*Ind. Jn. of Agri. Econ.*
*Vol. 59, No. 1, Jan.-March 2004*

# Implication of Land Degradation on Crop Productivity - Some Evidences from Saline Areas in North-West India

**K. K. Datta, C. de Jong and M.T. Rajashekharappa***

I

## INTRODUCTION

The twin problems of water logging and soil salinity are threatening the sustainability of agricultural production in large parts of Haryana. In 1985, a study conducted by UNDP/FAO concluded that almost 400,000 ha of land were threatened. About 13 years later, in 1998, the Drainage Master Plan of the Government of Haryana (Government of Haryana, 1998) revealed that almost 500,000 ha of highly productive land were under threat of degradation because of the rising water table. This is about a quarter of the irrigated lands in the state. The threat is more serious because the groundwater in most of the endangered area is brackish or saline. The area under critical water table depth (within 3m of the surface) is expected to increase dramatically in the coming decades if no curative measures are taken (Datta and de Jong, 2002).

Currently, the water table is within 1 to 2 metres of the surface in about 50,000 ha. A substantial part of this area is situated in the Rohtak-Sonepat-Gohana area. In this area, water logging and secondary salinisation have become serious problems. To counteract this adverse development, research done in the framework of the Indo-Dutch Operational Research Project (ORP) has revealed that a combination of surface and sub-surface drainage, supplemented by improved irrigation management is the most appropriate strategy.

The objective of this paper is to establish the suitable methodology to capture the trends of water logging and salinity and to quantify the economic loss especially in agriculture due to water logging and salinity in North-West India. The study also assesses the scope of salinity control measures at the farm level.

II

## METHODOLOGY

The study area is located in the Gohana sub-division of Sonepat district near the border with Rohtak district. It is situated along either side of the JLN Feeder and the parallel running Bhalaut sub-branch. The area is under command of Bhalaut sub-branch. It contains parts of the villages Bali, Rewara, Moi, Katwal, and Lath.

* ICAR Research Complex for NEH Region, Umiam, Meghalaya - 793103, India, International Institute for Land Reclamation and Improvement/ILRI, Wageningen, The Netherlands and National Centre for Agricultural Economics and Policy Research, Pusa, New Delhi-110012, respectively.

The comments of the anonymous referee were very helpful and are gratefully acknowledged.

Together, these villages cover an area of about 4,600 ha. They represent about 2,150 households and some 13,900 inhabitants. In the South, the area skirts the diversion drain No. 8, one of the main drains out falling in the Yamuna River. Given the quality of groundwater in the deeper aquifers, the farmers by trial and error try to tap fresh water lenses in shallow aquifers above the saline groundwater. These lenses are built up from infiltrating rainfall and surface irrigation water, and from canal seepage. This water resource is very limited in quantity and varies with space and time. In 1990, the Haryana State Minor Irrigation and Tubewell Corporation (HSMITC) reported that in the proposed project area of 2,000 ha (Pilot Area + Control Area) about 150 tubewells installed by the farmers were in use. Most of these tubewells were located near the canals on either side. At that time, the density in this area was 7 tubewells per square kilometre. Nowadays, the density is about 25 per square kilometre. All these tubewells are cavity tubewells with depth ranging from 7 to 10 m, and a yield of about 6 l/sec.

*Sampling Method*

To facilitate a systematic study of the effects of water logging and soil salinity, the sample plots were selected from the Gohana area with the help of a grid system. This grid was superimposed upon the existing grid system, which is based on the main grid blocks of 25 acres. These blocks are sub-divided into 25 grid blocks of 1 acre each. The dimensions of the one-acre blocks are 198 ft in the north-south direction and 220 ft in the east-west direction. To be able to sub-divide the area according to major soil type, farm type, and size of holding, the number of sample plots (and, consequently, the number of sample farms) was set at 250. Because some of the farmers possessed two to three selected sample plots, season-wise the plot and farm surveys were conducted amongst some 225 farmers and their families from the year 1994 (from *kharif*) to 1999(*rabi*).

To assess the damage caused by varying degrees of water logging and soil salinity, the "intensity" of these phenomena, and their effect on crop and land productivity, has to be measured simultaneously. For water logging, the generally used indicator is depth of the water table; for soil salinity it is the electric conductivity (ECe) of the saturated (soil) paste. But, also groundwater quality plays an important part. Its quality is expressed in the degree of electrical conductivity (EC). Crop productivity is roughly measured by crop yield. To measure crop productivity correctly, one also has to take into account the agricultural inputs. And, assessing land productivity involves the determination of cropping intensity, and cropping pattern as well.

For the soil salinity class-wise analysis of the data collected on the sample plots, the data sets have been classified according to the degree of soil salinity at the harvest of the *rabi* crops. Soil salinity data of the one-acre sample plots have been grouped according to five classes, i.e., 0-4 dS/m (normal), 4-8 dS/m (marginally affected), 8-12 dS/m (moderately affected), 12-16 dS/m (severely affected), and more than 16 dS/m (extremely affected). Many common agricultural crops, including wheat and paddy, are not affected in the range 0-4 dS/m. This is the case in the surrounding area as well. We used this class as the non-affected standard. No crops were grown on land with an $EC_e$ above 16 dS/m.

Cross-sectional (farm level) and time-series data for the years 1994-95 to 1998-99 were employed for the study. It represents a combination of cross-section and time-series data where we observed each factor over time. It also allows us to study the dynamic as well as cross-sectional aspects of a problem. In order to capture the effect of salinity, the Cobb-Douglas form of production function was employed in order to establish the economic loss due to salinity. Moreover, to elucidate the effect of different levels of land degradation on farm income, the available data were analysed season-wise and plot-wise. The present analysis is focused on two major crops, paddy and wheat, which are grown in the *kharif* and *rabi* season respectively. Together, these crops occupy about 80 per cent of the total cultivated area. Apart from the effect of soil salinity on crop yield and farm income, the effect of alkalinity also was investigated. The Logit function was used to study the relative effectiveness of the methods that the farmers adopt to reclaim the waterlogged and saline soils.

## III

## RESULTS AND DISCUSSION

The data in Table 1 show that the incidence of soil salinity in the period *kharif* 1994 to *rabi* 1999 differed from year to year and from season to season. The yearly variation is probably due to the amount of rainfall and its distribution. But the pattern is not very clear. The incidence of soil salinity is considerably higher in *rabi*, than in *kharif*. In *kharif*, 30 to 35 per cent of the area was affected by soil salinity. In *rabi*, it was 50 to 60 per cent. The farmers reported that crop loss in *rabi* (dry season) was mainly due to soil salinity, while in *kharif* (wet season) water logging and poor groundwater quality were the main causes of crop loss. High rainfall in the monsoon causes water logging in places and this, in turn, leads to rapid salinisation in *rabi*. Based on the figures (in Table 1), the salinity class distribution has been taken as follows: 44 per cent of the area is considered to be non-affected, 33 per cent is marg-

TABLE 1. PERCENTAGE OF THE GOHANA PROJECT AREA IN DIFFERENT SOIL SALINITY CLASSES ACCORDING TO SOIL SALINITY SAMPLING

| Year | Season | Soil salinity class (dS/m) and degree of salt effects | | | | |
|---|---|---|---|---|---|---|
| | | 0-4 Normal | 4-8 Marginal | 8-12 Moderate | 12-16 Severe | >16 Extreme |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 1994 | *Kharif* | 66 | 18 | 5 | 6 | 5 |
| 1994-95 | *Rabi* | 44 | 33 | 10 | 7 | 6 |
| 1995 | *Kharif* | 70 | 21 | 5 | 2 | 2 |
| 1995-96 | *Rabi* | 38 | 37 | 13 | 12 | 6 |
| 1996 | *Kharif* | 65 | 20 | 4 | 11 | 5 |
| 1996-97 | *Rabi* | 50 | 30 | 7 | 13 | 6 |
| 1997 | *Kharif* | 69 | 18 | 5 | 8 | 4 |
| 1997-98 | *Rabi* | 49 | 30 | 9 | 12 | 6 |
| 1998 | *Kharif* | 66 | 18 | 5 | 11 | 5 |
| 1998-99 | *Rabi* | 40 | 37 | 9 | 8 | 5 |
| Average | *Kharif* | 67 | 19 | 5 | 5 | 4 |
| | *Rabi* | 44 | 33 | 10 | 7 | 6 |
| | Total | 56 | 26 | 7 | 6 | 5 |

*Source:* Sharma (1996-98).

inally affected, 10 per cent is moderately affected, 7 per cent is severely affected, and 6 per cent is extremely affected. It is interesting to note that about 47 per cent of the farmers report that the problem area has remained constant over time. About 45 per cent of the farmers report that the problem area has either increased or decreased. In order to understand the farmers' strategies and practices for combating soil salinity, and also their willingness to participate in future sub-surface drainage projects, it is important to know their perception of the salinity problem. The farmers in the area are much more concerned about the quantity and quality of the groundwater than about the salinity of the soil in their fields.

*Trends of Problem Area*

The quality of the land in the study area has been categorised according to the farmers' perceptions. Table 2 shows that the farmers think that some 8 per cent of the land is marginally affected, some 15 per cent is moderately affected, and only 4 per cent is seriously affected. In other words, they think that almost 27 per cent of the area is salt-affected to some extent. About 60 per cent of the farmers report that the quality of their land has been deteriorating over the years because they have observed poor percolation of rainwater, salt appearance on the soil's surface, poor germination of seeds, and low crop yields. About 89 per cent of the farmers have observed poor germination of seeds in their fields. About 53 per cent of the farmers report that salts have appeared on the surface of their plots, and about 28 per cent report that although they have been using the same level of inputs, crop productivity in their fields is gradually decreasing. Although the farmers are aware of the drainage problems, they have not been overly concerned about them because of the slow pace of salinisation. They consider the quality of their land, their ability and willingness to bear risks, and their experience before they make investment decisions that will affect crop production. Usually they do not get the most important information on soil salinity from Government officers and extension workers. Rather, they get it from the fellow-farmers, who possess a wealth of practical knowledge that has been passed down from father to son, over generations. These farmers have tried innovations, modified them to suit their particular circumstances, done their own experiments, and developed new techniques.

TABLE 2. FARMERS' PERCEPTIONS OF SOIL QUALITY

*( per cent of total cultivable ha)*

| Soil quality (1) | Katwal (2) | Lath (3) | Moi (4) | Rewara (5) | Bali (6) | All villages (7) |
|---|---|---|---|---|---|---|
| Marginally affected | 10.25 | 9.03 | 6.02 | 10.89 | 5.29 | 7.88 |
| Moderately affected | 19.46 | 17.11 | 13.01 | 16.33 | 11.09 | 14.81 |
| Seriously affected | 0.39 | 2.90 | 7.08 | 2.42 | 5.03 | 3.88 |
| Total salt-affected soils | 30.10 | 29.04 | 26.11 | 29.64 | 21.41 | 26.57 |
| Total non-salt-affected soils | 69.90 | 70.96 | 73.89 | 70.36 | 78.59 | 73.43 |
| Total cultivable soils | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

It appears that the farmers are rather consistent in their judgment about the quality of their land. It is, of course, every time the same land about which they are asked for their opinion. In comparing the two sets of data on soil salinity, it seems that the farmers do not clearly observe the difference between non-affected and marginally affected land. The difference between those two levels is rather vague. But, when it comes to the choice between moderately and severely affected, they are inclined to over-estimate the damage caused by the drainage problem. The evaluation of the highest soil salinity class is obvious.[1]

*Farmers' Strategy to Control Salinity*

The farmers adopted more than eighteen measures to tackle the problems of waterlogging and salinity (Table 3). The most common measures were to raise the bunds, use farmyard manure (FYM), scrape accumulation of salt off the soil's surface, and level the land properly. It is interesting to note that about 90 per cent of the farmers raised the bunds around their plots to retain rainwater for leaching the salts from their fields. The largest group was the medium farmers (36 per cent), followed by the large farmers (29 per cent) and the marginal and small farmers (25 per cent). Raising the bunds is important because it helps to improve the uniformity of the irrigation application and to distribute salts over a larger area, thereby preventing harmful concentrations. At present, salts appear in patches, occurring first in low-lying areas, where they form a crust due to stagnation. To overcome these problems, the farmers are not only raising their bunds, but they are also levelling their land properly. About 64 per cent of the farmers practise proper land levelling to prevent saline patches formation in their plots.

TABLE 3. MEASURES ADOPTED BY FARMERS TO COMBAT WATERLOGGING AND SOIL SALINITY

*(per cent)*

| Measure | Marginal and small farmers | Medium farmers | Large farmers | All farmers |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| Deep ploughing | 2 | 1 | 3 | 6 |
| More frequent ploughing | 1 | 6 | 6 | 13 |
| Proper land levelling | 10 | 31 | 23 | 64 |
| Raise bunds | 25 | 36 | 29 | 90 |
| Make smaller plots | 1 | 1 | 1 | 3 |
| Conserve rainwater | 4 | 12 | 13 | 29 |
| Let fields lie fallow during *kharif* | 11 | 22 | 20 | 53 |
| Change cropping pattern | 2 | 1 | - | 3 |
| Use more FYM | 26 | 30 | 27 | 83 |
| Irrigate more | 2 | 2 | 3 | 7 |
| Scrape salt | 21 | 30 | 30 | 81 |

The second most common coping measure is the addition of FYM to the fields. About 82 per cent of the farmers use FYM as a remedial measure to control salinity. This strategy is more popular among the marginal and small farmers and the medium farmers than among the large farmers. Although it is not a technically effective measure to control salinity, it improves soil fertility and, to some extent, it neutralises the adverse effects of salinity. About 72 per cent of the farmers scraped the salt from their plots. Salt scraping is the practice of removing salts from the surface layer of the soil and collecting them in one place. It creates a favourable environment for seed germination and plant growth. The farmers have employed this method for a long time. As many as 60 per cent of the medium and large farmers practice it when there are accumulations of salt in their plots. The farmers reported that this method produces satisfactory results. In answer to the question of where they learnt this technique, most of the farmers replied that they observed other farmers doing it, either in plots in their own village or in the neighbouring villages. About 88 per cent of the farmers reported that they could reverse the effects of waterlogging and salinity if they managed to get good quality canal water. About 58 per cent of the farmers report that they could reverse such effects without applying tubewell water, which is of poor quality, if they had more canal water. About 35 per cent of the farmers feel that FYM applied with gypsum would help to reclaim their land and about 26 per cent reported that gypsum applied with canal water would help to tackle the salinity problem. It is interesting to note that only 39 per cent of the farmers responded that they are continuing to raise bunds and apply FYM as and when required in their plots. About 54 per cent of the farmers reported that they are slowly ceasing their use of proper agricultural practices in their plots because they realise that it is difficult for them to achieve the initial levels of productivity.

*Evaluating the Effect of Soil Salinity*

The approach undertaken in this study is to estimate the functions relating crop yields and soil salinity. The approach assumes that crop yield will decrease with increasing soil salinity. In a bid to determine the threshold value of the selected crops, a segmented, non-linear production function approach was first tried. But, it appeared that a Cobb-Douglas form of production function was producing the best fit. In order to study dynamic as well as cross-sectional, pooled cross-sectional time series (from 1994 to 1999), panel data were used.

$$Y = a X_1^b X_2^c \qquad ....(1)$$

where Y is the crop yield, in kilogram per hectare; $X_1$ is the salt concentration in the soil expressed by the electrical conductivity ($EC_e$ ). The unit for this is deci-Siemen per meter (dS/m). $X_2$ is the seasonal total rainfall (in mm). For *kharif* total rainfall for the month of June to October, and for *rabi*, October to February for the corresponding year were considered for the study, where b and c are the coefficients of the respective factors.

From this function, the yield depression due to soil salinity can be estimated. From Table 4 it is clear that the variation in yields is mainly explained by salinity and partly by rainfall. In *kharif* season, the variation in paddy yield due to synergetic effect of both salinity and rainfall explained to the tune of 84 per cent whereas in the case of wheat in *rabi* season it is about 42 per cent. In terms of production, the

TABLE 4. ESTIMATED PRODUCTION FUNCTION BETWEEN YIELD (KG/HECTARE) VS. SOIL SALINITY ($EC_E$) AND RAINFALL (IN MM)

| Particulars | Unit | Average value | | b-value | | Damage due to salinity (kg/hectare) | |
|---|---|---|---|---|---|---|---|
| | | Wheat | Paddy | Wheat | Paddy | Wheat | Paddy |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Yield | Kg/hectare | 2,619 | 1,691 | | | | |
| Salinity (ECe) | Deci-Siemen per meter | 6.56 | 4.39 | -0.8439 | -0.3893 | 336.92 | 149.96 |
| Seasonal total rainfall | In millimetres | 96.03 | 523.96 | 0.1298 | 1.3829 | | |

damage due to salinity in *kharif* season for paddy is about 150 kg per hectare. In relative terms the loss is between 8 to 9 per cent. In monetary terms, per hectare seasonal loss is about Rs. 1,650. The crop loss in *rabi* season is about 337 kg per hectare. In relative terms it is about 13 per cent of the average level of productivity. In value terms the losses is in the magnitude of Rs. 1,854 per hectare in *rabi* season. The rainwater helps to add about 4 kg per hectare at the marginal level both for paddy and wheat. The regression coefficients are statistically significant at 1 per cent significance level, both for *kharif* and for the *rabi* season which may be due to negligible losses at the farm level. The problem of land degradation due to soil salinity and its negative effect on the crop yields is still hardly felt. Although all the farmers are aware of the salinity problem, they are still not worried about it.

*Searching for Compensatory Measures*

To find out whether the (negative) effect of salinity will be compensated by the positive effect of the other inputs, a multiple regression analysis was done. In this analysis, it was tried to combine both physical factors and management factors. The equation used is:

$$Y = a\ \text{Input}^{\,b}\ \text{Irrigation}^{\,c}\ \text{Labour}^{\,d}\ \text{Machine}^{\,e}\ \text{pH}^{\,f}\ \text{ECe}^{\,g} \qquad \text{....(2)}$$

where, Y = gross seasonal income (Rs./acre); Input= per acre cost of seeds plus value of manure, fertiliser and insects pesticides. Irrigation = per acre cost of both canal and tubewell irrigation, Labour= per acre cost of hired labour, Machine= per acre cost of machine and bullock power used for sowing, transplanting and harvesting, pH = alkalinity in the soil in physical terms and $EC_e$ = soil salinity, expressed by the electrical conductivity ($EC_e$). The unit for this is deci-Siemen per meter (dS/m).

The estimated function from the pooled data shows that the coefficient of determinants for paddy in *kharif* season is about 45 per cent and for wheat in *rabi* season it is about 29 per cent. It indicates that the selected variables are able to explain about 45 per cent and 29 per cent of the gross income fluctuation in *kharif* and *rabi* season, respectively(Table 5). The regression coefficient of each factor, i.e.,

TABLE 5. ESTIMATION OF THE PRODUCTION FUNCTION OF WHEAT AND PADDY IN GOHANA AREA DURING 1994-99

| Variables (1) | Wheat (b-value) (2) | Paddy (b-value) (3) |
|---|---|---|
| Constant | 8.330* | 6.491* |
| | (0.500) | (0.679) |
| Inputs | 0.031 | 0.294* |
| | (0.086) | (0.044) |
| Irrigation | 0.0009** | 0.021** |
| | (0.000) | (0.011) |
| Labour | -0.0002 | 0.076* |
| | (0.088) | (0.017) |
| Machine | 0.2460* | -0.057* |
| | (0.049) | (0.017) |
| pH | -0.383* | -0.155* |
| | (0.153) | (0.279) |
| ECe | -0.1847* | -0.073* |
| | (0.019) | (0.020) |

* and ** Significant at 1 and 5 per cent probability level, $R^2$= 0.28 and $R^2$= 0.45, respectively for wheat and paddy.

inputs, irrigation, labour, machine, pH and ECe, namely, the elasticities of production of each input, which are less than one thus showing diminishing returns to each input. Most of the coefficients are statistically significant at different probability levels. The sign of labour value in *kharif* season is negative and also statistically non-significant for paddy. It seems the farmers are spending more amount on ploughing. The field observations indicate that the farmers are using more and more machine and bullock power to conserve the soil moisture, in order to compensate their loss through early sowing of the crop and conserve the rain water.

The production elasticity for each input indicates the estimated percentage change in gross income associated with 1 per cent change in the input, while other factors are held constant. The sum of elasticities, i.e., the regression coefficients is equal to –0.292 and 0.107, respectively for wheat and paddy. It is interesting to note that decreasing returns to scale both (Table 6) for paddy and wheat. The revenue-enhancing factors for paddy crop appeared to be as powerful as that of soil salinity. The positive response of the revenue increasing variables on crop income completely compensated the negative effect of soil salinity in case of paddy crop. The reason for this is that the salinity build up in the *kharif* season is less due to monsoon rain and due to the pounded water in the paddy fields, which facilitate the leaching of the salts. Hence, the crop is not much affected by salinity. Whereas in case of wheat crop, diminishing returns is observed (-0.292), mainly due to the strong negative effects of physical factors, i.e., salinity ($EC_e$) and alkalinity (pH). All the revenue-enhancing factors for wheat appeared to be positive but were unable to compensate the negative effects of that of soil salinity. This is mainly due to less rainfall in the *rabi* season and higher rate of evaporation compelled the capillary rise of the water table which indirectly helps to build up salinity level in the crop root zone.

TABLE 6. RETURNS TO SCALE FOR WHEAT AND PADDY IN THE STUDY AREA DURING 1994-99

| Particulars | Returns to scale for | |
|---|---|---|
| | Wheat | Paddy |
| (1) | (2) | (3) |
| Sum of the positive factors | 0.277 | 0.393 |
| Sum of the negative factors | -0.569 | -0.286 |
| Total | -0.292 | 0.107 |

In order to trace out the scope for additional amount spending for revenue enhancing, the marginal value productivity (MVP) for the various factors at the geometric mean level has been calculated from the estimated function. The reason for very low value of MVP for most of the factors indicates that the use of these resources has already reached a point at which very little scope exists for additional units of yield. It is observed from Table 7 that of an additional one rupee spending on inputs will help to add an additional Rs. 3.48 to total paddy income. Similarly, additional amount spending will help to add an additional of Rs. 0.66 on labour and Rs. 0.44 on paddy income. In the case of wheat, additional spending on machine power will help to add additional amount of Rs 1.85 in total income of wheat. In the case for physical factors like alkalinity (pH) and salinity ($EC_e$) an extra amount (successive accumulation of) of alkalinity and soil salinity over the average level will reduce the gross income of Rs. 969 and Rs. 583 per hectare for wheat and Rs. 365 and Rs. 326 for paddy respectively (Table 7).

TABLE 7. MARGINAL VALUE PRODUCTIVITIES OF DIFFERENT FACTORS FOR WHEAT AND PADDY IN THE STUDY AREA

| Variables (1) | Wheat (2) | Paddy (3) |
|---|---|---|
| Input | 0.318 | 3.446 |
| Irrigation | 0.040 | 0.639 |
| Labour | 0.001 | 0.898 |
| Machine | 2.543 | 0.688 |
| PH | -968.79 | -364.61 |
| $EC_e$ | -582.55 | -325.63 |

To estimate the factor-wise expenses required to compensate the loss due to alkalinity and salinity, an attempt has been made to compensate the loss through other inputs and these estimates are presented in Table 8. For salinity control in the wheat field, additional minimum compensation amount is needed on machine expenses to the tune of Rs. 229 and maximum on irrigation is about Rs. 14,612. A similar trend has been observed to tackle the alkalinity (pH) problem in the wheat field also. For salinity control in the paddy field the required amount per hectare are Rs. 474 and Rs. 510 on machine and irrigation (Table 8). For alkalinity control in the paddy field, factor wise required amount is more as compared to its salinity control expenses. These facts clearly indicate that the severity of crop loss due to salinity and alkalinity in *rabi* season is more than during *kharif* season. From Table 8, it may be interpreted that in the saline area cost of production would increase if curative measures were not adopted immediately.

TABLE 8. ESTIMATED FACTOR WISE EXTRA AMOUNT NEEDED (RS./HECTARE) TO COMPENSATE THE LOSS DUE TO ALKALINITY (PH) AND SALINITY ($EC_E$) FOR WHEAT AND PADDY IN THE STUDY AREA

| | Wheat | | Paddy | |
|---|---|---|---|---|
| Variables (1) | For pH (2) | For $EC_e$ (3) | For pH (4) | For $EC_e$ (5) |
| Input | 3,046 | 1,833 | 106 | 95 |
| Irrigation | 24,280 | 14,612 | 571 | 510 |
| Labour | - | - | 408 | 363 |
| Machine | 381 | 229 | 530 | 474 |

To estimate crop-wise gross income (income from main product plus by-product) loss both in absolute and relative terms, sensitivity analysis was carried out by using the estimated coefficients (in Table 5) and their respective average values. The estimated results are presented on per hectare basis and presented in Table 9. Crop-wise gross income at the initial estimated level assume to be the normal seasonal crop income as these two crops represent more than 80 per cent area respectively in both the seasons. For this analysis except salinity (ECe), other factors are kept constant at their geometric mean level. The absolute level per hectare income loss due to different salinity level ranges from Rs. 963 to Rs. 2,166 from paddy and for wheat it is in the tune of Rs. 1,146 to Rs. 3,851 (Table 9). The per hectare loss on income from wheat is more as compared to income from paddy. In terms of percentage loss it is in the range of 5 to 11 per cent and 6 to 19 per cent respectively for paddy and wheat.

TABLE 9. CROP-WISE ESTIMATED ECONOMIC LOSS AT DIFFERENT SALINITY LEVEL

| Salinity level (ECe) | Absolute level income loss (Rs./hectare) on | | Percentage wise economic loss from the existing income level | |
|---|---|---|---|---|
| | Paddy | Wheat | Paddy | Wheat |
| (1) | (2) | (3) | (4) | (5) |
| 8 | 963 | 1,146 | 4.96 | 5.54 |
| 12 | 1,506 | 2,186 | 7.76 | 10.56 |
| 16 | 1,882 | 3,145 | 9.70 | 15.19 |
| 20 | 2,166 | 3,851 | 11.17 | 18.60 |

To calculate the actual damage per cultivable hectare both in *kharif* and *rabi* seasons, the figures for the potential damage were multiplied by the corresponding cropping intensities. The average cropping intensities in *kharif* and *rabi* are 83 and 92 per cent, respectively. Therefore, to calculate the actual damage per cultivable hectare, the potential figures for *kharif* and *rabi* have been multiplied by the factors 0.83 and 0.92, respectively and the results are also presented in Table 10. The actual damage per cultivable hectare per agricultural year is the final aim of our soil salinity class-wise analysis. It should be observed that the damage in the first years is considerably lower than in the later years. This is mainly due to the sharply raised paddy price. The damage due to soil salinity in physical terms is still rather modest in this area. It is in the order of 10 to 15 per cent of the annual gross production per hectare obtained in the non-affected land. The damage in monetary terms, however, is 20 to 30 per cent of the annual net production value per hectare obtained in that category of land.

TABLE 10. POTENTIAL AND ACTUAL DAMAGE DUE TO SOIL SALINITY

*(Rs. per cultivable hectare)*

| Year | *Kharif* season | | *Rabi* season | | Agricultural year | |
|---|---|---|---|---|---|---|
| | Potential damage | Actual damage | Potential damage | Actual damage | Potential damage | Actual damage |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 1995-96 | 1,665 | 1,382 | 1,177 | 1,083 | 2,842 | 2,465 |
| 1996-97 | 974 | 808 | 1,647 | 1,515 | 2,621 | 2,323 |
| 1997-98 | 2,295 | 1,905 | 1,750 | 1,610 | 4,045 | 3,515 |
| 1998-99 | 2,105 | 1,747 | 1,736 | 1,597 | 3,841 | 3,344 |
| Average | 1,760 | 1,460 | 1,578 | 1,451 | 3,337 | 2,912 |

*Factors Influencing the Salinity Control Measures*

To identify and assess the factor that most influences the investment behaviour of the farmers for salinity control, it was necessary to study the relative effectiveness of the methods that farmers adopt to reclaim waterlogged and saline soils. The Logit function was used for this study. Table 11 shows that the model correctly predicted the likelihood of a farmer's adopting a particular method. The mean probability of a farmer's adopting a method is 0.93 and that of a farmer's not adopting a method is

0.32. Variables other than age (AGE) and presently affected area (PAFCT) are positively related to the adoption behaviour of the farmers. Education level (EDUCAT) and investment level (INVT) of the farmers significantly influence his adoption of a reclamation method. Each farmer whose land is affected by waterlogging and salinity adopts different methods and invests at least some amount to combat these problems. Although some of the methods are not effective solutions for the long term, it is clear that the farmers will invest in a technology if it may help to reclaim their waterlogged and saline soils.

TABLE 11. DETERMINANTS FOR FARMERS TO ADOPT A METHOD OF RECLAIMING WATERLOGGED AND SALINE SOILS

| Variable (1) | Estimated coefficients (2) | Standard error (3) | Significance level (4) |
|---|---|---|---|
| CONSTANT | 6.4979 | 3.9331 | * * |
| AGE | -0.1949 | 0.0634 | * * * |
| EDUCAT | 0.3011 | 0.0814 | * * * |
| FRAGME | 0.0399 | 0.1193 | NS |
| INVT | 0.0013 | 0.0004 | * * * |
| PAFCT | -0.2713 | 0.1471 | * * |
| TULCL | 0.1092 | 0.1120 | NS |
| LOG-LIKELIHOOD (FUNCTION): CONSTANT ONLY | | - 79.9164 | |
| LOG-LIKELIHOOD (FUNCTION): | | - 34.3828 | |
| -2 times log of LIKELIHOOD ratio: (d.f = 6) | | 91.0672 | * * * |

*** Significant at $p < 0.01$; ** Significant at $p < 0.05$; NS= not significant.

These results were subjected to a sensitivity analysis. The starting point of the analysis was that, given the current socio-economic situation, about 80 per cent of the farmers are willing to adopt some form of land-reclamation measure. The analysis predicted that if the level of Government investment increased by 10 per cent then the level of farmers' willingness to adopt land reclamation measures would rise to about 89 per cent, or 11 per cent more than at the starting point. Similarly, if the level of the farmers' education increased, then, their willingness would rise to 81 per cent, or 2 per cent more than at the starting point (Table 12).

TABLE 12. PREDICTED EFFECTS OF GOVERNMENT INTERVENTIONS ON FARMERS' ADOPTION OF LAND-RECLAMATION MEASURES

| Intervention (1) | Predicted number of farmers who will adopt land-reclamation measures (2) | Increase in relation to original number of farmers (per cent) (3) | Predicted increase in total number of farmers who will adopt land-reclamation measures (per cent) (4) |
|---|---|---|---|
| No intervention | 113 | - | - |
| Increase in educational level | 123 | 8.85 | 90 |
| Increase in investment | 125 | 10.62 | 91 |
| Increase in education and investment | 128 | 13.27 | 93 |

It is interesting to note that the predicted impact of the combination of increased Government investment and increased education of farmers is greater than that of either factor alone. The predicted impact is that 10 more farmers would be convinced to adopt land reclamation measures. In the current economic crisis, which offers limited scope for stepping up public investment, the results indicate that the farmers can - and do - put off expenditures for reclamation of waterlogged and saline soils. They see that opportunities to intensify reclamation of waterlogged and saline soils in future are limited. The new technology that is necessary for the prevention of waterlogging and salinity does not usually benefit the farmers as much as land reclamation does. Government intervention is essential for the prevention of soil degradation when farmers cannot make such investments themselves. Nevertheless, it is vital that the farmers' participate actively in the management of soil degradation.

## IV

## CONCLUSION AND POLICY IMPLICATIONS

The worst drainage problems are concentrated near the canal area. Unquestionably, in that area drainage is needed. Because of the larger distance from the canals, the remaining part of the Gohana area suffers less from the drainage problem. Therefore, at this moment, it might be less urgent to drain it. In the non-drained part of the study area, over time the affected parts will continue to increase in size as well as in severity. Ultimately, they may cover two-thirds of the whole area. The other relatively higher-lying parts, will probably remain in production if sufficient water is available for irrigation and leaching. Since 33 per cent of the farmers' fields are affected marginally, it is important to prevent this land from turning into moderate to severely saline areas. At the same time, improvement of the moderately affected (7 per cent) and severely affected areas (6 per cent) also needs more attention. In the affected areas, soil salinity is the principal factor that determines paddy and wheat yields. In the study area, the farmers increase input use as soil salinity increases. As a consequence, the incidence of soil salinity will result in an increase in production costs and a reduction in crop production. In highly saline areas, even the cultivation of paddy will no longer be economically viable. Therefore, soil salinity should be controlled.

In our opinion, sub-surface drainage systems are the most effective and efficient means to control the groundwater table and soil salinity, and to ensure reasonable paddy and wheat yields in the presently affected areas. In the extremely saline areas, which account for 6 per cent of the total cultivable area, additional measures might be needed to reclaim the soils. Curative measures to alleviate the soil salinity problem will only help the farmers temporarily in curbing the crop loss. Estimating crop damages will help to select appropriate technological or management measures, with a view to their technical and financial feasibility. Our earlier (Datta *et al*., 2002) analysis showed that subsurface drainage is the best choice to permanently solve the drainage problem. It may take several decades and injection of enormous capital to achieve this. Therefore, as a short-term measure, farmers could practice proper use of irrigation water, surface drainage improvement - cleaning, deepening and prevention of blockage of drainage canals at the farm level.

Excessive irrigation in the upstream should be controlled to prevent the water table from rising downstream. This can be achieved through institutional changes with close co-operation between the management agency and the farmer organisation. Application of organic matter is necessary to prevent the capillary rise in the area. During the off-season, fields should be kept under salt and drought tolerant crops such as sunflower, minor millets, etc. as plant cover retards salinisation. Drainage is to be managed up to the outlet. Hence, it is important to get farmers' co-operation to manage it. The decisions on drainage canal development should be done with full consultation and co-operation of the farmers. The farmers should accept crop losses during the installation of drainage and share in the construction labour and the operations and management. Local practices used by the farmers to reduce the adverse effect of salt in established irrigated areas should be considered. In this regard, farmers' organisations would be useful instruments to achieve this common goal. Participation in salinity control activities could be encouraged through subsidies, and farmer education and training.

In the study area, farmers have mentioned that they are willing to pay for the drainage service, at least for the operation and maintenance costs. This is a more positive step, because they are only becoming slowly aware of the fact that they have a serious problem, which they cannot tackle individually. In conclusion, it should be observed that irrigated lands should be drained as soon as the need arises. It makes no sense to let the farmers suffer great losses over long periods before an unsustainable situation is corrected.

*Received May 2002.* *Revision accepted January 2004.*

NOTE

1. All in all, it may be concluded that the farmers' judgment can be used roughly to assess the effect of water logging and soil salinity on the productivity of their land. For this analysis, however, we have used the measured data on soil salinity.

REFERENCES

Government of Haryana (1998), *Drainage Master Plan*, Chandigarh, India.

Datta, K. K. and C. de Jong (2002), "Adverse Effect of Water Logging and Soil Salinity on Crop and Land Productivity in Northwest Region of Haryana, India", Agricultural Water Management (Elsevier publication), Vol. 57, pp. 223-238.

Datta, K. K., C. de Jong and O. P. Singh (2002), "Feasibility of Subsurface Drainage for Salinity Control in the Trans-Gangetic Region of India", *Irrigation and Drainage* (The Journal of International Commission on Irrigation and Drainage), Vol. 51, No. 4, pp. 275-292.

Sharma, D. P. (1996-98), *Annual Report of Haryana Operational Pilot Project/HOPP Gohana*, Central Soil Salinity Research Institute, Karnal, Haryana.