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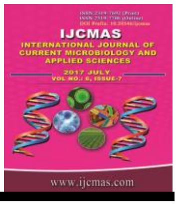

Original Research Article

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Impact of Subsurface Drainage System on Water Table and Soil Hydrologic Parameters

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ABSTRACT

A study was conducted to ensure the impact of subsurface drainage system on salt affected soils in the UKP command area, Karnataka. The *in-situ* hydraulic conductivity with average of 0.067 m d^{-1} before sowing, and improved slightly (14.92%) after the harvesting to 0.077 m d^{-1}.The geometric mean estimates of areal hydraulic conductivity obtained with 90 per cent confidence limits ranged from 0.69 to 1.280 m d^{-1} (K) and 0.88 to 1.620 m d^{-1} (K_b). Further, the areas estimates of K were far greater (15 to 16 times) than the *in-situ* measurements of K. The infiltration rate was very low due to considerable amount of clay (32-41%) and it improved slightly (by 5.45%) due to SSD system after the harvesting (2.90 mm h^{-1}) compared to that before sowing (2.75 mm h^{-1}).The B: C ratio, NPV, IRR and payback period were1.55, Rs. 2, 20, 832, Rs.104 per cent and 2 for the life span of 50 years for SSD system respectively.

Keywords

Subsurface drainage, Hydraulic conductivity, Water table and Infiltration.

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Introduction

To produce required food of the increasing population of the world, it is necessary to increase the cultivatedland productivity or more lands to be cultivated. Predictions show that food production in the next 25 years should be doubled (Ritzema, 2007). 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 a global phenomena affecting millions of hectares of productive land in more than hundred countries, posing a threat to sustainable agricultural production. Drainage in agriculture is the removal of excess water from surface or sub-surface of the soil in order to provide favourable conditions for crop production.

Materials and Methods

The area selected for the present study comes under the command of Narayanapur Left Bank Canal (NLBC) of UKP and is located in the Agricultural Research Station (ARS) Farm, Malnoor of the University of Agricultural Sciences Raichur at a distance of about 7 km from Hunasagi in Shorapur taluk, Yadgir district, Karnataka. In and around the farm also, considerable area was affected by the problems of water logging and salinity. The project area lies at 17^0 03' N latitude and $76^0$15' E longitude at an elevation of 460 m above the mean sea level. The annual average rainfall of the nearest raingauge station at Hunasagi is 547.1 mm, of which 340.6 mm occurs during June-September, which is 62.26 per cent of the average annual rainfall. The average number of rainy days in a year is 35. On an average daily.

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 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 (ed.), 1994

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) observed in the middle of pipe laterals (viz., LLII, LLI, LLIII, RRI, RRII and RRIII) in positions at L/2 distance and 2L/3 distance on fortnightly basis are presented in table 1. It was observed that at L/2 distance, the water table depth (bgl) ranged from 7.50 to 62.00, 7.40 to 63.00, 11.50-60.80 and 9.00 to 48.50 cm between LLII and LLI, LLIII and LLII, RRII and RRI and RRIII and RRI respectively. Similarly, at 2L/3 distances, it varied from 7.40 to 67.00, 8.50 to 65.50, 10.50 to 61.50 and 8.50 to 48.50 cm (bgl).

In-situ measurement of soil hydraulic conductivity

The *in-situ* hydraulic conductivity (K) was determined in the study area and the K-values are presented in table 2. The results revealed that the hydraulic conductivity before installation of subsurface drainage ranged between 0.053-0.085 $m\,d^{-1}$. The arithmetic mean (AM) of hydraulic conductivity for the area was 0.067 $m\,d^{-1}$, while the geometric mean (GM) of hydraulic conductivity was 0.066 m d^{-1}, which was lower than that of the AM. The combined average K of AM and GM was 0.067 m d^{-1}. Further, after installation of SSDs the hydraulic conductivity of the soil ranged from 0.065-0.096 m d^{-1}. The arithmetic mean (AM) of hydraulic conductivity for the area was 0.078 m d^{-1}. The geometric mean (GM) of hydraulic conductivity was 0.076 m d^{-1}, which was lower than that of the AM. The combined average K of AM and GM was 0.077 m d^{-1}.

The *in-situ* hydraulic conductivity ranged from 0.053 to 0.085 m d^{-1} depending on the variations in soil texture in the study area with arithmetic mean of 0.067 m d^{-1}, geometric mean of 0.066 m d^{-1} and combined average of 0.067 m d^{-1}. 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), Girish (2003), Shirahatti *et al.,* (2005) and Balakrishnan *et al.,* (2005).

Areal hydraulic conductivity of SSD system

The areal estimates of hydraulic conductivity (K) using Hooghoudt's equation, arithmetic and geometric means with their ranges for the SSDs along with 90 confidence limits are presented in table 3. The results indicated that the areal hydraulic conductivity (K) ranged from 0.510-1.340, and 0.680-1.700 m d^{-1} in the areas between the laterals of LLIII-LLII, and RRIII and RRII with the AM and GM K values of 0.810-0.770 and 1.160-1.120 m d^{-1} respectively. Whereas, the overall K by considering the whole SSD system ranged between 0.51 and 1.70 m d^{-1} with AM and GM values of 0.985 and 0.945 m d^{-1} respectively. The hydraulic conductivity at 90 per cent confidence limits between LLIII-LLII and RRIII-RRII varied from 0.690 to 0.920 and 1.030 to 1.280 m d^{-1} with the overall value of 0.690-1.280 m d^{-1}. The areal estimates of K were nearly 15 times higher than that of the *in-situ* estimates of K.

Similarly, the areal estimate ranges of hydraulic conductivity below the drain level (only K_b) by Hooghoudt's equation between the pairs of pipe drains (PSSDs) with arithmetic and geometric mean values and 90 per cent confidence limits are shown in table 3. The data revealed that K_b values ranged from 0.640-1.690 and 0.870-2.140 m d^{-1} for the areas between the laterals of LLIII-LLII and RRIII and RRII respectively.

The corresponding arithmetic and geometric mean values of K_b were 1.020 and 0.980 and 1.460 and 1.420 m d^{-1} respectively. Considering the whole system, K_b varied between 0.640 and 2.140 m d^{-1}, with the AM and GM K_b values of 1.240 and 1.200 m d^{-1} respectively. The K_b at 90 per cent confidence limits between LLIII- LLII and RRIII and RRII ranged from 0.880 to 1.680 and 1.310 to 1.620 m d^{-1} with the overall range of 0.880 to 1.620 m d^{-1}. The areal estimates of K_b were nearly 16 times greater than that of the *in-situ* estimates of K.

The geometric mean estimates of areal hydraulic conductivity were 0.945 (K) and 1.200 m d^{-1} (K_b) and the 90 per cent confidence limits ranged from 0.69 to 1.280 m d^{-1} (K) and 0.880 to1.620 m d^{-1} (K_b) (Table 3). Upon comparison, the hydraulic conductivity below the drain (K_b) was higher than the K by 26.52 per cent indicating that the flow below the drain was pre-dominant. This could be due to the presence of the permeable subsurface strata below drain level through which more amount of seepage could take place. Further, the areas estimates of K were far greater (15 to 16 times) than the *in-situ* measurements of K.

Table.1 Fortnightly water table depth in the middle of SSD laterals at L/2 and 2L/3 distance

Standard weeks	Water table depth (bgl, cm) at L/2									
	37	39	41	43	45	47	49	51	1	3
LLII and LLI	7.5	8.5	9.5	12.5	14.0	15.4	12.0	13.8	60.0	62.0
LLIII and LLII	10.0	11.6	11.5	12.5	7.4	8.0	13.5	15.5	50.0	63.0
RRII and RRI	11.5	12.3	13.0	14.4	15.5	12.8	14.0	13.1	57.0	60.8
RRIII and RRII	11.0	13.0	9.0	11.0	10.5	12.5	11.5	12.5	45.0	48.5
Water table depth (bgl, cm) at 2L/3										
LLII and LLI	8.5	7.4	10.5	13.1	14.5	14.5	13.1	14.3	65.0	67.0
LLIII and LLII	12.5	13.5	10.5	12.5	8.5	11.5	9.5	13.0	63.5	65.5
RRII and RRI	10.5	13.5	14.5	15.5	16.2	13.4	14.1	15.2	57.0	61.5
RRIII and RRII	10.0	12.5	10.0	12.0	8.5	12.5	12.0	13.5	47.0	51.5

Table.2 *In-situ* hydraulic conductivity measured in the study area Before and after installation of subsurface drainage

Grid no.	Hydraulic conductivity (K), m d^{-1}	Arithmetic mean (AM), m d^{-1}	Geometric mean (GM), m d^{-1}	Average of AM and GM, m d^{-1}
Before subsurface drainage system				
1	0.064	0.067	0.066	0.067
2	0.053			
3	0.085			
after subsurface drainage system				
1	0.073	0.078	0.076	0.077
2	0.065			
3	0.096			

Table.3 Areal hydraulic conductivity in SSD system

Sl. no.	Areal hydraulic conductivity, K (m d^{-1})				
	Between pipe SSDs	Range	Arithmetic mean (AM)	Geometric mean (GM)	90 per cent confidence limits
1	LLIII and LLII	0.510-1.340	0.810	0.770	$0.690 < K > 0.920$
2	RRIII and RRII	0.680-1.700	1.160	1.120	$1.030 < K > 1.280$
3	Average	0.510-1.700	0.985	0.945	$0.690 < K > 1.280$
	Areal hydraulic conductivity, K_b (m d^{-1})				
1	LLIII and LLII	0.640-1.690	1.020	0.980	$0.880 < K > 1.680$
2	RRIII and RRII	0.870-2.140	1.460	1.420	$1.310 < K > 1.620$
3	Average	0.640-2.140	1.240	1.20	$0.880 < K > 1.620$

Table.4 Infiltration rate in the study area before and after SSD system

Grids	Infiltration rate mm h^{-1} (Before)	Infiltration rate mm h^{-1} (After)	Average infiltration rate, mm h^{-1}(Before)	Average infiltration rate, mm h^{-1}(Before)
1	4.50	4.70	2.75	2.9
2	2.00	2.20		
3	3.00	3.10		
4	2.50	2.5		
5	2.00	2.20		
6	2.50	2.70		

Table.5 Economics of SSD system under the present study

Years	Total returns, Rs. ha^{-1}	Total cost of cultivation, Rs. ha^{-1}	Net returns, Rs ha-1	NPV, Rs ha^{-1}	BCR	IRR (%)	Payback period (seasons)
30	74,400	40,000	34,400	1,88,887	1.46	101	2
50	74,400	40,000	34,400	2,20,832	1.55	104	2

Studies by Balakrishnan *et al.*, (2005) showed 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 (10-13 times) 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); Holsambre *et al.*, (1982) and Suryawanshi *et al.*, (1991)

Infiltration rate of soils

The basic infiltration rate was measured during June, 2014 before sowing using double ring infiltrometer in the study area and the results of infiltration rate are presented in table 4. The results of infiltration showed that the infiltration rates ranged from 2.00 to 4.50 mm h^{-1} with AM and GM values of 2.75 and 2.63 mm h^{-1} respectively. Further, after harvesting of the crop the rate ranged from 2.20 to 4.70 mm h^{-1} with AM and GM values of 2.90 and 2.79 mm h^{-1}.

The infiltration rate was found to be very low as the soil consisted of considerable amount of clay (32-41%). There was only slight increase in infiltration rate by 5.45 per cent due to improvement by SSDs after the harvesting (2.90 mm h^{-1}) compared to that before sowing (2.75 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 Barker (2000), Girish (2003) and Srikant *et al.*, (2004).

Economics of subsurface drainage system

The total returns, cost of cultivation, net returns, NPV, BCR, IRR and payback period after the implementation of the subsurface drainage system are presented in table 5. It could be observed that the total cost of cultivation was found to be Rs. 40,000 ha^{-1}, while the NPV, IRR and B: C ratio were Rs.1, 88, 887, Rs.101 per cent and 1.46 respectively for 30 years of SSD life period. By considering all the investment and returns, the BCR was found to be above the acceptable limits and payback period obtained was 2 cropping seasons. Similarly, the NPV and IRR were Rs.2, 20, 832 and Rs.104 per cent with a B: C ratio of 1.55 for the life span of 50 years. This meant that the installation of the subsurface drainage was found to be profitable even though the investment was very high.

The late *kharif*2014 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.

In conclusion, the hydraulic conductivity below the drain (K_b) was higher than the K by 26.52 per cent indicating that the flow below the drain was pre-dominant. Further, the areas estimates of hydraulic conductivity were far greater (15 to 16 times) than the *in-situ* measurements of hydraulic conductivity. The infiltration rate was very low due to considerable amount of clay (32-41%) and it improved slightly (by 5.45%). 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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