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CM Pradeep
Ph.D Scholar (Agri. Engg.)
SWE, UAS, Raichur,
Karnataka, India

P Balakrishnan
Professors, University of Agricultural Sciences, Raichur, Karnataka, India

U Satishkumar
Professors, University of Agricultural Sciences, Raichur, Karnataka, India

AT Dandekar
Assistant Professors, University of Agricultural Sciences, Raichur, Karnataka, India

H Lokesh
Assistant Professors, University of Agricultural Sciences, Raichur, Karnataka, India

MA Bellakki
Assistant Professors, University of Agricultural Sciences, Raichur, Karnataka, India

Correspondence
CM Pradeep
Ph.D Scholar (Agri. Engg.)
SWE, UAS, Raichur,
Karnataka, India

Impact assessment of subsurface drainage system in waterlogged saline lands on improvement of soil Parametres and crop yield in UKP Command Area, Karnataka

CM Pradeep, P Balakrishnan, U Satishkumar, AT Dandekar, H Lokesh and MA Bellakki

Abstract
Subsurface drainage improves the productivity of poorly drained soils by lowering the water table, providing greater soil aeration, improving root zone soil salinity and enhancing the crop yield. Therefore, the study was conducted to check the impact of subsurface drainage system on soil quality parameters, land and crop performance in the UKP command Area, Karnataka. The study area is located at Malla-Buzurg (B) village in Shorapur taluk, Yadgiri district within 16°43'34.18" N to 16°44'10.52" N and longitude of 76°34'10.02" E to 76°34'43.13" E at an elevation of 458 m above the mean sea level. The mean pHs values before sowing and after harvesting ranged from 8.20 to 8.75 and 8.32 to 8.94 respectively. The mean EC_e and ESP values before sowing ranged from 8.57 to 20.08 dS m^{-1} and 19.70 to 24.14 and after harvesting of the crops results obtained were in range of 8.52 to 19.59 dS m^{-1} and 19.36 to 23.36 respectively. A glance at results reveals that pH and K^+ was observed to be increased due to sodic nature of soil and excess application of the fertilizer. ESP was noticed to be reduced as compared to pre-sowing conditions, gypsum needed to be applied in required amount in order to turn the soil from sodicity to saline or non-saline soils. Finally, the cropping intensity and crop yield was observed to be increased by 146.20 and 47.68 per cent respectively as compare to pre drainage condition.

Keywords: Electrical conductivity, soil reaction, ESP, cropping intensity and crop yield

1. Introduction

Land is a valuable asset of any country. Its efficient management with a view to conserve its fertility and productivity on sustainable basis is of vital importance for meeting the food demands of the growing population and the development of the country. Agriculture is an important sector of economic activity in India, accounting for a little less than two-fifth of the national income and more than two-third of its work force. However, the agricultural land resources in India are shrinking rapidly as more and more lands are consumed by urbanization, industrial and other developmental activities. If the present trend is an indication, the per capita land availability will be reduced to meager 0.124 ha by the turn of century (Ministry of Environment and Forests, Government of India (GOI), 2012). Therefore, the available land resources have to be properly used as well as the degraded lands be brought back under productive purposes to reduce the pressure on land.

The soil salinisation was a major problem influencing the global agricultural production and sustainable utilisation of land resources (Wang *et al.*, 2011) [14]. It is estimated that nearly 8.4 million ha of the irrigated lands are affected by soil salinity and alkalinity, of which about 5.5 million ha is also waterlogged (Ritzema *et al.*, 2008) [11]. As a worldwide problem, saline conditions also adversely affect the growth and survival of most of the crops, therefore, an understanding of responses of plants to salinity is of great practical significance (Ramoliya and Pandey 2003) [10].

The state of Karnataka is no exception to these phenomena as the command areas of its many irrigation projects are suffering from waterlogging and salinity problems. About 4 lakh ha has been affected by waterlogging and salinity in the state. The Upper Krishna Project (UKP) is the most prestigious and an ongoing major irrigation project in the state, that aims to irrigate the chronically drought hit areas of Kalaburagi, Yadgiri, Raichur, Koppal and Vijayapura districts in northern Karnataka. Under the UKP, irrigation water was first let out in September, 1982 and about 6 lakh ha irrigation potential has been created till date. The project on its full development envisages bringing 1 M ha under irrigation in three stages I, II, III and beyond. The predominant soils of the UKP command areas are black soils with fine texture and poor water transmission properties. Therefore, the problems of waterlogging and salinity are unavoidable processes in vertisols (black cotton soils) and they are increasing at alarming rate because of their inherent poor drainage property coupled with potential evapotranspiration rates that are much higher than the annual rainfall.

In most irrigated lands in the arid and semi-arid regions, artificial drainage is indispensable to overcome the problems of waterlogging and salinity. Drainage is essential on poorly drained agricultural fields to provide optimum air and salt environments in the root zone by removing the excess water and salts. Drainage is regarded as an important water management practice, and as a component of efficient crop production systems. Food supply and the productivity of existing agricultural lands can only be maintained and enhanced if drainage practices are undertaken on croplands currently affected by excess water and high water tables. Drainage (both surface and subsurface) is complementary to irrigation and is viewed as an essential component of irrigated agriculture. The objective is to increase production efficiency, crop yields and profitability on naturally poorly drained agricultural lands.

Materials and methods

Study area and climate

The study area selected for the present study comes under the command of Jevargi Branch Canal (JBC) of the Narayanpur Left Bank Canal (NLBC) taking off from the Narayanapur dam under the UKP. The study area is located at Malla-Buzurg (B) village in Shorapur taluk, Yadgiri district within 16°43'34.18" N to 16°44'10.52" N and longitude of 76°34'10.02" E to 76°34'43.13" E at an elevation of 458 m above the mean sea level. In and around the study area also, considerable area was affected by the problems of waterlogging and salinity. The total area of the NLBC command was 180 ha of which about was affected by these problems. The area of the study site was 50 ha and bounded by Shahapur-Malla-Kembhavi road on southern side and a main nala on the northern side. One distributary (*i.e.* Distributary-I and Lateral-3) taking off from Jevargi Branch Canal (JBC) running nearby irrigates the study area and the surrounding. The image of the study area of Malla-Buzurg (B) is shown in Figure 1.

The study area falls under the Northern Dry Zone (Zone-2) of Karnataka state agro-climatic zones. The study area is part of semi-arid region with average annual rainfall of 711.2 mm. This rainfall is received during south west monsoon. This area has short monsoon and majority of the rainfall is received during second fortnight of August to September months. January represents the coldest month and April and May being the hottest months of the year. The evaporation values ranged from 697 to 1522 mm, minimum and maximum temperature is ranged from 13.81°C to 27.46 °C and 28.67°C to 42.29 °C respectively, the relative humidity (RH) values are ranged from 24.19 to 83.04 per cent, wind velocity ranged from 3.98 to 11.05 km day^{-1} and the average sunshine hour of the study area is 6.25 h.

Observations recorded

In order to carry out systematic studies, the sampling points were identified on a grid size of 150 m X 150 m in the study area (22 points). The soil samples were collected at different depths of 0-30, 30-60, 60-90 and 90-120 cm in these grid points before sowing and after harvesting. The chemical analysis included estimating pH, EC, K^+, Na^+, Ca^{2+}, Mg^{2+}, ESP by adopting standard procedures to know the salinity and sodium level etc. The comparison of soil salts content before sowing and after harvesting of crop was carried out using paired t-test and F test was conducted to check the concentration of salts at particular depths but at different points.

Results and discussion

Effect of sub-surface drainage on soil quality parameters

Soil reaction (pH_s) and Electrical conductivity (EC_e)

The pH_s and EC_e values are presented in Table-1, which reveals that the mean pHs and EC_e values before sowing ranged from 8.20 to 8.75 and 8.57 to 20.08 dS m^{-1} respectively. Similarly, the mean pHs and EC_e values after the harvesting varied from 8.32 to 8.94 and 8.52 to 19.59 dS m^{-1} respectively.

The mean pH value before sowing and after harvesting was observed to be increasing as the depth increases. it could be noticed from the (Table-1) that Fcal value 4.33* and 3.66* was more than that of the F_{table} value 2.71, which implied that there was significant difference between the mean pH_s values drawn from different depths before sowing and after harvesting. A close examination of the same revealed that T_{cal} values 5.008, 3.015, 8.249 and 7.495 for the soil samples drawn from 0-30, 30-60, 60-90 and 90-120 cm depths at different grid points before sowing and after harvesting were more than the T_{table} value 2.080 (Table 2). This indicated that there was significant difference between the mean pHs values of soil samples drawn at different depths before sowing and after harvesting of the crop. There was no pronounced effect of SSD system alone in reducing the soil pHs. Before sowing the soil from 0-90 cm depth showed saline-sodic characteristics and from 90-120 cm depth exhibited sodic characteristics, but after the harvesting, the soil depth from 30-120 cm became sodic. There was no evident effect of SSD system alone in reducing the soil pH_s. In such cases, the amendment like gypsum also should have been applied particularly to sodic soils, which would have reduced the sodicity of the soils considerably. Therefore, to accelerate the process of complete reclamation of sodic portion of the affected area the amendment like gypsum should be applied. Similar results were reported by past studies which revealed that the pHs of the soil after the implementation of the subsurface drainage system or after the harvest of the crop increased (Babu *et al*., 2010 and Dong *et al.*, 2012) [1, 4].

The mean EC_e value before sowing and after harvesting was observed to be decreasing as the depth increases. it could be noticed from the (Table 1) that Fcal value 3.05* and 3.16* was more than that of the F_{table} value 2.71, which implied that there was significant difference between the mean EC_e values drawn from different depths before sowing and after harvesting. The soil salinity values of T_{cal} of different depths were 3.724, 3.007, 3.586 and 3.421 more than the T_{table} (*i.e.* 2.08) for the soil sample taken from four different depths at 0-30, 30-60, 60-90 and 90-120 cm respectively. This showed that there was significant difference between the mean EC_e values of the soil samples drawn before sowing and after harvesting of crops at all depths (Table 2). The salinity value at 0-30 cm depth was higher as compare to 30-60, 60-90 and 90-120 cm in both before sowing and after harvesting of crops (Table 1). This might be due to the fact that the salts got accumulated more at the surface layers in pre-drainage condition over a period of time due to development of waterlogging and salinity by excess flow of water along with salts and by the processes of high evaporative demands and capillary action and also because of the cropping practices followed in the study area. After installation of SSD_s the soil salinity values were reduced by season to season. The results obtained are in agreement with the findings of Steppuhn and Wall 1997 (Buckland *et al.*, 1986 and Hogg and Tollefson 1992) [3, 5]. Prasad *et al.* (2007) [9] also reported positive results with open sub surface drainage system in reducing the salinity of problematic soils.

Exchangeable cations

The exchangeable cations of Ca^{2+}+Mg^{2+}, Na^+ and K^+ values are presented in Table 3, which shows that the mean exchangeable Ca^{2+}+Mg^{2+}, Na^+ and K^+ values before sowing varied from 29.34 to 36.00, 7.77 to 11.03 and 0.102 to 0.201 meq $(100g)^{-1}$ respectively. Similarly, the mean pHs and EC_e values after the harvesting varied from 29.02 to 35.07, 7.37 to 10.67 and 0.127 to 0.260 respectively. Moreover, it was noticed that F_{cal} values of all exchangeable Ca^{2+}+Mg^{2+}, Na^+ and K^+ was more than the F_{table} value (271), hence there was significant difference between the mean exchangeable calcium and magnesium, sodium and potassium values of soil samples drawn from different depths before sowing and after harvesting. A glance of comparative analysis of exchangeable Ca^{2+}+Mg^{2+}, Na^+ and K^+ before sowing and after harvesting reveals that that T_{cal} values for soil samples drawn from different depths were more than the T_{table} 2.080 value (Table 4). Thus, it could be concluded that there was significant difference in the mean exchangeable calcium and magnesium, sodium and potassium content of soil samples drawn before sowing and after harvesting. The soil exhibited higher exchangeable sodium content in the surface layer than that of the deeper layers due to higher evaporation and capillary rise of dissolved sodium in the summer season. With the ponding of water after the transplanting of the paddy crop, part of the sodium was dissolved in the water and drained away though the drains were found working well, but not found much efficient in the reduction of the sodium concentration from the soil. In semi-arid irrigated area, irrigation practice mobilise naturally occurring salt in the soil and concentrate those salts already present in the supply water. Therefore, the drains were found working well, but not found much efficient in the reduction of the exchangeable sodium, calcium and magnesium and potassium concentration from the soil (Mathew *et al.*, 2001 and Jadhao *et al.*, 2009) [7, 6].

Exchangeable sodium percentage

The exchangeable sodium percentage (ESP) is the most important cation that threatens the clay soil. The exchangeable sodium percentage (ESP) values of the soil samples before sowing after harvesting drawn from different depths are shown in Table 3. The mean ESP values of the soil samples before sowing drawn from different depths ranged from 19.70 to 24.14. Similarly, the mean ESP values of the soil samples before sowing drawn from different depths ranged from 16.36 to 21.36. The ESP value at 0-30 cm depth was higher as compare to 30-60, 60-90 and 90-120 cm in both before sowing and after harvesting of crops (Table 3). Also, since the F_{cal} values for before sowing and after harvesting were 3.19 and 4.43 respectively, which were more than the F_{table} value (2.71), there was significant difference between the mean values of ESP drawn from different depths before sowing and after harvesting. A glance of comparative analysis of ESP before sowing and after harvesting reveals that that T_{cal} values for soil samples drawn from different depths were more than the T_{table} 2.080 value (Table 4). This meant that there was significant difference in the mean exchangeable sodium percentage values of the soil samples drawn before sowing and after harvesting. The reduction in ESP was due to the SSD system, which helped in leaching of salts. However, the reduction was not considerable without the application of gypsum as it was to needed to be applied to tackle the sodicity conditions. With application of the gypsum in the following season, it is expected that the reclamation process would be complete by significant reduction in ESP. The present results obtained are in agreement with the findings of Bharambe *et al.* (2001) [2] and Tian *et al.* (2013) [13].

Land Improvement and Crop Performance Studies

It was observed that annual cropping intensity before the installation of subsurface drainage was 25.12 per cent which were improved to 146.2 per cent after the installation of subsurface drainage system. Before the installation of SSDs the average paddy and cotton yield of the study area was ranging between 25 to 29 and 10.0 to 11.25 q ha^{-1} respectively. After installation of SSDs the paddy yield was range between the 45.90 to 50.89 q ha^{-1} and the yield of cotton was ranged between 19.23 to 23.21 p ha^{-1} during the period 2014-'15 (Table 5). Therefore, there is a 45.59 and 49.77 per cent increase in of paddy and cotton yields as compare to pre-drainage condition. Naftchali and Shahnazari (2014) [8] reported the introduction of the subsurface drainage resulted in an increase in both crop yield and cropping intensity in the study area.

Summary and conclusions

The twin menacing problems of waterlogging and soil salinity in the short and medium terms, adversely affect the crop productivity and production. In the long run, they lead to abandoning of once productive agricultural lands. Therefore, in most irrigated lands in the arid and semi-arid regions, artificial drainage is indispensable to overcome the problems of waterlogging and salinity. The performance and the impact of the SSDs were monitored during 2014-'15 for improvement in the soil chemical parameters as well as the cropping intensity and yield response of the crops in the post-drainage scenario compared to the pre-drainage conditions.

Based on the study and examination of the soil samples collected during the study period, it could be observed that soil salinity and exchangeable cations was found to be reduced significantly as compared to pre-sowing condition but except soil reaction and exchangeable potassium was found to be increased due to increase in sodicity of the soil and use of more quantity of fertilizers. The ESP was observed to be reduced as compared to pre sowing conditions, as the soil was found to be sodic in nature, there is need of application of gypsum in requires amount in order to turn the soil from sodicity to saline or non saline soils. The cropping intensity and crop yield was observed to be increased by 146.20 and 47.68 per cent respectively as compare to pre drainage condition.

Drainage has not been given importance as much as irrigation by the farmers as well as the Government Agencies. So there is a great demand for the concerned research and development efforts to reclaim all the salt affected and water logged soils and bring them back to profitable farming with increased agricultural production as well as cropping intensity. The only means to overcome the salinity and water logging permanently is selection and adoption of suitable subsurface drainage system.

Table 1: Impact of SSD system on soil pH_s and EC_e (dS m^{-1})

Soil depth, cm	Soil reaction (pH_s)		Electrical conductivity (EC_e) dS m^{-1}	
	Before sowing	After harvesting	Before sowing	After harvesting
0-30	8.20	8.32	20.08	19.59
30-60	8.27	8.56	10.97	10.32
60-90	8.48	8.89	8.95	8.54
90-120	8.75	8.94	8.57	8.52
F_{cal}	4.33*	3.66*	3.05*	3.16*
F_{table}	2.71		2.71	

* - Significant

Table 2: Comparison of soil salinity before sowing and after harvesting of crop using paired t-test.

Soil depth, cm	Soil reaction (pH_s)		Electrical conductivity (EC_e)	
	T_{cal}	T_{table}	T_{cal}	T_{table}
0-30	5.008*	2.080	3.724*	2.080
30-60	3.015*		3.007*	
60-90	8.249*		3.586*	
90-120	7.495*		3.421*	

* - Significant

Table 3: Impact of SSD system on soil Exchangeable cations and ESP

Soil depth, cm	$Ca^{2+}+Mg^{2+}$ meq (100 g)$^{-1}$		Na^+ meq (100 g)$^{-1}$		K^+ meq (100 g)$^{-1}$		ESP	
	Before sowing	After harvesting	Before sowing	After harvesting	Before sowing	After harvesting	Before sowing	After harvesting
0-30	36.00	35.07	11.03	10.67	0.201	0.260	24.14	21.36
30-60	33.95	33.77	9.98	9.36	0.130	0.172	22.92	19.85
60-90	29.34	29.02	8.56	7.93	0.113	0.146	22.69	18.51
90-120	31.66	31.34	7.77	7.37	0.102	0.127	19.70	16.36
F_{cal}	14.13*	12.52*	15.94*	22.63*	13.54*	13.85*	3.19*	4.43*
F_{table}	2.71		2.71		2.71		2.71	

* - Significant

Table 4: Comparison of ESP and Exchangeable cations before sowing and after harvesting of crop using paired t-test.

Soil depth, cm	$Ca^{2+}+Mg^{2+}$ meq (100 g)$^{-1}$		Na^+ meq (100 g)$^{-1}$		K^+ meq (100 g)$^{-1}$		ESP	
	T_{cal}	T_{table}	T_{cal}	T_{table}	T_{cal}	T_{table}	T_{cal}	T_{table}
0-30	6.047*	2.080	3.238*	2.080	2.278*	2.080	7.633*	2.080
30-60	2.961*		4.310*		4.138*		10.390*	
60-90	2.229*		3.042*		2.346*		7.646*	
90-120	2.433*		2.856*		2.520*		6.162*	

* - Significant

Table 5: Crop yield and cropping intensity during the period 2014-’15

Paddy (q ha^{-1})		Cotton (q ha^{-1})		Cropping intensity (%)	
Pre-drainage,	Post-drainage	Pre-drainage,	Post-drainage	Pre-drainage,	Post-drainage
25.0 to 29.0	45.90 to 50.89	10.00 to 11.25	19.23 to 23.21	25.12	146.20

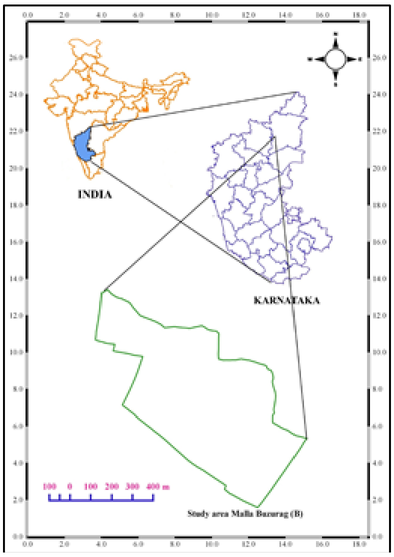

Fig 1: Location map of study area at Malla B

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