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Impact of Waterlogged Saline Soil Reclamation on Land Productivity and Farm Income — An Economic Study from Haryana

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Abstract

The study has looked into the impact of subsurface drainage technology on reclamation of waterlogged saline soil, in relation to improvement in land productivity and enhancing farm income by sustainable agricultural production in Haryana. The study is based on the primary data collected from 90 farmers under the technology. The study has presented a comparison of cropping pattern, cropping intensity, soil salinity, soil pH, water table depth, yield of major crops and economics of major crops in the district of Fatehabad before (2007-08) and after (average of 2011-2014) installation of subsurface drainage technology. The study has revealed that reclamation of waterlogged saline soils through installation of subsurface drainage system helps to enhance farm income by increasing land productivity. The study has suggested that the farmers should be made aware about the benefits of this drainage technology to increase crop yield and farm income.

Key words: Waterlogging, soil salinity, soil reclamation, impact of subsurface drainage, farm income, Haryana

JEL Classification: Q15, Q13

Introduction

Waterlogging and soil salinity are threatening the sustainability of agricultural production on approximately 0.5 million hectares area in the state of Haryana (GoH, 1998). The threat is more serious because the groundwater in most of the endangered area is brackish or saline. Agriculture in semi-arid and arid regions of India is predominantly practised by small and marginal farmers with landholdings of even less than one hectare. These resource-poor farmers are not in a position to invest in irrigation and drainage facilities, which are very expensive. Most of the irrigation and drainage projects are funded by the central or state governments. The subsurface drainage technology has proved to be a technically feasible and cost-effective tool to combat the twin problems of waterlogging and soil salinity (Datta *et al.,* 2004; Mathew, 2004; Chinnappa and Nagaraj, 2007; Ritzema and Schultz, 2010). But, the installation of subsurface drainage system requires a considerable amount of money and technical skill as well as manpower. So far, most of the research has been conducted on the effects of soil salinity on crop yield (Maas and Hoffman, 1977; Bresler *et al*., 1982; Tanji, 1990), but reports on its effect on net returns per ha and, consequently, on farmers' incomes are very limited (Datta and Jong, 2002). The present study was carried out with the objective of the reclamation of waterlogged saline soils through subsurface drainage technology

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and its impact on sustainable agricultural production in Haryana. The study has estimated the economic impact due to reclamation of waterlogged saline soil and feasibility of technological intervention on increasing productivity of land and enhancing farm income.

The study was carried out at subsurface drainage area located in the village Banmandori, Fatehabad district of Haryana. The study area is located in an alluvial plain of the Indo-Gangetic basin in the western parts of Haryana. The district is characterized by its dryness and extremes of temperature and scanty rainfall, about 400 mm. About 71 per cent of the annual normal rainfall is received during the south-west monsoon period in July-September (Statistical Abstract of Haryana, 2010-11). The sub-soil water of the district is overall brackish or saline. The quality of water varies from place to place. The extensive canal irrigation introduced by the Bhakra Nangal Project had changed the water table configuration with rise in water level by 2 to 7 m between 1974 and 1978 (Statistical Abstract of Haryana, 1978-79). The groundwater is saline and unfit for human consumption and agricultural production. In the study area, crop and land productivity are directly affected by the drainage problems, whereas livestock production is indirectly affected.

The Drainage Features

Under the subsurface drainage system installed in 2009-10 in the Fatehabad district, the total area covered is 277 ha and 125 farmers are associated with this technology. The drainage system was designed with a discharge rate of 1.5 mm/day, depth of drain as 1.0-1.5 m and spacing of lateral pipe as 60 m. The size of laterals and collector pipe are 80 mm and 160-200 mm, respectively. The approximate installation cost was estimated at ₹ 62,000/ha.

Data and Methodology

The primary data were collected from 90 farmers covered under the subsurface drainage using area-random sampling with the help of a grid system map of 1 acre plot obtained from the *patwari*. After selection of plots, crop cutting experiments were carried out during harvest of both *kharif* and *rabi* seasons. Simultaneously, soil samples were collected and analysed to know the salinity status. The representative soil samples were drawn from all the drainage blocks up to 90 cm depth. Water table depth was recorded on regular intervals from the sumps of all the drainage blocks. The sample of drain water was collected and analyzed to know the status of drain water salinity. The depth of the water table, pH and electrical conductivity (EC) of the soil and water were recorded. The primary data included socio-economic status, cropping pattern, cropping intensity, crop yield, and input-use. The secondary data were also collected wherever necessary.

The analysis was carried out to estimate the data obtained from block No. 3, where the subsurface drainage is functioning. The benefit-cost ratio was estimated to know returns obtained from the investment on subsurface drainage. The average values of input and output were compared with the situation before (2007-08) and after (average value of 3 years data of 2011-12, 2012-13 and 2013-14) the installation of subsurface drainage. The EC and pH of soil and drain water samples collected from the study area were also compared in a similar basis.

Results and Discussion

Socio-economic Features

The socio-economic features of the sample farmers revealed that the average family size was of 7 persons and literacy rate was around 60 per cent. Agriculture was the main occupation and about 93 per cent households were engaged in activities such as crop production and dairying. The majority of farmers were smallholders, with average farm size of 1.47 ha, of which approximately 50 per cent land was problematic, being affected by waterlogging or soil salinity. The farmers had 52 per cent of their annual family income from crop production and 22 per cent from dairying. Many farmers supplement their income through off-farm activities. The major irrigation source was canal (90% area irrigated). Among farm machineries owned by farmers, 14 per cent had tractors, 13 per cent had trolley and 8 per cent had seed-cum-fertilizer drills.

Impact on Cropping Pattern

The cropping pattern in the study area during both *kharif* and *rabi* seasons is depicted in Table 1. The major *kharif* crops were cotton, rice and guar during both before and after the subsurface drainage

Table 1. Cropping pattern during *kharif* and *rabi* seasons before and after subsurface drainage installation in Fatehabad district

Crop	Before drainage (%)	After drainage (%)	Per cent change
	***Kharif* season**		
Cotton	44.83	51.51	14.90
Rice	9.89	11.45	15.77
Guar	20.81	16.01	-23.07
Bajra	4.82	3.96	-17.84
Groundnut	3.49	4.04	15.76
Fodder	1.04	1.05	0.96
Other crops	0.86	1.1	27.91
Fallow land	14.26	10.88	-23.70
	***Rabi* season**		
Wheat	61.08	71.1	16.40
Mustard	12.05	13.83	14.77
Barley	1.34	1.31	-2.24
Oat	1.17	0.88	-24.79
Berseem	0.24	0.24	0.00
Castor	0.23	0.15	-34.78
Other crops	7.92	1.02	-87.12
Fallow land	16.01	11.46	-28.42

installation. Similarly, in *rabi* season wheat was the most important crop followed by mustard. It has been observed that the area under major crops has significantly increased after drainage installation during both *kharif* and *rabi* season. After installation of subsurface drainage, the area under rice crop has increased by 15.77 per cent followed by groundnut (15.76%) and cotton (14.90%). The reduction in the area under guar crop after drainage was mainly attributed to reduction in market price of the crop after 2010. Similarly, during *rabi* season, the area under wheat and mustard crop was increased by 16.40 per cent and 14.77 per cent, respectively. Other crops were grown as well in *kharif* season but in *rabi* season the importance was given only to major commercial crops. We could notice that, after the installation of subsurface drainage, the area under fallow land has significantly reduced by 23-28 per cent during both *kharif* and *rabi* seasons.

Impact on Cropping Intensity

The cropping intensity of the drainage area before and after subsurface drainage installation is presented in Table 2. The cropping intensity before drainage installation was 73.71 per cent during *kharif* and 74.14 per cent during *rabi* season and after the drainage installation, it increased to 87.79 per cent and 90.10 per cent, respectively. Thus, the increase in cropping intensity after the installation of subsurface drainage was 19.11 per cent in *kharif* and 21.53 per cent during *rabi* season. The overall cropping intensity increased by 20.32 per cent due to installation of subsurface drainage in the region. The increase in cropping intensity during both the seasons shows a positive impact of drainage technology on reclamation of waterlogged saline soils.

Table 2. Cropping intensity of study area before and after subsurface drainage installation in Fatehabad district

Cropping season	Before drainage (%)	After drainage (%)	Percent change
Kharif area	73.71	87.79	19.11
Rabi area	74.14	90.10	21.53
Cropping intensity	147.84	177.89	20.32

Impact on Soil Salinity

To assess the impact of subsurface drainage on soil health, samples were collected after the harvest of *kharif* and *rabi* crops. It was observed that soil salinity in the study area varied between the seasons and with depth of soil. This variation was probably caused by the amount of rainfall and its distribution. The surface soil (0-30 cm) had higher salinity compared to soil at the lower depth (up to 90 cm). The study revealed that after installation of subsurface drainage, there was a tremendous reduction in soil salinity, recorded up to 44.24 per cent (Table 3). It shows positive impact of subsurface drainage technology on salinity management. The soil pH of the study area remained in the normal range (around 8.00) and had no adverse effect on crop production.

Water Table Depth and Salinity (EC) Status of Drain Water

The requirement of irrigation water increases as water-table depth decreases in the study area. Crops can meet their water requirements, if water table is at a depth shallower than 1.2 metre. To study the groundwater fluctuation, the water table depth was measured on regular intervals from the sumps located

Table 3. Soil salinity (ECe) and pH before and after subsurface drainage installation in Fatehabad district

Value	ECe (dS/m)			pH		
	Before drainage	After drainage	Per cent change	Before drainage	After drainage	Per cent change
Mean	8.60	4.80	-44.24	8.32	8.19	-1.56
Minimum	4.99	3.07	-38.52	8.13	8.03	-1.23
Maximum	13.86	7.15	-48.44	8.50	8.30	-2.35
Standard deviation	4.03	2.02	-49.90	0.16	0.12	-25.00
Coefficient of variation (%)	47.01	42.11	-10.41	1.89	1.52	-19.58

Table 4. Water table depth and salinity of drain water before and after subsurface drainage installation in Fatehabad district

Value	Water table depth (m)			Salinity (EC) of drain water		
	Before drainage	After drainage	Per cent change	Before drainage	After drainage	Per cent change
Mean	0.55	0.75	35.8	9.10	4.60	-49.5
Minimum	0.40	0.66	64.2	5.50	3.52	-36.1
Maximum	0.70	0.91	30.0	15.00	5.88	-60.8
Standard deviation	0.21	19.22	8962.6	6.25	1.04	-83.4
Coefficient of variation (%)	38.57	38.11	-1.2	55.62	22.80	-59.0

in all the drainage blocks. Simultaneously, the drain water was collected from the sumps to measure its salinity level.

The data revealed that the mean water table depth in the drainage area was 0.55 m and 0.75 m, respectively, before and after installation of subsurface drainage. Thus, there was 35 per cent reduction in the mean water table after the installation of subsurface drainage (Table 4). After drainage installation, the water table was recorded 0.91 m below the ground level during May and 0.66 m below during September. Due to drainage outflow, the minimum and maximum depths of water table went down up to 64 per cent and 30 per cent, respectively, after installation of subsurface drainage. The lowest water table depth during the month of May was due to higher temperature and higher evaporation rate in this month. The higher water table during September was due to monsoon rainfall in the region. The drain water from the higher side moves towards the lower side where sump is located and due to this, the farmers in the upper side, or who are away from the sump are significantly benefitted in comparison to those whose land is towards lower side or near the sump. However, the natural slope of the land makes the difference.

The salinity of water before installation of subsurface drainage was 9.10 dS/m, it reduced to 4.60 dS/m after installation of subsurface drainage, indicating a reduction of 49.5 per cent (Table 4). Thus, there was a significant reduction in salinity of the drain water after the installation of subsurface drainage.

Impact on Crop Yield

The major crops grown in the region are rice and cotton in *kharif* and wheat and mustard in *rabi* seasons and therefore these four crops were considered for economic analysis. The mean yield of all the major crops in the drainage area has significantly increased after the installation of subsurface drainage. The yield of rice and cotton crops before drainage was 18.65 q/ha and 9.63 q/ha, respectively and after installation of subsurface drainage, it increased to 22.44 q/ha and 11.20 q/ha in that order. Similarly, in the *rabi* season, wheat and mustard yield before drainage was 27.39 q/ha and 8.72 q/ha, respectively, which increased to 34.14 q/ha and 10.03 q/ha in that order. Across these four crops, the highest increase in yield was recorded for rice crop, followed by wheat, cotton and mustard crops (Table 5).

Table 5. Yield of major crops before and after subsurface drainage installation in Fatehabad district

(q/ha)

Crop	Before drainage	After drainage	Per cent change
	***Kharif* season**		
Rice	18.65	22.44	20.46
Cotton	9.63	11.20	16.26
	***Rabi* season**		
Wheat	27.39	34.14	19.75
Mustard	8.72	10.03	15.01

Before installation of subsurface drainage in the region, the loss in yield of major crops was up to 50 per cent due to waterlogging and soil salinity in the year 2007 (as recorded by Haryana Operational Pilot Project), but after the installation of subsurface drainage, the situation is slowly changing towards positive side and farmers are getting relatively better yields.

Economics of Major Crops

The cost of production was estimated separately for *kharif* (rice and cotton) and *rabi* (wheat and mustard) crops before and after subsurface drainage installation (Table 6). The costs of all inputs and output parameters pertaining to rice, cotton, wheat and mustard production were based on average values of the sampled farms. The cost concepts, viz. cost A1, A2, B1, B2, C1 and C2, were considered for the estimation. The cost C1 was considered to estimate net income and benefit-cost ratio (Tripathi *et al.*, 2013). The cost C1 included all direct expenses made in cash and kind for crop production such as hired human labour, machine labour, seeds, fertilizers, irrigation, plant protection measures, imputed value of family labour, interest on working capital and depreciation on fixed assets (CSO, 2008). The gross income included the total value of main crop as well as of by-products. The estimated total cost was high in the region. The unit cost of production increases with the level of soil degradation.

The cost of production and net returns for the selected crops were estimated and are presented in Table 6. It reveals that cost of production increased after drainage installation between 20 and 27 per cent due to increase in cost of inputs used. The net income

Table 6. Cost of production and net income of major crops before and after subsurface drainage installation in Fatehabad district

Crops	Before drainage	After drainage	Per cent change
	Cost C1 (₹/ha)		
Rice	30527	36901	20.88
Wheat	27695	35283	27.40
Cotton	29431	37115	26.11
Mustard	22551	28539	26.55
	Net income over cost C1 (₹/ha)		
Rice	-2338	15676	770.51
Wheat	-1530	9312	708.75
Cotton	-5157	4818	193.42
Mustard	-2963	6239	310.59

estimated for all major crops, which was negative before subsurface drainage installation, became positive after drainage installation. The net income was highest for rice (₹ 15676/ha), followed by wheat (₹ 9312/ha), mustard (₹ 6239/ha) and cotton (₹ 4817/ha). The increase in net income was largely related to the increase in crop yield due to intervention of subsurface drainage technology.

The benefit-cost ratio for major crops of the study area before and after installation of subsurface drainage is presented in Table 7. Before drainage installation, the B-C ratio was less than one for all crops, but after the drainage installation, there was a significant improvement in this ratio; it was found 1.42 for rice, 1.26 for wheat, 1.13 for cotton and 1.22 for mustard. It indicates the worthiness of the subsurface drainage technology for reclaiming waterlogged saline soil in the study area.

The salinization is a dynamic process and its influence changes over time. In the study area, the farmers reported that salinity and waterlogging

Table 7. Benefit-cost ratio of major crops before and after subsurface drainage installation in Fatehabad district

Major crops	Before drainage	After drainage	Per cent change
Rice	0.92	1.42	54.30
Wheat	0.85	1.26	32.67
Cotton	0.82	1.13	37.57
Mustard	0.87	1.22	40.29

problems started during 1990s. As per farmers' experience, before the introduction of Bhakra irrigation canal, their lands were productive and providing normal yield. But, after the canal introduction, salinity problem started slowly in the initial years and became problematic during late-1990s and finally their lands changed to less productive, till the installation of subsurface drainage during 2009-10. This was mainly due to the location of study area along the banks of irrigation canal that causes seepage problem. To overcome the problem of waterlogged soil salinity, installation of subsurface drainage technology was very much required. The higher lying areas relatively remain in production if sufficient water is available for irrigation and leaching takes place. The water table is maintained by pumping out drain water and over the years, the upper groundwater layer is suitable for irrigation (Datta and Jong, 2002).

The important implication from this study is that installation of diesel pumps should be facilitated for pumping out drain water. The farmers should be made aware about the advantages of drainage systems. In the arid and semi-arid regions, irrigation systems require a drainage system and without proper management of drainage system, irrigation systems will not sustain in the long run (Datta *et al*., 2000).

Conclusions and Policy Implications

The study has revealed that reclamation of waterlogged saline soils through installation of subsurface drainage system helps to enhance farm income by increasing land productivity. Both cropping intensity and crop yield increased with decrease in soil salinity. After installation of subsurface drainage system in the study area, the average soil salinity decreased by 44 per cent and the groundwater table was 35 per cent deeper, especially during the monsoon period. In the subsurface drainage area, cropping pattern has also changed towards more remunerative crops. The higher benefit-cost ratios show the economic feasibility of drainage technology in the waterlogged saline areas. However, there is a need to educate farmers about the need of drainage system and its benefits in the study area.

References

Bresler, E., McNeal, B.L. and Carter, D.L. (1982) *Saline and Sodic Soils-Principles–Dynamics–Modeling*. Springer, New York.

Chinnappa, B. and Nagaraj, N. (2007) An economic analysis of public interventions for amelioration of irrigation-induced soil degradation. *Agricultural Economics Research Review,* **20:** 375-384.

CSO (Central Staistical Organization) (2008) *Manual on Cost of Cultivation Surveys*. Ministry of Statistics and Program Implementation, Government of India, New Delhi.

Datta, K.K and Jong C. de (2002) An adverse effect of waterlogging and soil salinity on crop and land productivity in northwest region of Haryana, India. *Agricultural Water Management,* **57**: 223-238.

Datta, K.K., Jong, C. de and Singh, O.P. (2000) Reclaiming salt-affected land through drainage in Haryana, India: A financial analysis. *Agricultural Water Management,* **46**: 55-71.

Datta, K.K., Tewari, L. and Joshi, P.K. (2004) Impact of subsurface drainage on improvement of crop production and farm income in north-west India. *Irrigation and Drainage Systems,***18:** 43-55.

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

Maas, E.V. and Hoffman. G.J. (1977) Crop salt tolerance-current assessment. *Journal of the Irrigation and Drainage Division*, **103**: 115–134.

Mathew, E.K. (2004) Adaptability constraints of a technically and economically feasible subsurface drainage system in the low-lying acid sulphate soils of Kerala, India. *Irrigation and Drainage Systems,* **18:** 329-346.

Richards, L.A. (Ed) (1954) *Diagnosis and Improvement of Saline and Alkali Soils*. Agriculture Handbook. No. 60. United States Department of Agriculture, WA, USA.

Ritzema, H. and Schultz, B. (2010) Optimizing subsurface drainage practices in irrigated agriculture in the semi-arid and arid regions: Experiences from Egypt, India and Pakistan. *Irrigation and Drainage,* **60**(3): 360-369.

Statistical Abstract of Haryana (1978-79) Government of Haryana, Chandigarh.

Statistical Abstract of Haryana (2010-11) Government of Haryana, Chandigarh.

Tripathi, R.S., Raju, R. and Thimmappa, K. (2013) Impact of zero tillage on economics of wheat production in Haryana. *Agricultural Economics Research Review*, **26**(1): 101-108.