Journal of Soil Salinity and Water Quality 8(1), 72-81, 2016

Impact Analysis of Reclamation of Waterlogged Saline Soils through Subsurface Drainage Technology in Haryana

R Raju*, K Thimmappa, Parveen Kumar, Satyendra Kumar and RS Tripathi

ICAR-Central Soil Salinity Research Institute, Karnal-132001, Haryana, India
**Corresponding author E-mail: R.Raju@icar.gov.in.*

ABSTRACT

Agriculture in the state is predominantly practiced by 68 per cent of small and marginal farmers. Waterlogging and soil salinity are threatening the sustainability of agricultural production on, approximately 0.5 m ha area in Haryana. Reclamation of these soils is necessary to increase food grain production to feed the ever increasing population of the country. Subsurface drainage technology is economically viable, as it removes excess salts and water from the root zone through leaching and creates favourable conditions for crop production. But, this technology can't be afforded by small and marginal farmers to install in small scale as it requires capital, technical skill and manpower. Haryana operational pilot project in Haryana is having a lead role in installing this technology in the farmers' fields with almost free of cost and reclaimed more than 9000 ha saline area. The current study has assessed the impact of drainage technology on soil salinity and land productivity of Banmandori drainage area where 277 ha was reclaimed with installation of subsurface drainage. The study reveals that after introduction of subsurface drainage, the water table depth has gone down to 13.7 per cent and drain water salinity has showed a tremendous reduction of 98 per cent. The yield obtained with drainage has 10-20 per cent more yield advantage over the yield obtained without drainage. The net income obtained from drainage was 30-40 per cent more compare to without drainage situation.

Key words: Subsurface drainage, Benefit-cost ratio, Waterlogged saline soils, Land reclimation

Introduction

Haryana is located in the northwest part of the country and the climate is arid to semi-arid with average rainfall of 354.5 mm. Though the state receives less rainfall, it is blessed with canal irrigation facility. About 89 per cent of agriculture area is irrigated as against 49 per cent for India. Being a small state with 3.49 per cent area of the country contributes 6.41 per cent food grains to the national food basket. The state has a cropping intensity of 185 per cent as against 135 per cent in India. Agriculture in the state is predominantly practiced by 68 per cent of small and marginal farmers who has land holding of less than 2 ha (GoH, 2014). Waterlogging and soil salinity are threatening the sustainability of agricultural production on, approximately 0.5 m ha area in Haryana (Sharma *et al.,* 2015). No crop can be grown on severely salt affected soils without proper treatment (Tripathi, 2011). Reclamation of these soils is necessary to increase food grain production to feed the ever increasing population of the country.

Subsurface drainage removes excess salts and water from the root zone through leaching and creates favourable conditions for crop production (Gajja *et al.,* 2002). Many studies (Joshi *et al.,* 1987, Datta and Joshi, 1993, Datta *et al.,* 2004, Mathew, 2004, Shekhawat, 2007, Ritzema and Schultz, 2010) indicated that the subsurface drainage (SSD) technology for saline land reclamation is technically viable, economically feasible and socially acceptable by all the categories of farmers (Chinnappa and Nagraj, 2007; Tripathi, 2011). But, subsurface drainage technology is a capital intensive, requires high cost of installation along with technical skill and manpower. The small and marginal farmers do not have the capacity to pay for the investments in irrigation and drainage facilities and hence, most of the irrigation and drainage projects are funded by the central or state governments. Haryana operational pilot project (HOPP) in Haryana is having a lead role in installing this technology in the farmers' fields with almost free of cost and reclaimed more than 9000 ha of saline soils. Subsurface drainage technology was developed initially for Haryana state and later it has been widely adopted and replicated in Rajasthan, Gujarat, Punjab, Andhra Pradesh, Madhya Pradesh, Maharashtra and Karnataka. Subsurface drainage installed in different locations of Haryana state were Gohana, Sampla, Jhajjar, Kalayat, Bhivani, Sonepat, Sirsa, Fatehabad, etc., which covers more than 9000 ha area especially Western Yamuna and Bhakra command area. This study has assessed the impact of drainage technology on soil salinity and land productivity.

Data and Methodology

Study Area

The present study was carried out in subsurface drainage project area of village Banmandori located in Bhattu block of Fatehabad district in Haryana. Fatehabad district is located in an alluvial plain of Indo-Gangetic basin in the western part of Haryana. The geographical area of the district is 2520 sq. km., which is 5.4 per cent of the state share. Bhakra and Western Yamuna are the two major canals which irrigate most part of the district. The climate of the district is of tropical type with intensively hot summer (47^0C in June) and cool winter (2^0C in December and January). The average rainfall of the district is 312 mm. 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 has caused rapid changes in water table configuration. After the introduction of canal, the water level has risen by 2 to 7 m in this area between 1974 to 1978 (GoH, 1978-79). The water level is up to 15 m deep in the central part of the district. The ground water is saline and unfit for domestic consumption as well as for the purpose of agricultural production.

Salient Features of Subsurface Drainage of Banmandori

The block-wise drainage area and number of farmers covered were presented in Table 1. Total area under subsurface drainage in Banmandori village is 277 ha, which covers 152 farmers. The subsurface drainage area was divided into ten blocks, each covering drainage area of 16.5 ha to 52 ha. Each drainage blocks are having one sump and 1 to 4 manholes, depending on the size and structure of the drainage area. During study period, only one drainage block No. F-3 was functioning and other nine blocks were not functioning (other blocks were functioned for a week in September 2013, when HOPP provided 170 liters of diesel as per the provision).

The salient features of subsurface drainage system installed at Banmandori are presented in Table 2. The subsurface drainage was installed in three phases i.e, 80 ha during 2009-10, 117 ha during 2010-11 and 80 ha during 2011-12. The type of drainage system was pipe drainage with pumped outlet, which was designed with a discharge rate of 1.5 mm/day. The depth of drain varies from 1.0 to 1.5 m and spacing of lateral

Table 1: Blockwise area under subsurface drainage in Banmandori

Drainage blocks	Total area (ha)	Farmers covered (No.)	Sump (No.)	Manholes (No.)	Actual length of lateral (m)
F-1	28	8	1	2	450
F-2	23	9	1	3	270
F-3	49	23	1	4	402
F-4	52	27	1	3	390
F-5	26	14	1	2	603
F-6	30	6	1	2	536
F-7	16.5	18	1	1	402
F-8	23	20	1	1	200
F-9	29.5	27	1	2	-
F-10			1	4	-
Total	277	152	10	24	

Maximum permissible length of lateral was 621.5 m

Table 2: Salient features of subsurface drainage system of Banmandori project area

Parameters	Description
Area under subsurface drainage (ha)	277
No. of farmers (beneficiaries) covered	152
Type of drainage system	Pipe drainage with pumped outlet
Design drainage discharge	1.5 mm/ day
Drain depth (m)	1.0-1.5
Drain spacing (m)	60 or 67
Size of laterals OD (ID) in mm	80 (72)
Total length of lateral pipes (m)	16087
Size of collector pipes OD (ID) in mm	160 (144), 200 (178) and 294 (258)
Length of collector pipes (m)	4536
Total drainage blocks (sumps)	10
Years of installation	2009-10 (80ha), 2010-11 (117ha) & 2011-12 (80ha)
Approximate cost of installation (Rs./ha)	62000

pipe is 60 or 67 m the size of lateral pipe is 80 (72) mm and collector pipes were of three sizes, viz., 160 (144) mm, 200 (178) mm and 294 (258).

Cost of Saline Land Reclamation through Subsurface Drainage

The land reclamation cost through subsurface drainage was estimated to Rs. 62000 per ha. The actual component wise land reclamation cost was recorded from installing agency HOPP (Fig. 1). Total land reclamation costs were broken down into following five major cost components (Datta, *et al.*, 2000 and Datta and Jong, 2002): (i). Drainage installation costs (75%) which includes drainpipes, envelope material, earthworks and labour costs, (ii). Connection costs (8%) includes sump construction, connecting drain, pump and pump house, (iii). Land development costs accounts to 12 percent involves levelling and bunding of land, (iv). Other costs (5%) which includes overhead costs, training of staff and farmers and (v). Annual operation and maintenance costs includes pump operation and system maintenance which is actually not considered under initial investment.

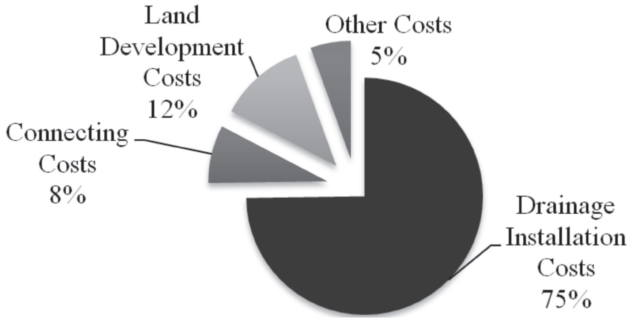

Fig. 1: Distribution of saline land reclamation cost

Results and Discussion

Socio-economic Features of the Project Area

The socio-economic survey was conducted during 2011-12 using pre-designed interview schedule and the data was collected from sample farmers in the project area (Table 3). The study reveals that the average family size was 7 persons per family and literacy rate was around 60 per cent.

Table 3: Socio-economic features of sample farmers of drainage area in Banmandori

Particulars	Percentage/Numbers
General Information	
Age (years)	43
Overall Literacy level (%)	60
Family size (No.)	7
Average farm size (ha)	3.04
Sources of family income (%)	
Crop production	52
Livestock	22
Other Sources	26
Farm Machineries (%)	
Tractors	14
Seed-cum-fertilizer drills	8
Trolley	13
Livestock (No.)	
Cow	1
Buffaloe	2.0
Young Stocks	2.0

Agriculture was the major occupation and the average land holding was 3.04 hectare, of which around 50 per cent land was problematic either affected by soil salinity or waterlogging. The major irrigation source was canal (>90% area irrigated). The major sources of farmers' annual family income were 52 per cent from crop production followed by 22 per cent from dairying. Other sources include income generated from wage earnings and other works done during off season. Among farm machineries owned by farmers, only 14 per cent were having tractors followed by trolley (13%) and Seed-cum-fertilizer drills (8%). Among the livestock holdings, project area farmers were having two buffaloes and one cow mainly for the purpose of milk production for home consumption as well as for obtaining subsidiary income.

Cropping Pattern of the Project Area

Kharif season cropping pattern

The *kharif* season cropping pattern of the project area from 2006 to 2013 is presented in Table 4. Cotton being the major crop of the village occupies 40 to 58 per cent area. Cluster bean was the next best crop with 15 to 27 per cent area followed by rice crop which occupies 10 to 21 per cent area. Pearl millet, groundnut, fodder and green gram were other prominent *kharif* crops. The study reported that, the area under major crops was not stable over the years. Because most of the area was affected by waterlogging and soil salinity and due to non-functioning of subsurface drainage system in some drainage blocks. The rainfall pattern that decides the performance of crops in the project area as higher rainfall favours rice production but affects cotton and vice versa. The area under guar crop was reduced over the years due to reduction in the market price of cluster bean crop in recent years.

Rabi season cropping pattern

The *rabi* season cropping pattern of the project area from 2007-08 to 2013-14 is presented in Table 5. In *rabi* season, wheat was the major crop representing an area of 68 to 76 per cent and mustard was the next best crop with 13 to 16 per cent area. Barley, oats, berseem and castor were other significant *rabi* season crops of the project area. The reduction in area under wheat crop after

Table 4: *Kharif* season cropping pattern of the project area during 2006-2013

Major crops	2006	2007	2008	2009	2010	2011	2012	2013
Cotton	53.8	44.7	40.4	41.9	58.2	58.6	49.5	46.4
Rice	0.1	10.0	21.7	21.2	2.6	2.8	10.2	11.4
Cluster bean	25.4	27.4	25.5	19.3	15.1	14.9	17.1	16.1
Pearl millet	3.9	3.9	3.1	5.9	6.4	6.3	2.8	2.8
Ground nut	1.8	0.6	0.7	0.6	2.2	2.3	4.7	5.1
Fodder	1.0	1.1	0.9	1.1	1.1	1.0	1.0	1.1
Green gram	0.1	0.1	0.1	0.1	0.6	0.6	1.8	0.0
Other Crops	0.4	0.6	0.7	0.6	0.5	0.4	0.2	0.4
Fallow Land	13.4	11.6	6.9	9.3	13.3	13.2	12.7	16.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 5: *Rabi* season cropping pattern of the project area during 2007-08 to 2013-14

Major crops	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Wheat	73.9	75.5	76.6	68.2	68.2	68.5	67.9
Mustard	14.5	13.6	13.2	13.9	15.3	15.3	16.0
Barley	0.4	0.6	0.8	1.2	1.1	0.9	1.9
Oats	0.7	0.7	0.9	0.8	0.8	0.9	0.9
Berseem	0.1	0.2	0.3	0.4	0.1	0.2	0.4
Castor	0.9	0.0	0.0	0.0	0.3	0.1	0.0
Other Crops	0.5	1.2	0.7	0.9	0.9	0.9	1.0
Fallow Land	8.9	8.1	7.4	14.6	13.4	13.1	11.9
Total	100	100	100	100	100	100	100

Table 6: Cropping intensity of the project area during 2006-2013

Cropping season	2006	2007	2008	2009	2010	2011	2012	2013
Kharif	87	88	93	91	87	87	87	83
Rabi	91	91	92	93	85	87	87	88
Overall	177	179	185	183	172	173	174	171

2009-10 was mainly due to the occurrence of nematode problem in wheat and increase in waterlogging and salinity in some of the drainage blocks, where the subsurface drainage was not functioning. Therefore some farmers were shifted towards cultivation of mustard crop in recent years.

Cropping intensity of the project area

Cropping intensity represents the gross cropped area over the total land area in terms of percentage. The cropping intensity for both *kharif* and *rabi* seasons for the period 2006 to 2013 were presented in Table 6. The cropping intensity of *kharif* and *rabi* seasons were 83-93 per cent and 85-93 per cent, respectively. The overall cropping intensity was 171 to 185 per cent. The season wise as well as the overall variation in the cropping intensity after 2009-10 may be attributed to the non-functioning of drainage system and also influenced by weather parameters like heavy rainfall years which has brought more area under water logging and low rainfall years led to soil salinity in the recent years.

Rainfall of Fatehabad District

Fatehabad district was created in 1997, hence the average rainfall data was obtained for the period 1997 to 2013 (Table 7 and Fig. 2). The average annual rainfall of the district was 312 mm. The highest rainfall of 691 and 796 mm was received for the year 1997 and 1998, respectively. During 1999 to 2013, the rainfall was ranging between 75 mm to 426 mm indicating a significant variation in the annual rainfall. The variation in rainfall leads to variation in cropping pattern as well as cropping intensity in the district.

Table 7: Rainfall of Fatehabad district during 1997-2013

Parameters	Rainfall (mm)
Mean (1997-2013)	311.5
Minimum	75.0
Maximum	796.0
Standard Deviation	193.3
Coefficient of Variation (%)	62.04

Compiled from various issues of statistical abstract of Haryana.

Impact of Subsurface Drainage

Impact on water table depth, salinity and pH of drain water

To study the temporal changes in groundwater depth and characteristics of drainage outflow, the water table depth was measured and the drain water samples were collected and analyzed in a regular interval. Similarly, soil salinity status was recorded by collecting and analyzing soil samples

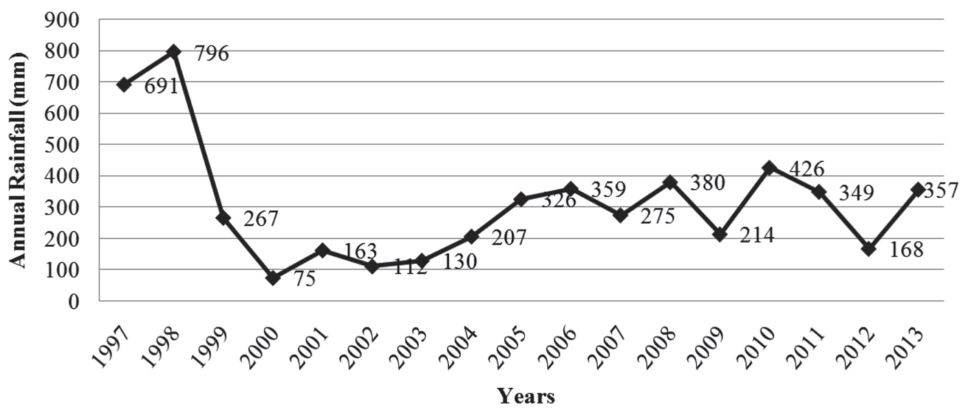

Fig. 2: Annual rainfall of Fatehabad district during 1997 to 2013

from the project area. The major parameters assessed were; periodic measurement of water table depth, salinity of soil and drain water by measuring the electrical conductivity (dS m^{-1}) and pH of the soil and drain water for its alkalinity status.

The details of water table depth, salinity and pH of the drain water during study period is presented in Table 8. Water table depth was measured during the critical months of April/ May, August/September and October/November for the year 2011 to 2014. The mean water table depth was recorded as 0.53, 0.72, 0.58 and 0.86 m respectively, for the year 2011, 2012, 2013 and 2014. The depth of water table varies among the drainage blocks depending on the slope of the land. It was noticed that there was a fluctuation in the water table depth during study period. In general, water table depth depends upon rainfall distribution and in the project area it was observed that water table depth was very high during rainy season and was very low during off-season.

Before installation of subsurface drainage, the water table was around 0.5 to 1.0 m below ground level (as recorded by HOPP). It was noted that in some areas water table depth was less than 0.5 m which had a problem of both waterlogging and salinity. The drain water salinity was ranged between 15 to 16 dS m^{-1} during 2007 (before drainage). After installation of subsurface drainage, the mean drain water salinity was 10.88, 10.52, 10.17 and 8.30, respectively for the year 2011, 2012, 2013 and 2014. The overall salinity of the drain water showed a decreasing trend during the study period but there was no clear trend observed among the different drainage blocks. The pH of the drain water was in the normal range and has no negative impact on crop growth. Katiyar *et al.* (2014) recorded similar results for groundwater quality of Sirsa district (electrical conductivity upto 15 dS m^{-1} and pH upto 8.8) which is adjacent to Fatehabad district in Western Haryana.

Impact of subsurface drainage on soil salinity and soil pH

The soil samples were collected after the harvest of *kharif* (November) and *rabi* (May) crops and it was analysed for observing its salinity status. The block wise and season wise salinity and soil pH measured during study period 2011 to 2014 were presented in Table 9 and Table 10, respectively. The lowest and highest soil salinity of 8.2 and 10.8 was observed respectively, during November 2011 and May 2012. It was observed that in the study area, the salinity varies between the blocks. Some block has soil salinity as low as 1.3 (Block F-9 in May 2014) and some has as high

Table 8: Water table depth, EC and pH of drain water of Banmandori drainage area

Drainage block No.	Water table depth (m)				EC (dS m^{-1})				pH			
	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
F-1	0.95	1.07	0.94	1.17	3.31	2.85	2.70	2.96	7.95	7.79	7.92	7.92
F-2	0.61	0.86	0.78	0.71	4.59	4.51	3.60	5.30	7.85	7.84	7.68	7.83
F-3	0.73	0.87	0.64	0.74	5.24	5.02	4.37	4.87	7.82	7.82	7.64	7.80
F-4	0.38	0.72	0.48	1.09	4.05	4.02	2.99	1.81	7.52	7.55	7.30	7.49
F-5	0.24	0.59	0.53	0.78	6.11	6.44	4.70	5.07	7.73	7.80	7.48	7.71
F-6	0.33	0.38	0.27	0.62	39.56	39.98	38.05	45.12	7.97	7.87	7.89	7.95
F-7	0.67	0.77	0.62	0.95	19.98	18.44	20.43	10.40	8.01	7.95	7.88	7.98
F-8	0.32	0.53	0.36	0.51	4.22	2.87	4.49	4.53	7.80	7.82	7.60	7.78
F-9	-	-	-	1.01	-	-	-	1.59	-	-	-	7.65
F-10	-	-	-	1.06	-	-	-	1.30	-	-	-	7.83
Mean	0.53	0.72	0.58	0.86	10.88	10.52	10.17	8.30	7.83	7.81	7.67	7.79
Minimum	0.24	0.38	0.27	0.51	3.31	2.85	2.70	1.30	7.52	7.55	7.30	7.49
Maximum	0.95	1.07	0.94	1.17	39.56	39.98	38.05	45.12	8.01	7.95	7.92	7.98
S.D.	0.25	0.22	0.22	0.22	12.81	12.95	12.70	13.21	0.16	0.11	0.22	0.15
C.V.	47.04	30.25	37.70	25.67	117.67	123.11	124.92	159.24	2.01	1.47	2.85	1.90
Normal water					1.85	0.24	0.63		7.67	7.89	7.78	

Table 9: Blockwise soil salinity of subsurface drainage area during 2011-2014

Drainage block	Soil salinity ECe (dS m^{-1})					
No.	Nov-11	May-12	Nov-12	May-13	Nov-13	May-14
F-1	3.66	2.12	5.42	4.72	5.15	4.28
F-2	NA	9.51	5.06	3.62	4.42	8.26
F-3	4.60	4.96	4.63	5.00	4.86	5.02
F-4	16.35	17.63	16.11	16.17	16.22	10.86
F-5	NA	21.12	27.56	22.36	20.04	23.06
F-6	NA	13.72	11.11	11.14	11.21	NA
F-7	NA	9.42	6.24	14.55	10.47	NA
F-8	NA	8.03	5.15	5.65	5.48	NA
F-9	NA	NA	NA	NA	NA	1.30
F-10	NA	NA	NA	NA	NA	4.67
Mean	8.20	10.81	10.16	10.40	9.73	8.21
Minimum	3.66	2.12	4.63	3.62	4.42	1.30
Maximum	16.35	21.12	27.56	22.36	20.04	23.06
S.D.	7.07	6.35	8.09	6.80	5.88	7.23
C.V.	86.19	58.71	79.66	65.42	60.44	88.07

Table 10: Blockwise soil pH of subsurface drainage area during 2011-2014

Drainage block No.	Soil pH					
	Nov-11	May-12	Nov-12	May-13	Nov-13	May-14
F-1	8.59	8.00	8.20	8.16	8.11	8.13
F-2	NA	8.10	8.32	8.28	8.22	8.06
F-3	8.49	7.99	8.24	8.05	8.22	8.24
F-4	8.98	7.98	8.23	8.15	8.10	8.12
F-5	NA	8.11	8.04	8.14	8.16	8.18
F-6	NA	7.88	8.10	7.92	7.93	NA
F-7	NA	8.38	8.43	8.44	8.44	NA
F-8	NA	7.97	8.26	8.16	8.10	NA
F-9	NA	NA	NA	NA	NA	7.99
F-10	NA	NA	NA	NA	NA	8.15
Mean	8.72	8.09	8.23	8.17	8.16	8.12
Minimum	8.59	7.88	8.04	7.92	7.93	7.99
Maximum	8.98	8.38	8.43	8.44	8.44	8.24
S.D.	0.23	0.17	0.12	0.15	0.15	0.08
C.V.	2.58	2.05	1.50	1.79	1.78	1.00

as 27.56 (Block F-5 in November 2014). Since the subsurface drainage was functioning in block No. F-3, the soil salinity was stable around 4-5 dS m^{-1}. In the study area, soil pH was in the normal range and has no negative impact on crop production.

The subsurface drainage was functioning only in drainage block No. F-3. Therefore, soil salinity of this block was measured and compared with soil salinity measured without drainage system in the adjacent area (Table 11). It was observed that in block No. F-3, soil salinity was stable during the study period and ranges between 4-5 i.e., slightly saline affected. While, without subsurface drainage, soil salinity was recorded between 7-11 dS m^{-1} which indicates that the soil was moderately affected.

Impact on crop yield

As mentioned in the cropping pattern, cotton and rice were the major *kharif* crops and wheat and mustard were major *rabi* crop of the project area. The yield data was obtained by carrying crop cutting experiments in the selected sample plots where soil sample was drawn. Whereas, yield data

Table 11: Soil salinity and soil pH with and without subsurface drainage

Particulars	ECe (dS m^{-1})			pH		
	With drainage	Without drainage	Per cent difference	With drainage	Without drainage	Per cent difference
Nov-11	4.60	7.69	67.17	8.49	8.59	1.18
May-12	4.96	10.68	115.32	7.99	8.27	3.50
Nov-12	4.63	8.91	92.44	8.24	8.28	0.49
May-13	5.00	7.12	42.40	8.05	8.15	1.24
Nov-13	4.86	8.23	69.34	8.22	8.42	2.43
May-14	5.02	9.95	98.21	8.24	8.33	1.09

EC of soil before drainage was around 15 dS m^{-1} (recorded by HOPP)

was also recorded from sample farmers of the drainage area. The mean crop yield were presented and compared the same with and without subsurface drainage.

The yield of major crops obtained with drainage was compared with yield obtained without drainage in block No. F-3 as this was the only block where the system was functioning (Table 12). With drainage indicates the area where the system was installed and was functioning. Without drainage indicates the area which was adjacent to the block No. F-3, where subsurface drainage was required but not installed because the area was not severely affected by waterlogging and soil salinity. The average yield obtained with drainage were 22.37, 10.64, 33.93 and 8.06, respectively, for rice, cotton, wheat and mustard crops during the study period. Whereas yield obtained without drainage was little less than the other situation for all the crops. In general, there was 12-20 per cent more yield obtained from drainage area compare to without drainage.

Impact on farm economy

The cost of cultivation and returns generated were estimated for major crops of the study area as presented in table 13. The cost of cultivation was carried out based on procedure given in CSO (2008). The overall cost of production of rice, wheat and cotton in drainage area remains at about Rs. 38000 per ha as against the cost incurred in without drainage area where it remains little more than the cost of drainage area. Whereas the cost of mustard production remains similar in both the cases. The net income obtained from rice production remains higher in both the situations as compared to the net income obtained from other crops. The net income obtained from rice production was Rs 17232 for drainage area and Rs 11397 for without drainage, which was due to the increase in market price of Basmati rice in recent years. The net income obtained from cotton and wheat production were Rs 6411 and Rs 8352 for drainage area and Rs 3085 and Rs 4670 for without drainage area, respectively. The mustard production yielded lower return of Rs 1053 per ha in drainage area and negative returns from without drainage area. Comparison between with and without drainage study reveals not much variation in the per cent change in cost of cultivation and it shows 9 to 14 per cent change in the gross income. There was 33 to 325 per cent change in net income was observed between two situations. This is mainly due to the increase in yield in the drainage area that makes significant increase in net income.

Table 12: Yield (q ha^{-1}) of major crops with and without drainage in Banmandori

Year	With drainage	Without drainage	Per cent difference
Rice	22.37	20.06	11.59
Cotton	10.64	8.94	18.15
Wheat	33.93	29.47	15.21
Mustard	8.06	6.73	19.98

The benefit cost ratio was estimated for major crops of the study area as shown in Table 14. The benefit cost ratio indicates the profit obtained per rupee of investment. As indicated in the cost and returns, the rice production has yielded highest benefit cost ratio as compared to the other crops

Table 13: Economics of production of major crops with and without drainage in Banmandori

Year	With drainage (Rs ha^{-1})			Without drainage (Rs ha^{-1})			Percent Change		
	Gross Income	Total Cost	Net Income	Gross Income	Total Cost	Net Income	Gross Income	Total Cost	Net Income
Rice	54596	37364	17232	49654	38257	11397	9.05	-2.39	33.86
Cotton	44592	38181	6411	41571	38486	3085	6.77	-0.80	51.88
Wheat	46221	37869	8352	42908	38238	4670	7.17	-0.97	44.09
Mustard	29007	27954	1053	24971	27349	-2378	13.91	2.16	325.83

Table 14: Benefit-Cost Ratio of crops produced with and without drainage in Banmandori

Crop	With drainage	Without drainage	Per cent difference
Rice	1.46	1.30	12.58
Cotton	1.17	1.08	8.13
Wheat	1.22	1.12	8.77
Mustard	1.04	0.91	13.65

produced in the subsurface drainage area. The benefit cost ratio for rice crop was 1.46 and 1.30 respectively for with drainage and without drainage area. The least benefit cost ratio was obtained from mustard production which was 1.04 and 0.91, respectively for with and without drainage. The percent increase of benefit-cost ratio with drainage over without drainage were between 8 to 14 percent. This was similar to the result obtained by Tripathi (2010). The highest benefit-cost ratio of 7.83 was obtained from alkali land reclamation (Tripathi, 2013).

Summary and Conclusion

The total area of 277 ha was reclaimed with installation of subsurface drainage in Banmandori village. The drainage area was divided into ten blocks, each covering an area of 16.5 ha to 52 ha. Out of ten drainage blocks, only block No. F-3 was functioning. Major crops of the project area during *kharif* season were cotton, rice, guar and groundnut and during *rabi* season, wheat and mustard. Over the years cropping intensity remains to more than 170 per cent, constituting 85 to 90 per cent during *kharif* and *rabi* seasons, respectively. After introduction of subsurface drainage, the water table depth was lowered down to 13.7 per cent and drain water salinity has showed a tremendous reduction of 98 per cent. The salinity of soil with drainage was showed more than 50 per cent reduction compare to soil salinity without drainage. The yield obtained with drainage has 15-20 per cent more yield advantage over the yield obtained without drainage. The net income obtained from drainage was 34 to 52 per cent more (except in case of mustard which shows 326 percent change) in drainage compare to without drainage situation.

The subsurface drainage technology has a significant contribution in increasing yield and income besides balancing water table and reduction of soil and drain water salinity in the saline and waterlogged area. In the study area, the subsurface drainage was not properly functioning except in block no. F-3, hence yield of all the major crops depends on weather condition of the region. So, the above data may not represent the actual impact of subsurface drainage. Overall, the saline soil reclamation requires a community approach and collective action for proper functioning of the subsurface drainage system. Therefore, people's participation is essential, which ultimately determines the performance of subsurface drainage. The contribution of beneficiaries in operation and maintenance required for pumping the drain water, affects the long term social returns on research investment.

References

GoH (Government of Haryana) (1978-79) *Statistical Abstract of Haryana*, Department of Economics and Statistics, Haryana, India.

GoH (Government of Haryana) (2014) *Statistical Abstract of Haryana 2012-13*, Department of Economics and Statistical Analysis, Haryana, India.

Chinnappa B and Nagaraj N (2007) An economic analysis of public interventions for amelioration of irrigationinduced 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 KK and Joshi PK (1993) Problems and prospects of cooperatives in managing degraded lands - case of saline and waterlogged soils. *The economics and political weekly (EPW)* **28 (12 & 13)**: A-16 - A-24.

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

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

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

Gajja BL, Tiwari JC and Prasad R (2002) *Management of Natural Resources in Sustainable Surface*. 12th ISCO Conference, Beijing.

Joshi PK, Singh OP, Rao KVGK and Singh KN (1987) Subsurface drainage for salinity control: an economic analysis. *Indian Journal of Agriccultural Economics* **47(2)**: 198–206.

Katiyar DK, Walia CS, Singh R, Singh SP and Verma TP (2014). Groundwater quality and its suitability for irrigation in western Haryana. Journal of Soil Salinity and Water Quality. **6** (2): 115-118.

Mathew EK (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.

Raju R, Tripathi RS, Thimmappa K, Kumar Parveen and Kumar Satyendra (2015) Impact of Waterlogged Saline Soil Reclamation on Land Productivity and Farm Income-An Economic Study from Haryana. *Agricultural Economics Research Review* **28** (Conf. No.). 177-182.

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

Sharma DK, K Thimmappa, Chinchmalatpure R Anil, Mandal AK, Yadav RK, Chaudhari SK, Kumar S, Sikka AK (2015) *Assessment of Production and Monetary Losses from Salt-affected soils in India*. Technical Bulletin No. 05. ICAR-Central Soil Salinity Research Institute, Karnal, p.6.

Shekhawat RS (2007) Economic Analysis of Sub-surface drainage under Indira Gandhi Nahar Priyojna Command Area-A case study. *Agricultural Economics Research Review* **20**: 361-374.

Tripathi RS (2010) Impact of subsurface drainage on resource-use efficiency in rice-wheat farming system. *Journal of Soil Salinity and Water Quality* **3**: 110-126.

Tripathi, RS (2011) Socio-economic impact of reclaiming salt affected lands in India. *Journal of Soil Salinity and Water Quality*, **3(2)**: 110-126.

Tripathi, RS (2013) Returns to investment made for alkali land reclamation technology in India. *Journal of Soil Salinity and Water Quality*, **5(1)**: 65-72.

Received: March 2016; Accepted: May 2016