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Effect of subsurface drainage system on water table and soil hydrologic parameters at Gundur village of TBP command area

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Abstract
A study was conducted to ensure the impact of subsurface drainage system on salt affected soils in the TBP command area, Karnataka. The *in-situ* hydraulic conductivity with average of 0.113 m d^{-1} before sowing, and improved slightly after the harvesting to 0.177 m d^{-1}. The areal hydraulic conductivity values above drain level M_3-between L_{15} and L_{16} laterals along M_3 main drain and M_4-between L_{11} and L_{12} laterals along M_4 main drain at Gundur village during *kharif* 2015-'16 were ranged from 0.089-2.461 and 0.097-2.193 m d^{-1}. Further, the areas estimates of K were far greater (20 to 21 times) than the *in-situ* measurements of K. The infiltration rate was very low due to considerable amount of clay (46-51%) and it improved slightly due to SSD system after the harvesting (4.21 mm h^{-1}) compared to that before sowing (3.92 mm h^{-1}).The B:C ratio, IRR and payback period were 1.37, 50 and 2 for the life span of 50 years for SSD system respectively.

Keywords: Infiltration rate, hydraulic conductivity, subsurface drainage, water table

Introduction

To produce required food of the increasing population of the world, it is necessary to increase the cultivated land productivity or more lands to be cultivated. Predictions show that food production in the next 25 years should be doubled (Ritzema, 2007) [11]. In Indian agriculture, crop production suffers not only from drought but also from non-scientific use of available irrigation water. In most of the command areas incidence of water table rise and secondary salinization are common. Thus, salinity and waterlogging have become global phenomena affecting millions of hectares of productive land in more than hundred countries, posing a threat to sustainable agricultural production. Subsurface drainage is a solution and considered as a most suitable approach for groundwater balance and land and water management practices containing the groundwater table at a suitable level (Luthin 1978; Gates and Grismer, 1989) [4, 7]. Agricultural subsurface drainage is a process of removal of excess groundwater from the crop root zone system which promotes safe environment for efficient crop growth and for better health in rural and urban areas. Subsurface drainage lowers the high water tables. The main causes of the rise in water table are precipitation, excess irrigation, leaching water, seeps from higher land or irrigation canal and ditches and groundwater under artesian pressure. This technique has gained international acceptance. Subsurface agricultural drainage provides agronomical and environmental benefits in terms of improved crop yield, improved soil trafficability, field operations and reduction in sediment and phosphorus losses from agricultural fields (Kornecki *et al*., 2001) [8]. Subsurface drainage has been found to be the only solution for providing land reclamation on a long-term basis when salts are present in the soil and groundwater. in India during late 1920s (Thatte and Kulkarni, 2000) [16], and FAO (1999) [3] reported that India has 2.5 million ha waterlogged land and 3.1 million ha salinity-affected area, while this hazard on the state level in India is extended, i.e., Uttar Pradesh has salinity-affected area over 1 million hectares, 1 million hectares in Gujarat, 0.5 million ha in Punjab, 0.2 million ha in Haryana and a smaller area in Rajasthan, and significant less proportionate area in Tamil Nadu and Karnataka in the south is also affected. At the time of nineties, subsurface drainage installed <10 % of the total irrigated area. But currently <0.02% irrigated area in India is provided with subsurface drainage (Tiwari, 2011) [17] and Maharashtra state has minimum salt-affected area to the extent of 0.6 M ha (Sethi *et al*., 2010) [12].

India is facing varying degree of salinity problems such as saline soil, costal saline and alkalinity (Patel *et al*., 2002; Mandal and Sharma, 2011) [10, 9].

In Karnataka, after the introduction of irrigation in TBP command area, the ill-effects of waterlogging and salinity are overwhelming in the command area due to many reasons. The extent of problem, which was under 20,200 ha during 1979-'80, has increased to over 80,000 ha during 1996-'97. It seems that since 1978-'80, the area under waterlogging and soil salinization is increasing at the rate of 3,000 ha per year. Although, ground water table generally builds-up in the command area whenever irrigation is introduced but in this case intensive irrigation through paddy helped hasten the process. According to statistics, the water table in the command was rising at the rate of 13-14 cm per annum. The recent studies revealed that depth of water table was rising at the rate of 10 cm per year on the farm at the Agricultural Research Station, Gangavati under the University of Agricultural Sciences, Raichur, which has a typical terrain as that of the irrigation command area. Hence this study has taken up.

Materials and Methods

The area selected for the present study comes under the command of Tungabhadra Left Bank Canal (TLBC) of TBP and is located in Gundur village of Koppal district, Karnataka. In and around the farm also, considerable area was affected by the problems of water logging and salinity. The annual average rainfall of the nearest raingauge station at Siddapur is 582 mm.

Water table measurement for performance of SSD system

In order to assess the impact of the SSDs on water table, the water levels were monitored fortnightly in observation wells, which were installed in the study area at a distance of L/2 and 2L/3 and L/3 along the laterals and in between laterals at a depth of about 1 m from the ground level.

Hydraulic conductivity measurement

The *in situ* hydraulic conductivity was determined using post hole auger method on 150 m x 150 m grid basis in the experimental plot. The areal estimates of hydraulic conductivity were computed by reverse technique (drain outflow method) by knowing drain discharge entrance head and available hydraulic head and drain discharge which were measured in the field. These measurements were obtained following the standard procedures using q-h relation as described in Ritzema, 1994 [6].

Infiltration rate measurement

The infiltration rate of the study area was determined using double ring infiltrometer method based on the grid pattern and compared that with that of the pre-drainage situation.

Economics of subsurface drainage system

The economics involving cost benefit analysis of the subsurface drainage system was carried out to know the impact of drainage works on crop production and consequently on the improvement in cost returns and resource use pattern after the drainage. The benefit-cost ratio and also investment payback period were worked out.

Results and Discussion

Water table investigation for performance of SSD system

The particulars of water table depth below ground level (bgl) in Gundur village were observed in the laterals (*viz.,* M_1-between L_{27} and L_{28} along M_1 main drain, M_2-between L_{23} and L_{24} along M_2 main drain, M_3-between L_{15} and L_{16} along M_3 main drain, M_4-between L_{11} and L_{12} along M_4 main drain, M_5-between L_6 and L_7 along M_5 main drain) in positions at 2L/3, L/2 and L/3 on fortnightly basis are presented in Table 1 during *kharif* 2015-'16. It was observed that at 2L/3 distance during *kharif* 2015-'16, the watertable depth (bgl) ranged from 7.5-68.8, 6.9-64.1, 6.2-57.4, 5.9-59.8 and 7.9-58.9 cm. For distance L/2, the water table depth varied from 9.5-64.7, 10.4-61.0, 12.8-57.2, 13.1-65.7 and 12.9-62.8 in cm. Finally at a distance L/3 WT depth varied from 12.5-68.1, 13.1-58.3, 14.2-61.8, 13.4-59.8 and 12.9-58.7 cm respectively.

Table 1: Fortnightly water table depth (BGL, cm) in the middle of laterals at 2L/3, L/2 and L/3 distance at Gundur village (Head region of TLBC) during *kharif* 2015-'16

Water table depth (BGL, cm) at 2L/3												
Standard weeks	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**
M_1-Between L_{27} and L_{28}	7.5	9.5	9.7	8.5	12.4	11.9	9.9	26.2	39.8	57.4	68.8	70.2
M_2-Between L_{23} and L_{24}	6.9	7.2	8.9	9.2	11.6	12.3	10.2	27.4	35.7	55.2	64.1	66.5
M_3-Between L_{15} and L_{16}	6.2	7.3	7.6	8.9	11.5	12.9	11.8	26.1	32.5	50.9	57.4	60.1
M_4-Between L_{11} and L_{12}	5.9	6.8	7.9	8.8	12.4	13.6	12.2	25.4	33.6	52.1	59.8	63.4
M_5-Betwwen L_6 and L_7	7.9	7.4	8.3	9.2	11.1	12.9	13.2	26.3	34.2	49.8	58.9	61.8
Water table depth (BGL, cm) at L/2												
M_1-Between L_{27} and L_{28}	9.5	12.5	11.7	13.6	12.3	14.1	11.8	27.5	43.8	59.6	64.7	72.8
M_2-Between L_{23} and L_{24}	10.4	13.5	12.6	14.1	13.9	15.2	14.7	28.3	45.2	59.6	61.0	67.7
M_3-Between L_{15} and L_{16}	12.8	11.9	9.8	10.6	11.3	12.6	9.6	13.9	24.1	41.3	57.2	64.3
M_4-Between L_{11} and L_{12}	13.1	12.8	10.4	11.9	12.3	12.6	10.2	25.9	39.2	52.6	65.7	69.2
M_5-Betwwen L_6 and L_7	12.9	11.4	10.1	11.8	11.9	13.2	10.4	20.2	31.8	43.4	62.8	65.1
Water table depth (BGL, cm) at L/3												
M_1-Between L_{27} and L_{28}	12.5	13.8	11.9	14.7	13.1	15.2	15.4	23.9	45.8	56.9	68.1	73.1
M_2-Between L_{23} and L_{24}	13.1	13.9	11.8	15.2	14.9	15.6	15.9	25.9	42.8	46.9	58.3	66.9
M_3-Between L_{15} and L_{16}	14.2	13.4	12.9	14.3	13.9	16.8	14.9	29.6	38.9	57.2	61.8	69.3
M_4-Between L_{11} and L_{12}	13.4	12.6	11.9	14.8	12.7	15.5	14.7	26.4	35.9	54.2	59.8	65.2
M_5-Betwwen L_6 and L_7	12.9	10.9	10.3	11.9	12.4	13.8	10.8	22.9	34.2	45.8	58.7	64.8

In-situ measurement of soil hydraulic conductivity

The hydraulic conductivity (K) was measured in the Gundur village during *kharif* 2015-'16 by inverse auger hole method before transplantation as well as after harvesting. The hydraulic conductivity of Gundur village is presented in Table 2. The results revealed that the hydraulic conductivity before transplantation ranged between 0.081 and 0.187 m d^{-1}. The arithmetic mean (AM) of hydraulic conductivity for the area was 0.115 m d^{-1}. The geometric mean (GM) of hydraulic conductivity was 0.112 m d^{-1}, which was lower than that of the AM.

The combined average K of AM and GM was 0.113 m d^{-1}. The arithmetic mean and geometric mean at Gundur village after harvesting was 0.187 m d^{-1} and 0.167 m d^{-1} respectively depending on the variations in soil texture in the study area. The minimum values were observed in the upper reach of the area and highest was observed in the lower reach nearer to the nala, where the soil was slightly coarser in nature. The arithmetic and geometric mean values were almost close to each other. The results obtained were similar to the findings of Barker (2000) [2], Girish (2003), Shirahatti *et al.*, (2005) [13] and Balakrishnan *et al.*, (2005) [1].

Table 2: Hydraulic conductivity, K (m d^{-1}) at Gundur village (Head region of TLBC) before sowing and after harvesting of the paddy crop during *kharif* 2015-'16

Before transplanting				After harvesting			
Hydraulic conductivity m d^{-1}	AM	GM	Average of AM and GM	Hydraulic conductivity m d^{-1}	AM	GM	Average of AM and GM
0.187	0.115	0.112	0.113	0.196	0.187	0.167	0.177
0.106				0.125			
0.154				0.106			
0.103				0.114			
0.097				0.105			
0.103				0.217			
0.092				0.205			
0.102				0.136			
0.087				0.148			
0.081				0.231			

Areal hydraulic conductivity of SSD system

The areal hydraulic conductivity value of above and below drain level in subsurface drainage system in M_3-between L_{15} and L_{16} laterals along M_3 main drain and M_4-between L_{11} and L_{12} laterals along M_4 main drain at Gundur village were conducted during the period *kharif* 2015-'16. The areal hydraulic conductivity values above drain level were ranged from 0.089-2.461 and 0.097-2.193 m d^{-1}. The mean areal hydraulic conductivity values below drain level in M_3-between L_{15} and L_{16} laterals along M_3 main drain and M_4-between L_{11} and L_{12} laterals along M_4 main drain at Gundur village during *kharif* 2015-'16 were 3.14 and 3.35 m d^{-1}. From all this data, the areal hydraulic conductivity below drain level was pre-dominant which was 20 to 21 per cent higher than the areal hydraulic conductivity of above the drain level due to the existence of the porous subsurface strata below drain level through which more amount of seepage could take place. It is important to notice that the areal estimates of hydraulic conductivity (K) and hydraulic conductivity below drain level (K_b) values obtained by the drain outflow method were far greater than the point measurements of hydraulic conductivity by post auger-hole method obtained from the investigations. The observation of higher hydraulic conductivity by drain outflow method in comparison with the post-auger hole method measurements was also in agreement with the findings of El-Mowelhi and Van Schilfgaarde (1982) [2]; Holsambre *et al.*, (1982) [5] and Suryawanshi *et al.,* (1991) [15].

Infiltration rate of soils

The infiltration rate was measured in the study areas during *kharif* 2015-'16 using double ring infiltrometer. The infiltration rate before transplantation and after harvesting in Gundur village was ranged from 0.31 to 3.92 mm h^{-1} and 1.02 to 4.21 mm h^{-1}. The infiltration rate was found to be very low as the soil consisted of considerable amount of clay (46-51%). There was only slight increase in infiltration rate by 4.25 per cent due to improvement by SSDs after the harvesting (4.21 mm h^{-1}) compared to that before sowing (3.92 mm h^{-1}). Though this change in infiltration rate after the installation of drainage was presently insignificant it could be expected that with continuous cultivation of crops in the following seasons and with application of gypsum and organic matter, there would be considerable improvement. Similar, findings were observed by Srikant *et al.*, (2004) [14].

Economics of subsurface drainage system

The data of total cost of cultivation, total return, net return, NPV, BC ratio, IRR and payback period of paddy area under subsurface drainage system for life span of 30 years presented in Table 3. The NPV of paddy crop under SSD system have been found for 30 years life span were 363996.00, 376960.53 and 253934.58 Rs ha^{-1} respectively for Gundur village, Mallapur village and Chagabhavi village and their BC ratio were 1.37, 1.39 and 1.26 and IRR were 50, 58 and 62 per cent for 30 years life span respectively. The payback period for SSD system under paddy crop was 2 seasons for both 30 years analysis. The adoption of SSD system from the above observation of economic analysis was found to be cost-effective even though the investment was very high. The late *kharif* 2015 was the first cropping season after the installation of SSDs and there was considerable improvement in land conditions and paddy yield. Therefore, it could be expected the yield levels of crops would go still high in the succeeding cropping seasons and also the total returns, net returns, NPV, BCR, IRR and payback period would improve further.

Conclusion

The hydraulic conductivity below the drain (Kb) was higher than the K by 20.82 per cent indicating that the flow below the drain was pre-dominant. Further, the areas estimates of hydraulic conductivity were far greater (20 to 21 times) than the *in-situ* measurements of hydraulic conductivity. The infiltration rate was very low due to considerable amount of clay 46-51% and it improved slightly by 4.25%. Looking at the Economics it meant that the subsurface drainage work was found to be worth investing and profitable even though the investment was huge.

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