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Subsurface drainage for combating soil salinity and waterlogging in vertisols of canal command, Karnataka

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Abstract: Considerable increase in crop production is achieved due to introduction of irrigation and adoption of new crop production technologies and crop varieties in India. In spite of its beneficial effects of irrigation, soil salinity and waterlogging are unavoidable processes in vertisols in semi-arid regions because of their inherent poor drainage property coupled with high potential evapo-transpiration rates. Vast area has been already affected due to these twin problems and more land is likely to go out of cultivation if non-judicious use of water is continued. Re-habilitation of these vast stretches of saline/waterlogged lands has become vital, as there is an obligation to provide food to the ever-growing population. Subsurface drainage system was installed in the farmer's field near Virupapur village, in Karnataka during 1998 in an area of 62 ha and its performance was studied in terms of changes in soil salinity, water table, crop yield and cropping intensity. Considerable reduction in soil salinity, lowering of water table, and increase in paddy yield and improvement in cropping intensity was recorded in the subsurface drained area. Nitrogen loss through subsurface drainage system was estimated and it was in the range of 2 to 7 per cent of the recommended dose of nitrogen for paddy (*i.e.*, 150 kg/ha) during different crop season. Partial blocking of the drainage system by the farmer's was also observed resulting in increase in soil salinity in the lower profiles of the soil.

Key words: Soil salinity, Waterlogging, Subsurface drainage, Land reclamation and Crop improvement

Introduction

Agriculture depends largely on the monsoon; rains, however, are unevenly distributed in time and space. To sustain agricultural production against these vagaries of rainfall, irrigation has been created in about 57 million ha, covering about 34% of the total arable land in India (Ritzema *et al.,* 2008). In spite of its beneficial effects, irrigated agriculture in the arid and semi-arid regions has resulted in the development of waterlogging and soil salinization due to many reasons including inadequate provision of drainage system. It is estimated that nearly 8.4 million ha of once productive agricultural land is affected due to these twin problems and more land is likely to go out of cultivation if non-judicious use of water is continued (Ritzema *et al.,* 2008). In Tungabhadra project (TBP) area, more than 80,000 ha of cultivated land have been affected by soil salinity and waterlogging. Re-habilitation of these vast stretches of lands has become vital, as there is an obligation to provide food security to the ever-growing population. In different agroclimatic sub-regions of India, subsurface drainage system became a technically feasible, cost effective and socially acceptable technology to reclaim waterlogged and saline lands (Ritzema *et al.,* 2008, Shakya and Singh, 2010). Due to adoption of drainage measures, soil physical and chemical properties improved and crop yield also showed substantial increase (Datta *et al.*, 2000; Mathew *et al*., 2001; Gupta, 2002). Many secondary benefits and socio-economic impacts of land reclamation through drainage have been also reported by Christen *et al.* (2001); Ayars *et al.* (2006) and Niazi *et al.* (2008). Keeping these in view, subsurface drainage system (SSD) was installed in the farmer's field near Virupapur village, Sindhanur taluk, Karnataka during 1998 to study its performance on changes in soil salinity, depth to water table, crop yield and cropping intensity. Nitrogen loss through SSD was also estimated.

Material and Methods

Subsurface drainage system was installed in the farmer's field during 1998 in an area of 62 ha to intercept the incoming seepage flows from canal and to prevent waterlogging and soil salinization in low laying areas. The study area was located in the command area of the TBP in the left bank main canal on D-36/1 distributory canal near Virupapur village, Sindhanur taluk, Karnataka. Soils of the area are mainly vertisols (over 85%) but occasionally red soils are also found on the ridges, covering 10 to 15% of the command area. Vertisols contain 40-45 % montmorillonitic clay and have high moisture holding capacity with low infiltration rates of 0.02 to 0.2 m/day (Manjunatha *et al.,* 2002). Subsurface drains of 100 mm diameter [corrugated perforated PVC pipes with nylon filter] were laid at a depth of 0.75 m below ground level. Rigid PVC pipes of 150 mm diameter were used for the collector drains. Three drains were laid parallel to the natural drain and D-36/1 distributory canal across the major slope at a spacing of 150 m. The study was initiated during *kharif*, 1998 and continued up to *rabi/ summer,* 2005-06.

Drain discharges were measured manually with the help of measuring cans at 15 days interval in each junction box and the total drain discharge was calculated. In total, there are 21 junction boxes for three drains. Mean drain discharge per day for each crop season was calculated and were used for interpretation The electrical conductivity of the drainage water was measured with an EC meter and the average drain water salinity was calculated. Drain water samples were also analyzed for possible nitrogen losses through SSD using standard procedure and the amount of nitrogen losses through drainage system was estimated. The recommended dose of fertilizer for paddy crop is 150 N, 75 P_2O_5 and 75 K. The paddy crop was transplanted in August and January months and harvested during December and May months for kharif and rabi/summer seasons, respectively. Water table depths were recorded on fixed grid points in each crop season after the harvest of the crop. The average water table data of all the 12 grid points were used to evaluate the effectiveness of the SSD. Changes in soil salinity were evaluated by collecting soil samples at 0-30 cm depth on fixed grid points. The electrical conductivity (EC) of the mixed soil was determined in a soil water extract (1:2.5) using EC meter. The average soil salinity data of all the 12 grid points were used for interpretation. Profile soil samples (0-30, 30-60 and 60-90 cm) were also collected and were analyzed for EC. Crop performance was studied by conducting crop cutting tests (plot size of 2 m x 2 m) at all the 12 fixed grid points where the soil samples were drawn and the average yield data of all the grids were used for interpretation. Cropping intensity was also worked out by collecting the data from the farmers during 1998-2006.

Result and Discussion

Drain discharge and drain water salinity: Higher drain discharge was recorded during kharif season in the initial periods due to proper functioning of the drainage system. The maximum drain discharge (240- 250 m^3/day) was recorded during kharif, 1998 and 1999 (table -1). Gabriele and Borin (2010) reported that subsurface corrugated drains with free drainage gave the highest measured drainage volume. Due to partial blockage of the drainage system by the farmers, lower drain discharge was recorded from the year 2000 onwards to till 2005. During that period, drain discharge was ranged from 4.15 to 28.1 m^3/day. During the study period, salinity of drainage water was ranged from 4.12 to 6.44 dS/m with a mean salinity of 5.14 dS/m in the kharif season. The higher drain water salinity (6.44 dS/m) was observed during kharif, 2000 while, the lower salinity (4.12 dS/m) was observed in the year 2005. From 2001 to 2004, more or less, the drain water salinity remains constant in the range of 5.19 to 5.64 dS/m.

During *rabi/summer*, in general lesser drain discharges were observed due to limited application of irrigation water. The highest and lowest drain discharges of 50.6 and 3.72 m^3/day were recorded in the year 1999 and 2005, respectively (Table-1). During the same period, drain water salinity is ranged from 4.43 to 7.90 dS/m with an average salinity of 5.84 dS/m. Higher salt concentration in the drain water was observed during rabi/summer season as compared to kharif season.

Nitrogen loss: Nitrogen loss during kharif, 2004 was estimated to the extent of 0.105 kg/hectare for the drainage coefficient [DC] of 0.01mm. For the design DC of 1.0 mm /day, the estimated nitrogen loss through SSD was about 10.5 kg/ha (Table - 2). This loss is accounts for about 7 per cent of the recommended dose of nitrogen applied for the paddy (*i.e.*,150 kg N/ha). During rabi/summer, *2004-05,* for DC of 1.0 mm /day, nitrogen loss was estimated about only 2.0 kg/ha. The estimated nitrogen loss through SSD was about 4.6 and 4.7 per cent of the nitrogen applied for the paddy during kharif, 2005 and rabi/summer 2005-06, respectively. Variation in nitrogen loss with time through SSD is presented in figure - 1. Significant amount of nitrate-nitrogen losses through SSD was also reported by Singh et.al. (2002) and Gabriele and Borin (2010). There is a large variation in nitrogen loss with time during each cropping season and among the cropping seasons.

Table - 1: Variation in drain discharge and drain water salinity with time

Year	Mean drain discharge (m^3/day)		Mean salinity of drainage water (dS/m)	
	Kharif	Rabi/summer	Kharif	Rabi/summer
1998	248	41.6	4.76	5.92
1999	250	50.6	4.50	7.90
2000	27.2	15.7	6.44	6.04
2001	28.1	14.9	5.22	5.37
2002	25.0	-	5.30	-
2003	7.23	-	5.19	-
2004	6.25	5.52	5.64	5.42
2005	4.15	3.72	4.12	4.43

(-) indicates no crop due to canal closure

Table - 2: Nitrogen loss through subsurface drainage system

Drainage coefficient (mm/d)	Nitrogen loss (kg/ha) K-2004	R/S 2004-05	K-2005	R/S 2005-06	Mean nitrogen loss (kg/ha)
0.01	0.105	0.02	0.069	0.07	0.066
0.10	1.05	0.20	0.69	0.70	0.66
0.50	5.25	1.00	3.45	3.50	3.30
1.00	10.5 (7)	2.00 (1.3)	6.89 (4.6)	7.00 (4.7)	6.59 (4.4)

( ) indicates % loss of the RDN of 150 kg/ha; K-Kharif; R/S-Rabi/summer

Table -3: Effect of subsurface drainage system on changes in average soil salinity, water table, crop yield and cropping intensity

Crop season	Soil salinity (dS/m)	Water table (bgl,cm)	Crop yield (q/ha)	Cropping intensity (%)
Initial	8.40	-	21.8	143
K-1998	2.64	50	33.2	177
R/S 1998-99	2.15	67	66.7	
K-1999	2.43	62	59.5	186
R/S 99-2000	3.63	85	60.9	
K-2000	2.51	62	63.9	191
R/S 2000-01	2.18	87	66.0	
K-2001	2.63	-	70.0	191
R/S 2001-02	3.30	-	75.0	
K-2002	3.80	-	78.1	95
K-2003	3.02	-	82.5	95
K-2004	3.10	-	82.9	95
R/S 2004-05	3.85	-	80.8	62
K-2005	2.67	-	82.5	192
R/S 2005-06	3.66	-	83.5	
Mean	3.04	-	70.4	91.7 (per season)

K-Kharif; R/S-Rabi/summer

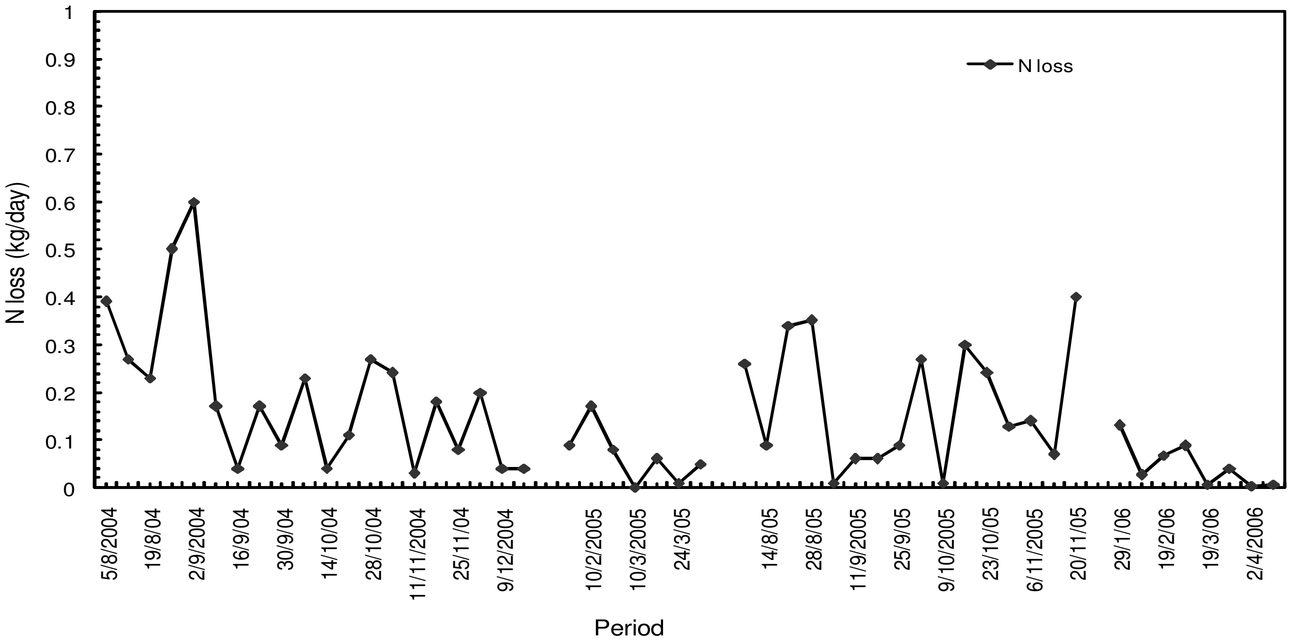

Fig. 1: Nitrogen loss through subsurface drainage system

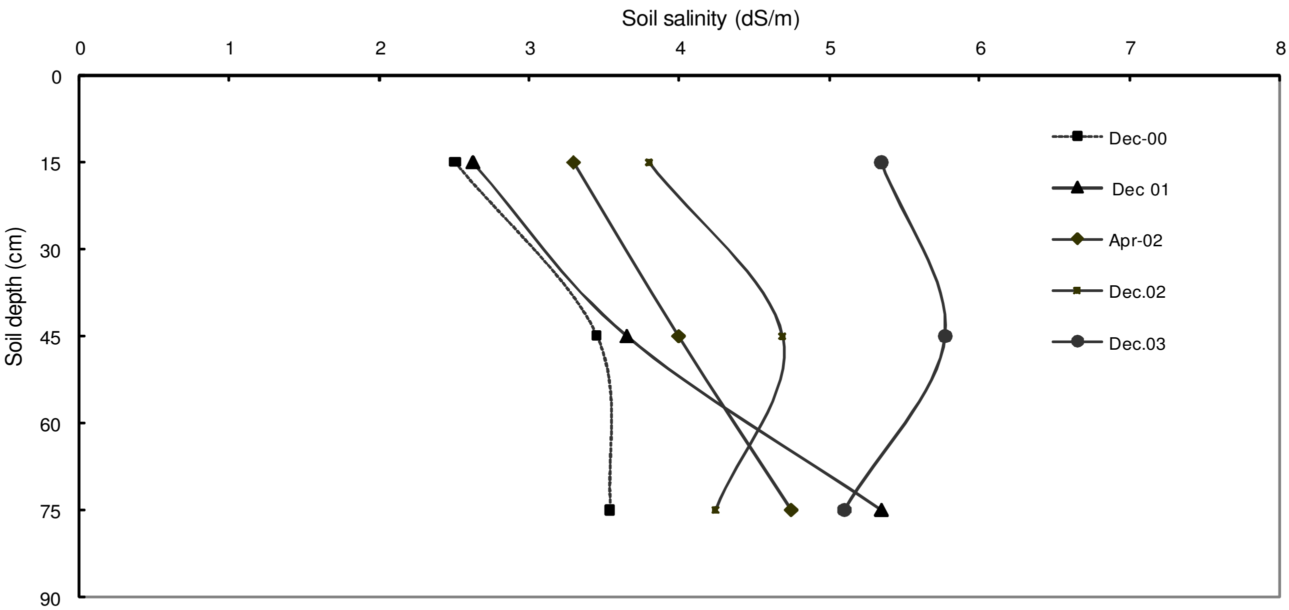

Fig. 2: Variation in profile soil salinity with time under subsurface drainage system

Soil salinity: Considerable reduction in soil salinity in all the 12 grid points was observed during the first season and thereafter salinity remains constant with time. The mean soil salinity (0-30 cm deep) decreased from initial value of 8.40 dS/m to 2.64 dS/m during *kharif* , 1998 and decreased further to 2.15 dS/m during *rabi/ summer*, 1998-99 (Table -3). From *rabi/summer* 1998-99 (after one year) onwards, salinity remained constant with time and maintained in the normal salinity range of 2 to 4 dS/m. Such salinity levels are considered normal for the cropping pattern that is followed in the command. During *kharif*, 2005 and *rabi/summer*, 2005-06, the average soil salinity (for 0-30 cm) was 2.67 dS/m and 3.66 dS/ m, respectively. In general, slightly higher salinity was observed during *rabi/summer* season compared to the salinity levels in *kharif* season. Mastrocicco *et.al.*(2013) also reported that SSD systems are effective in ameliorating soil properties by reducing soil salinity even in agricultural field consisting of low permeability materials.

Profile soil salinity (0- 90 cm) in the adjacent area where there is no SSD [control] was observed to be 8.5 ± 0.8, 7.9 ± 0.6 and 6.8 ± 0.6 dS/m for the 0-30, 30-60 and 60-90 cm depth, respectively, during December 2000. Where as in the drained area, the profile soil salinity was observed to be 2.5 ± 0.4, 3.4 ± 0.5 and 3.5 ± 0.5 dS/m for the 0-30, 30-60 and 60-90 cm depth, respectively. This indicated that the soluble salts in the soil rhizosphere were leached more effectively throughout the soil profile with drainage. The results are in conformity with that of Mathew *et.al.* (2001), who reported that the salinity in the soil could be reduced considerably through SSD system. Due to partial blockage of the drainage system, a marginal rise in profile soil salinity was observed in the subsequent seasons *i.e.*, during December 2001, April 2002 and December 2002 and December,2003. (fig. 2). During this period, the average profile soil salinity was increased from 3.17 dS/m to 5.41 dS/m, highlighted the importance of the proper maintenance of the drainage system**.**

Water table: Lowering of water table over a period of time was recorded in all the 12 observation grid points. The mean depth to water table was lowered from 50 cm to 67 cm during first year. In the second and third year, depth to water table is further lowered from 67 cm to 85 cm indicating the functioning of the SSD (Table - 3). Lowering of water table which in turn resulting sufficient aeration in the root zone under SSD system was also reported by Sharma & Gupta (2006).

Crop yield: The average paddy yield in the study area increased substantially from its initial yield of 21.8 q/ha to 33.2 q/ha in the first season (kharif, 1998) itself. It improved further to 66.7 q/ha in the second season (rabi/summer 1998-99). Higher paddy yields (>75 q/ha) were recorded in the subsequent crop seasons (Table-3). Highest paddy yield of 83.5 q/ha was recorded during rabi/summer, 2005-06. The improvement in paddy yield (>200 %) is ascribed mainly to decrease in soil salinity. The findings are in conformity with that of Mathew et.al (2001) who reported that the overall increase in rice yield due to subsurface drainage was 1.36 t/ha. Ritzema et.al. (2008) also reported that after the introduction of SSD, significant increase in paddy yields (*i.e*., 69 %) due to lowering of water table and reduction in soil salinity. The increasing trend of the crop yield even when the salinity is slightly increasing could be ascribed to introduction of improved management practices, switchover to high yielding varieties and increased use of nutrients upon reclamation of soils.

Cropping intensity: Significant increase in the cropping intensity was observed in the study area due to installation of SSD. The average cropping intensity, which was 143 per cent before the installation of the SSD improved to 177 per cent during 1998-99 and further improved to 191 per cent during 2000-01 and 2001-02 (Table - 3). In the year, 2005-06, cropping intensity observed was 192 per cent. This improvement in the cropping intensity is mainly due to reclamation of the salt-affected soils and the awareness created to the farmers about the importance of the SSD. Due to non-release of canal water during rabi/summer, 2002-03 and 2003-04, crops was not taken-up by the farmers in the study area. The cropping intensity (for one season) during kharif, 2002, 2003, 2004 and 2005 was 95 percent. Due to uneven distribution and shortage of irrigation water, the cropping intensity was reduced to 64 per cent during rabi/summer, 2004-05. Increase in cropping intensity after the introduction of SSD has been also reported by Datta *et al.* (2000) and Mathew *et al.* (2001).

Based on eight years of field study in the farmer's field in an area of 62 ha, it was concluded that, reduction in soil salinity, lowering of water table, improvement in crop yield and cropping intensity highlighted the necessity and importance of SSD to reclaim the salt affected soils. Hence promotion of SSD on larger scale and creating awareness among the farming community/department personnel's about the proper maintenance of SSD through extension activities is required. Comparing the magnitude of nitrogen application to paddy (150 kg N), the estimated nitrogen loss through SSD was about 2.00 to 7.00 per cent of the RDN. This loss can even be reduced by applying nitrogen in more number of split doses than three splits. This can also be further minimized by controlling irrigation water during the time of fertilizer application.

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