent) is the result of this *kharif* fallow. The various reasons for keeping *kharif* fallow have been reported in Table 4. Water stagnation is a common problem in soils irrigated with high-SAR saline as well as alkaline water. Water logging is also a major problem restricting nearly one-fourth of the sample farmers to keep a portion of their cultivable

TABLE 4. REASONS FOR KEEPING LAND FALLOW DURING KHARIF SEASON UNDER SALINE ENVIRONMENT

(per cent of farmers)

Reasons (1)	2000-01 (2)	2003-04 (3)
Water stagnation	36.36	11.54
Water logging	31.82	23.08
To sow mustard early	4.55	0.00
To sow potato early	4.55	7.69
Lack of labour availability	9.09	30.77
Others	4.55	19.23
Can not say	9.09	3.85
Percent of farmers keeping some part of their land fallow	73.33	86.67

land fallow during *kharif* season followed by lack of availability of labour (the problem increased three-fold during 2003-04 as compared to 2000-01), to facilitate mustard sowing early (4.55 per cent during 2000-01) as well as potato (4.55 per cent during 2000-01 and 7.69 per cent during 2003-04, respectively). Overall nearly two-third of the farmers were forced to keep some part of their land fallow during 2000-01, which increased up to 87 per cent during 2003-04, indicating the aggravating problem of agricultural operation due to saline and alkaline problem and non-availability of good quality water for irrigation.. Overall the cropping intensity was calculated to be 145 per cent during 2000-01, which has decreased to 142 per cent during 2003-04. However the change in cropping intensity was not found to be statistically significant during these two reference years.

Resource Use Pattern and Profitability

The resource use pattern and returns for various crops grown under saline condition was examined to assess the change in profitability of agricultural operations during the study period. Valuation of all inputs and output was calculated based on current prices for 2003-04 to have valid comparison between the two reference periods. The results showed that per ha net return declined during the later period 2003-04 as compared to 2000-01 for all the crops at varying magnitude irrespective of seasons in which crops are grown (Table 5). The highest net return was calculated to be Rs. 22,501 per ha for mustard during 2000-01 followed by potato (Rs. 14,110 per ha), wheat (Rs. 7,217 per ha) and *bajra* (Rs. 639/ ha) whereas the net returns was observed to be declined at Rs. 18,388 per ha for mustard during 2003-04 followed by wheat (Rs. 3,894 per ha), potato (Rs. 3,373 per ha) and *bajra* (Rs. 60 per ha). Similar to net return, yield also was observed to be declining for all the crops during 2003-04 as compared to 2000-01. The declining trend in yield can be mainly attributed to the rainfall pattern, which has very high positive correlation with yield of crops. The average yield of *bajra* was calculated to be 12.10 qtl/ha during 2000-01 which declined

TABLE 5. INPUT USE AND RETURN FROM MAJOR CROPS GROWN IN SALINE ENVIRONMENT ON SAMPLE FARMS

Crops	Irrigation (No.)	Human labour (Rs./ha)	Fertiliser (Rs./ha)	Total Cost (Rs./ha)	Total Return (Rs./ha)	Average yield (qtl/ha)	Net Return (Rs./ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bajra							
2000-01	0.30	3510	1097	4807	5446	12.10	639
2003-04	0.00	4158	939	5178	5238	11.64	60
Wheat							
2000-01	5.29	8112	2549	12658	19875	31.80	7217
2003-04	5.00	9843	2119	14962	18856	30.17	3894
Mustard							
2000-01	2.17	4910	1820	9731	32232	18.96	22501
2003-04	2.00	6555	1860	11413	29801	17.53	18388
Potato							
2000-01	5.00	8559	7378	34056	48166	240.83	14110
2003-04	5.00	11831	8583	35983	39356	196.78	3373

Note: All the valuation of input and output have been calculated at current prices of 2003-04.

to 11.64 qtl/ha in 2003-04. Similarly, for wheat the yield was observed to be 31.80 qtl/ha and 30.17 qtl/ha, mustard 18.96 qtl/ha and 17.53 qtl/ha and potato 240.83 qtl/ha and 196.78 qtl/ha during 2000-01 and 2003-04, respectively.

Risk and Uncertainty of Crop Output

Risk in terms of instability associated with major crops grown under saline condition was analysed through estimating the co-efficient of variation in cropped area, yields and net returns (Table 6) whereas the uncertainty was judged based on

TABLE 6. INSTABILITY OF CROP PRODUCTION AND RETURN IN SALINE ENVIRONMENT

Particulars	Bajra		Wheat		Mustard	
	2000-01	2003-04	2000-01	2003-04	2000-01	2003-04
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cropped area (CV)	98.75	88.79	67.45	72.19	56.57	84.85
Yield (CV)	80.33	96.29	27.25	49.26	22.03	26.56
Net return (CV)	17.89	30.04	12.37	20.01	17.68	19.95
Farms below average yield (per cent of farms)	30	58.33	35.71	55.56	60.00	60.00
Farms obtained negative return (No.)	0	2 (17)	0	2 (7.4)	0	0
Crop failure (per cent of farmers)	12	14	0	0	0	0

CV indicates coefficient of variation in percentage.
Figures in parentheses shows percentage to the respective total.

calculating percentage of farmers obtaining below average yield, occurrence of negative returns and cases of crop failure. Very high variability in cropped area, yield and net returns were observed under *kharif* crop (*bajra*) as compared to *rabi* crops (wheat and mustard). The reason being, the decision of growing *a kharif* crop completely depends on the timely monsoon, inspite of having nearly cent per cent area under poor quality saline irrigation facilities due to the saline nature of groundwater problem and irrigation facilities due to the salinity problem. Timely rainfall helps to facilitate the good germination and growing of crops; otherwise it creates crop damage or complete failure due to salinity and alkalinity. In fact, the salinity problem transformed the irrigated areas into a rainfed area. It is interesting to note from the table that instability of cropped area for *bajra* was higher (99 per cent) during 2000-01 as compared to 2003-04 (89 per cent) but the reverse is true in case of instability of yield and net returns, where coefficient of variation is higher during 2003-04 than 2000-01. This implies that higher rainfall (548 mm during 2000-01) leads to increase in instability of cropped area but has positive impact on yield and net returns through reducing the instabilities. The results depicted that the percentage of farms obtaining below average yield under *kharif* crop (*bajra*) has increased to 48 per cent during 2003-04 from 30 per cent in 2000-01. Similarly, two farms have experienced the negative return during 2003-04, which was nil in 2000-01. This may be due to stagnant water in the field which spoil the whole crop. Thus we may say that risk and uncertainty have direct bearing with the rainfall pattern, which is characterised due to saline problem. Growing of *kharif* crops is like gambling with nature and associated with high risk and uncertainties, as it is mainly guided by the availability of good quality water either through rain or from surface irrigation source in the pre-sowing stage of the crops.

Rabi crops also showed quite high instability in cropped area, yield and net returns and the instability were observed to have increased during 2003-04 as compared to 2000-01. Also, the percentage of farms obtaining below the average yield was high for *rabi* crops (wheat and mustard) and increased in 2003-04 over 2000-01. Most alarmingly, 2 wheat growers (7.4 per cent) experienced negative return for wheat during 2003-04 indicating the aggravating salinity problem in study area.

Salinity and Alkalinity Effect on Yield

To analyse the effect of salinity and alkalinity on crop yield, production function analysis was carried out considering salinity level, *ECe* (Electrical Conductivity in dS/m) and alkalinity level (Sodium Absorption Ratio in mmo/L) as the causal factor affecting yield variability under saline condition. The quadratic form of production function was found to be able to explain the more variability in yield as compared to linear and Cobb-Douglas type of production function. It has also been observed that most of the estimated co-efficient values are statistically significant at various significant levels particularly with the salinity level. Due to inadequacy of the number of observations, the quadratic yield response function for bajra and mustard were estimated by pooling the data for the two years (2000-01 and 2003-04). Yield response function under wheat was estimated for both the years separately. Quadratic yield response for bajra under saline condition was able to explain the variation in yield by 57 per cent (Table 7). The estimated value of the parameter for *ECe* was found to

TABLE 7. ESTIMATED QUADRATIC YIELD RESPONSE FUNCTION UNDER SALINE ENVIRONMENT FOR BAJRA

	Response function under				
	Saline environment		Alkaline environment		
Variables	Regression coefficient	Standard error	Variables	Regression coefficient	Standard error
(1)	(2)	(3)	(4)	(5)	(6)
Intercept	3.2609***	0.2934	Intercept	2.3684	1.9324
ECe (dS/m)#	0.0765**	0.0364	SAR (mmo/L)$	0.9882	1.4558
ECe^2 (dS/m)	- 0.3372**	0.1561	SAR^2 (mmo/L)	- 0.2611	0.2729
R square	0.5684		R square	0.6137	
No. of observations	22		No. of observations	22	

** and *** Significant at 5 and 1 per cent level, respectively.

and $ indicate Electrical Conductivity in deci-Siemen per meter and Sodium Absorption Ratio in mili-mohs per liter.

be statistically significant, but negative at second degree which implied that at higher salinity level yield would decline. However, under alkaline condition, the estimated coefficient values were not found to be significant, stating that the alkalinity level is not significantly affecting the *bajra* yield. This is because bajra is a salt tolerant crop and the available rainwater may help to keep the moisture regime favourable and the negative effect of alkalinity on crop yield nullified. But the problem may aggravate if the alkalinity level reaches to a very high level.

Yield response function under wheat (during 2000-01) indicated that salinity and alkalinity, both are significantly affecting the crop yield. The coefficient of determination, which showed the variability explained by the independent variable, were found to be 33 per cent and 42 per cent under saline and alkaline conditions, respectively during 2000-01 and the same were 47 and 48 per cent during 2003-04 (Tables 8 and 9). The magnitude of damage is quite high (negative coefficient at

TABLE 8. ESTIMATED QUADRATIC YIELD RESPONSE FUNCTION UNDER SALINE ENVIRONMENT FOR WHEAT DURING 2000-01

	Response function under				
	Saline environment		Alkaline environment		
Variables	Regression co-efficient	Standard error	Variables	Regression co-efficient	Standard error
(1)	(2)	(3)	(4)	(5)	(6)
Intercept	3.5702***	0.6431	Intercept	6.1801*	3.8992
ECe (dS/m)#	0.1523**	0.0723	SAR (mmo/L)$	0.3521**	0.1747
ECe^2 (dS/m)	- 0.1355**	0.0613	SAR^2 (mmo/L)	0.1334	0.1840
R square	0.3334		R square	0.4179	
No. of observations	28		No. of observations	26	

** and *** Significant at 5 and 1 per cent level, respectively.

and $ indicate Electrical Conductivity in deci-Siemen per meter and Sodium Absorption Ratio in mili-mohs per liter.

TABLE 9. ESTIMATED QUADRATIC YIELD RESPONSE FUNCTION UNDER SALINE ENVIRONMENT FOR WHEAT DURING 2003-04

	Response function under				
	Saline environment		Alkaline environment		
Variables	Regression coefficient	Standard error	Variables	Regression coefficient	Standard error
(1)	(2)	(3)	(4)	(5)	(6)
Intercept	3.2917***	0.5347	Intercept	1.7814**	0.8751
ECe (dS/m)#	0.3797**	0.1519	SAR (mmo/L)$	0.6865**	0.3613
ECe^2 (dS/m)	- 0.1341**	0.0633	SAR^2 (mmo/L)	- 0.2601**	0.1406
R square	0.4776		R square	0.4814	
No. of observations	28		No. of observations	29	

*, ** and *** Significant at 10 per cent, 5 per cent and 1 per cent level, respectively.
and $ indicate Electrical Conductivity in deci-Siemen per meter and Sodium Absorption Ratio in mili-mohs per liter

second degree) under saline condition as compared to alkaline condition. But during 2003-04 alkalinity level is adversely affecting the wheat yield similar to salinity effect. This implied that inadequate/low rainfall is affecting the wheat yield through dual problem of alkalinity and salinity.

Yield response function for mustard showed the similar effect like in bajra and the model could explain the variability of 65 per cent and 46 per cent under saline and alkaline conditions, respectively (Table 10). The estimated coefficients under saline condition was observed to be significant and contributing negatively to the crop yield. Alkalinity level was not found to be significantly affecting the mustard yield.

TABLE 10. ESTIMATED QUADRATIC YIELD RESPONSE FUNCTION UNDER SALINE ENVIRONMENT FOR MUSTARD

	Response function under				
	Saline environment		Alkaline environment		
Variables	Regression coefficient	Standard error	Variables	Regression coefficient	Standard error
(1)	(2)	(3)	(4)	(5)	(6)
Intercept	3.2471***	1.5462	Intercept	2.3719	1.3623
ECe (dS/m)#	0.0128*	0.0071	SAR (mmo/L)$	0.0822	0.0740
ECe^2 (dS/m)	- 0.0083*	0.0046	SAR^2 (mmo/L)	- 0.0058	0.0043
R square	0.6494		R square	0.4576	
No. of observations	16		No. of observations	15	

*, and *** Significant at 10 and 1 per cent level, respectively.
and $ indicate Electrical Conductivity in deci-Siemen per meter and Sodium Absorption Ratio in mili-mohs per liter.

Resource Use Efficiency

To estimate the resource use efficiency under saline condition, Cobb-Douglas type of production function was applied as this form of relationship provided the best results (Table 11). The yield (kg/ha) was considered as dependent variable and seed rate (kg/ha), irrigation (hr/ha), operational cost (Rs./ha) and cost of fertiliser and manure, input cost (Rs./ha) were included in the model as independent variable. The regression analysis was carried out for pooled data (2000-01 and 2003-04) in case of *bajra* and mustard due to inadequacy of the required number of observations. For wheat the regression analysis was employed for both the years separately (2000-01 and 2003-04) to capture the change in magnitude of estimated values of parameters.

TABLE 11. ESTIMATED COBB-DOUGLAS YIELD RESPONSE FUNCTION FOR MAJOR CROPS GROWN UNDER SALINE ENVIRONMENT

Variables	Bajra	Wheat		Mustard
		2000-01	2003-04	
(1)	(2)	(3)	(4)	(5)
Intercept	1.8043***	3.3955*	3.4028***	1.8638***
	(0.2971)	(2.0273)	(1.2725)	(0.9310)
SR (kg/ha)	0.0397	0.3195	0.0667*	0.6684*
	(0.2701)	(0.3136)	(0.0357)	(0.2899)
IRRI (hr/ha)	-	-0.2495**	-0.2518**	-0.5228*
		(0.1196)	(0.1291)	(0.2439)
OC (Rs./ha)	0.4600***	0.4078***	0.2341**	0.2393
	(0.2012)	(0.1799)	(0.1184)	(0.3479)
IC (Rs./ha)	0.1454	0.0391	0.1258**	-0.0258*
	(0.0931)	(0.0456)	(0.0653)	(0.0139)
R square	0.5163	0.5963	0.5381	0.6617
No. of observations	22	28	29	16

*, ** and *** Significant at 10, 5 and 1 per cent level, respectively.

SR, IRRI, OC and IC represent seed rate, irrigation, operational cost and input cost, respectively.

The estimated function from the pooled data showed that the coefficients of determination for *bajra* (*kharif* crop) was about 52 per cent. and operational cost (OC) was observed to be a significant factor for yield variation. Operational cost, which includes labour required for various intercultural operations and crop management practices. The positive magnitude implied that there is scope for improving yield for *bajra* through increasing the operational cost. However, input cost (IC) and seed rate (SR) were not found to be significant factors causing yield variation in *bajra*.

The functional relationship for wheat indicated that the independent variables included in the model could explain upto 60 per cent and 54 per cent yield in variation during 2000-01 and 2003-04, respectively. Most of the estimated values of parameters were observed to be significant during 2003-04 but seed rate, SR (kg/ha) and input cost, IC (Rs./ha) were not found to be significant factor for yield variability during 2000-01. The most important thing to note from the table is that irrigation, IRRI (hr/ha) was found to be a significant factor with negative effect and the magnitude of the effect (negative) increased during 2003-04 as compared to 2000-01. This yield damage has direct bearing with the amount of poor quality water (salt affected) applied for the crop production. The rainfall pattern has strong influence to cater this negative effect of salinity on crop yield. Availability of good/normal rain water may reduce the negative effect; even in *rabi* crops through residual moisture content and vice versa. The significant coefficient for seed rate (kg/ha) implied that in the case of low/erratic rainfall, the amount of seed rate used is also a factor to effect the wheat yield, because, adequacy of rainfall have positive influence on seed germination and in turn on yield.

The estimated Cobb-Douglas type of production function explained the yield variability of mustard by 66 per cent and all the estimated parameters were observed to be significant except operational cost (OC). Similar to wheat, irrigation (IRRI) showed negative and significant factor to affect the mustard yield under saline condition. Also the input cost, (IC) was found to have negative effect on mustard yield, suggesting high level of input use pattern for its production. Negative and significant coefficients for irrigation and input cost implied that if the irrigation hour or input cost under mustard crop is increased, the crop yield will be reduced. Seed rate (kg/ha) was found to be a significant factor to effect the yield variability and positive sign implying that increasing the seed rate may increase the crop yield further, because, under saline condition, germination percentage of seed and initial crop growth is dependent on the amount of rainfall received (through residual moisture level) and normal/good rainfall facilitates the seed germination and vice versa.

Returns to Scale

The production elasticities for each input indicate the estimated percentage change in yield associated with 1 per cent change in the input, while the other factors are held constant. Due to inadequacy of the number of observations, the pooled data (combining 2000-01 and 2003-04 observations) was used for production function analysis for bajra and mustard. Functional analysis for wheat was carried out for both the years, 2000-01 and 2003-04, separately. The sum of elasticities of regression coefficients indicates the returns to scale, which was estimated to be 0.6451 and 0.3591 under bajra and mustard, whereas the same were 0.5169 and 0.1748, for wheat during 2000-01 and 2003-04, respectively (Table 12). The estimated returns to scale for *bajra* is positive but less than one, suggesting the decreasing returns to scale, i.e., if all the inputs are increased by 1 per cent the yield will increase but at a magnitude of less than one per cent. The reason for this is that the salinity builds up in *kharif* season is less due to monsoon rain, which facilitates the leaching of the salt. Hence the crop is not so much affected by the salinity problem. Similarly, the decreasing

TABLE 12. RETURNS TO SCALE FOR MAJOR CROPS GROWN UNDER SALINE ENVIRONMENT

Particulars	Bajra	Wheat		Mustard
		2000-01	2003-04	
(1)	(2)	(3)	(4)	(5)
Sum of the positive factors	0.6451	0.7664	0.4266	0.9077
Sum of the negative factors	-	-0.2495	-0.2518	-0.5486
Total	0.6451	0.5169	0.1748	0.3591

returns to scale were also prevailing under wheat but the rate of decrease was higher as compared to *bajra*. Most importantly, the magnitude of decreasing returns to scale is much higher in wheat during 2003-04 (0.1748) as compared to 2000-01 (0.5169), indicating the aggravating problem of salinity build-up on crop yield. This is mainly due to less rainfall during 2003-04 (518mm) and higher rate of evaporation compelling the capillary rise of water table, which indirectly helps to rise up salinity level in the root zone.

Marginal Value of Productivity

The efficiency of input use was judged by estimating the marginal value of productivity (MVP) of various inputs affecting the crop yield under saline condition, such as, seed rate (kg/ha), irrigation (hr/ha), operational cost (Rs./ha) and input cost (Rs./ha) (Table 13). The MVPs of different factors suggest the scope for additional amount of spending for revenue enhancing for crop cultivation as it encompasses the

TABLE 13. MARGINAL VALUE PRODUCTIVITY OF DIFFERENT FACTORS FOR MAJOR CROPS GROWN UNDER SALINE ENVIRONMENT

Variables	Bajra	Wheat		Mustard
		2000-01	2003-04	
(1)	(2)	(3)	(4)	(5)
Seed	0.7370	3.9612	12.5760	10.8252
Irrigation	-	-4.0240	-6.3841	-2.0554
Operational cost	1.9472	2.9392	2.5280	0.8603
Input cost	0.7606	3.4083	1.6272	0.0532

prices of input and output both. The estimated MVPs were found to be quite low for all the inputs, which suggested there is limited scope to increase the additional amount of spending on these inputs with ensuring profitability. Most importantly, the MVP of irrigation input was estimated to be negative (Rs. 4.02 and Rs. 6.38, for wheat during 2000-01 and 2003-04 respectively and Rs. 2.05 for mustard) for *rabi* crops indicating sub-optimal/inefficient use of irrigation water under saline condition. Additionally, the MVP of water use was declined during 2003-04 as compared to 2000-01, suggesting the intensity of the problem has aggravated due to lesser rainfall.

Valuation of Yield Losses

The yield losses for various crops were calculated by taking the difference between experimental yield and observed yield, and then were valued at 2003-04 current prices to have valid comparison of the magnitude of losses over different periods (Table 14). It can be observed from the table that value losses were experienced for all the crops at varying magnitude ranging from Rs. 1,188 per ha (wheat), Rs. 578 per ha (mustard) and Rs. 638 per ha (*bajra*), during 2000-01 and the

TABLE 14. VALUATION OF YIELD LOSSES OF MAJOR CROPS GROWN UNDER SALINE ENVIRONMENT

Crops (1)	Experimental yield (qtl/ha)* (2)	Observed yield (qtl/ha) (3)	Yield loss (qtl/ha) (4)	Value of losses (Rs./ha) (5)
Bajra				
2000-01	13.60	12.10	1.50	638
2003-04	12.50	11.64	0.86	366
Wheat				
2000-01	33.70	31.80	1.90	1,188
2003-04	34.90	30.17	4.73	2,956
Mustard				
2000-01	19.30	18.96	0.34	578
2003-04	21.70	17.53	4.17	7,089

Valuation of losses have been estimated at current prices of 2003-04.
*Experimental yield has been taken from AICRP, Agra.

magnitude of loss increased (except for *bajra*) to Rs. 366 per ha (*bajra*), Rs. 2,956 per ha (wheat) and Rs. 7,089 per ha (mustard), during 2003-04.

CONCLUSIONS

The present study reveals that salinity problem is increasing the risk and uncertainty of agricultural operation considerably and hence, reducing the income from agricultural operation. The Salinity problem is severely restricting the alternative crop choice to be grown and the farmers are forced to keep their land fallow during *kharif* season. Additionally, the resource use efficiency, particularly for irrigation water was observed to be highly affected by this saline problem and in fact, the marginal value of productivity under all the crops were estimated to be negative. The negative effect of salinity on crop yield was more pronounced as compared to alkalinity in the study area. The agricultural operation was heavily dependent on the availability of rainwater in spite of having almost cent per cent area with irrigation facilities. Because, the salt concentration in root zone increases the above threshold limit must be reduced by mixing good/normal water to facilitate crop growth, which (good water) can be possible only through available rainwater.

Policy intervention in the form of ensuring availability of canal water (good/normal) during the time of sowing is an essential component in the saline environment. Its availability at this critical stage would reduce the risk for crop failures and encourage the farmers to use saline waters for irrigation at later stages of crop growth. The irrigation authority should take care, that canal water must be available in the saline groundwater zone at least during sowing season, on time. If timely canal water is available it will encourage the farmers to bring additional area for crop production and will use their saline ground water either through conjunctive use (if canal water is provide by the agency one or two) or subsequent irrigation afterwards as per the crop's requirement (Datta and Bhu Dayal, 2000). A strong link is needed between researchers and the end users of the technology, i.e., farmers on the one hand, and the extension workers on the other. Thus intervention of the state for developing a sound technology transfer network on the management of poor quality waters is desirable. Salt tolerant varieties should be encouraged. Farmers' knowledge about salt tolerant varieties is limited. Moreover due to location-specific demand, the seed growers are not encouraged to multiply the salt tolerant varieties. Public sector should extend subsidised credit for the purchase of efficient systems of irrigation, e.g., sprinkler and drip, along with supplying the salt tolerant varieties. Perhaps drainage would not be a sole cure for problems created. Inefficient irrigation practices that waste the irrigation water resource and any kind of formal or informal group approach to manage problem soils will have to assure individual participant that the decisions of other individuals will not cause any negative externality. Finally, it may be mentioned here that without correcting the fundamental incentive gap through a radical transformation of existing water laws and institutions, it is certainly not possible to ensure either ecological security or economic efficiency or even social equity in water resource use.

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