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Effect of Subsurface Drainage on Water Soluble Ions of Saline Vertisol Under TBP Command Area

Sahana[1*], H. Veeresh[2], K. Narayana Rao[3], S.N. Bhat[4] and B.S. Polisgowdar[5]

[1]M.Sc. Scholar, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur University of Agricultural Sciences, Raichur-584104, (Karnataka), India.
[2]Assistant Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur University of Agricultural Sciences, Raichur-584104, (Karnataka), India.
[3]Professor and Head, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur University of Agricultural Sciences, Raichur-584104, (Karnataka), India.
[4]Assistant Professor, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Raichur-584104, (Karnataka), India.
[5]Professor, Department of Soil and Water Engineering, College of Agricultural Engineering, Raichur University of Agricultural Sciences, Raichur-584104, (Karnataka), India.

(Corresponding author: Sahana)*
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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 mean values of water soluble cations i.e., Ca+ Mg, Na and K of pre-drainage soil samples was ranged from 8.12 to 20.02, 26.37 to 44.19 and 0.24 to 0.35 meq 100 g^{-1} respectively and it was reduced in post- drainage soil samples i.e., 3.26 to 11.86, 11.08 to 32.09, 0.16 to 0.28 meq 100 g^{-1} for Ca+Mg, Na and K respectively. Similarly the mean values of SAR and water soluble anions i.e., Cl^-, SO_4^{2-} and HCO_3^- of pre-drainage soil samples was ranged from 8.23 to 14.41, 37.14 to 65.76, 18.39 to 37.86 and 2.13 to 3.12 meq 100 g^{-1} respectively it was reduced in post- drainage soil samples i.e., 5.46 to 12.19, 19.95 to 38.13, 10.82 to 31.55 and 1.27 to 1.72 meq 100 g^{-1} for Cl^-, SO_4^{2-} and HCO_3^- respectively. The concentration of SAR, water soluble cations and anions in the post-drainage soil samples was reduced in all the depths than that of corresponding depths in pre-drainage soil samples by leaching effect and draining of water from the field, thus indicating the positive effect of SSD in removal of salts throughout the profile soil depth.

Keywords: SSD, post- drainage, post-drainage, SAR, water soluble cations, water soluble anions.

INTRODUCTION

Agriculture plays a vital role in the Indian economy with its large resources of land, water and sunshine. Despite the focus on industrialization, agriculture remains a dominant sector of the Indian economy both in terms of contribution to gross product as well as a source of employment to millions across the country. Indian agriculture sector accounted for 17.4 per cent of India's gross domestic product and employed just a little less than 60 per cent of the country's work force (2011-12). The statement "Agriculture Sustains Life, but Irrigation Sustains Agriculture" is true for India. The spectacular development of irrigation since independence in India is unparalleled in the world; which has greatly boosted the agricultural production. Irrigation development in India, with a mere 22.7 m ha during 1950 has gone up to 66.1 m ha during 2012-13 (Directorate of Economics and Statistics, Ministry of India). However, the same attention has not been given to land drainage to create conductive atmosphere to the crop growth. As a result, the impact of irrigation over decades due to the absence of appropriate drainage measures and unscientific land and water management practices over the years have led to groundwater table rise to nearby or at root zone. The water table rise also brings up salts with it from subsurface thereby rendering salinity in the root zone (Kapourechal *et al*., 2013). Therefore, irrigation water could be a boon or bane depending on its use.

As per the projections made, an area of about 15.5 million ha is likely to be affected by the problems of water logging and soil salinity/sodicity in the irrigation commands of India by 2030 (CSSRI, 2011). In irrigated areas, the increased use of saline water together with poor management practices aggravates the problem, particularly when there is inadequate drainage of water exceeding plant requirements. As the water table rises, salts stored within the soil profile are mobilized and carried towards the soil surface, resulting in salinization. These require an efficient technique to decrease the salinity in the upper soil layer for improved root growth and crop development. If the natural drainage is insufficient to remove excess water and salts away from an affected area, the installation of the subsurface drainage (SSD) technology has been found to be the most affordable and feasible technology under reclamation programme (Babu *et al*., 2008), On the other hand main reason of using subsurface drainage in paddy field is to improve the soil and create a more conductive working condition for the use of farm machinery. The system mainly consists of corrugated perforated PVC drain pipes and synthetic materials as drain envelope. Therefore, in order to tackle the problem of water logging and soil salinity and to reclaim the affected soils TBP CADA has planned to carry out the reclamation work in a phased manner. Under phase-IV, it has initiated work in an area of 4080.64 ha distributed under four sub divisions.

MATERIALS AND METHODS

Study area and climate. The study area selected for the present study comes under the Tungabhadra command area and project site is situated at a distance of 21.0 km on Ballari to Gotur road and it is 2.00 km from the Gotur village with 15°13′93.93″N latitude and 76°92′14.43″E longitude at a elevation of 495 m above the mean sea level. A block of 80 ha area comprising of different farmers' fields has been selected where in the subsurface drainage system was implemented during 2016. The study area falls under the Northern Dry Zone (Zone-2) of Karnataka State Agro-climatic Zones Classification. The area is a part of semi-arid region characterized by mild winter, short monsoon and hot summer. The mean annual temperature is 27.4ºC. Summer season is very hot with temperatures rising to 42ºC or more, whereas winter season (November to February) is relatively cool and dry. The hottest months are April and May, and December is the coldest month. The average annual rainfall at Ballari rain gauge station is 550.16 mm, of which 350.6 mm occurs during June-September, which is 62.26 per cent of the average annual rainfall.

Collection and preparation of soil samples for chemical analysis. In order to carry out systematic studies, the sampling points were identified on a grid size of 50 m × 50 m in the study area (9 points). The soil samples were collected at different depths of 0-30, 30-60, 60-90 and 90-120 cm from each grid points during 2016 before the installation of subsurface drainage. The post subsurface drainage soil samples were collected after the harvest of first crop *i.e.,* during 2017. However, care was taken to keep the soil sampling points as same as those of pre-drainage points using GPS. The soil samples were air dried in the shade, ground with wooden pestle and mortar and passed through 2 mm sieve. Samples were preserved in polyethylene bags for further chemical analysis. The chemical analysis included estimating water soiluble cations and anions *i.e.,* Ca + Mg, Na, K, Cl^-, SO_4^{2-} and HCO_3^-. The comparison of soil parameters of pre SSD and post SSD soil samples was carried out by using paired t-test and impact of SSD was assessed.

Estimation of water soluble ions

Water Soluble cations. The water soluble cations analysed were calcium+magnesium, sodium and potassium as described by Richards (1954).

Water soluble anions

The water soluble ions were extracted using distilled water (1:5 soil: water extract) as described by Richards (1954). Using suitable aliquot following water soluble anions were analyzed in the extracts.

Exchangeable sodium percentage

The exchangeable sodium percentage of soil samples was calculated by using the below formula:

$$\mathrm{ESP} = \frac{\text{Exch. Na}^+}{\text{Cation exchange capacity}} \times 100$$

RESULT AND DISCUSSION

Water Soluble Cations. The concentration of water soluble cations in the pre and post-drainage soil samples of study area followed the order of Na > Ca+Mg > K. It is clear that sodium, calcium and magnesium were dominant cations. The results pertaining to water soluble Ca+Mg, Na and K of pre and post drainage soil samples are presented in Table 1. In general, among the pre-drainage soil samples the Ca+Mg values ranged from 8.12 to 20.02 meq 100 g^{-1}, the Na values ranged from 26.37 to 44.19 meq 100 g^{-1}, while K values ranged from 0.24 to 0.35 meq 100 g^{-1} irrespective of soil depths. The results revealed that the surface soil layers recorded higher water soluble Ca+Mg, Na and K. The mean values of water soluble cations of pre-drainage soil samples were 18.37, 14.46, 12.17, 10.42 meq 100 g^{-1} for Ca+Mg, 40.01, 35.27, 36.16, 31.67 meq 100 g^{-1} for Na and 0.31, 0.29, 0.31, 0.26 meq 100 g^{-1} for K for soil depths *viz.,* 0-30, 30-60, 60-90 and 90-120 cm respectively (Table 1). Thus, showing a trend of slight decrease in water soluble Ca+Mg with increase in soil depth while there was no clear trend observed with the water soluble concentrations of Na and K.

Table 1: Effect of SSD on water soluble cations (meq 100 g^{-1}) content of 1:5 soil: water extract recorded in soil samples collected from different sampling points.

Soil depth (cm)	Ca+Mg			Na			K		
	a) Pre-drainage								
	Min.	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**
0-30	16.23	20.02	18.37	35.78	44.19	40.01	0.28	0.34	0.31
30-60	12.07	17.53	14.46	31.08	40.16	35.27	0.26	0.33	0.29
60-90	9.98	15.00	12.17	30.19	41.28	36.16	0.29	0.35	0.31
90-120	8.12	13.04	10.42	26.37	37.33	31.67	0.24	0.30	0.26
b) Post-drainage									
0-30	3.26	6.38	4.89	11.08	19.06	15.48	0.16	0.24	0.20
30-60	4.03	7.01	5.49	14.07	21.12	17.21	0.18	0.26	0.22
60-90	6.09	9.86	7.41	18.79	27.47	22.36	0.19	0.28	0.24
90-120	7.86	11.86	9.24	22.14	32.09	25.65	0.19	0.26	0.23

On the other hand, in the case of post SSD soil samples, in general the Ca+Mg values ranged from 3.26 to 11.86 meq 100 g^{-1}, the Na values ranged from 11.08 to 32.09 meq 100 g^{-1}, while K values ranged from 0.16 to 0.28 meq 100 g^{-1} irrespective of soil depths. The post-drainage soil sample indicated that the concentration of water soluble calcium + magnesium, sodium and potassium were reduced in all the depths when compared to corresponding depths of pre-drainage soil samples. The mean values for water soluble cations of post-drainage soil samples drawn from 0-30, 30-60, 60-90 and 90-120 cm were 4.89, 5.49, 7.41, 9.24 meq 100 g^{-1} for Ca+Mg, 15.48, 17.21, 22.36, 25.65 meq 100 g^{-1} for Na and 0.20, 0.22, 0.24, 0.23 meq 100 g^{-1} for K respectively (Table 1b). The concentration of water soluble cations in the post-drainage soil samples was reduced in all the depths than that of corresponding depths in pre-drainage soil samples (Fig. 1a and b) by leaching effect and draining of water from the field, thus indicating the positive effect of SSD in removal of salts throughout the profile soil depth. Sharma and Singh (1998), Rahul *et al.,* 2016 have also reported similar observation and attributed it to the leaching of water soluble cations.

The t_{cal} and t_{cri} values computed in comparison of water soluble Ca+Mg, Na and K content of pre and post-drainage soil samples using paired t test are presented in Table 2. From the table it is clear that SSD had impacted the positive changes in the water soluble concentration throughout the profile depth significantly.

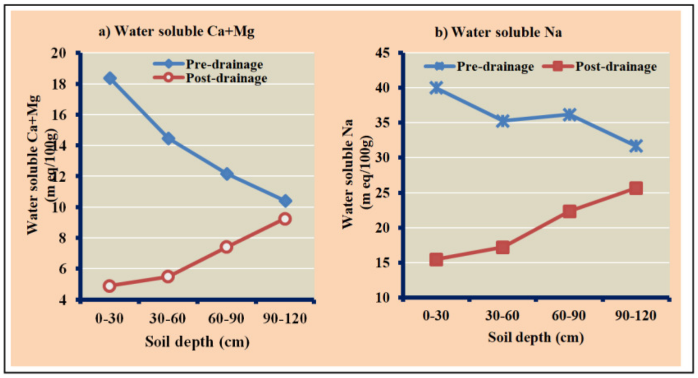

Fig. 1. Influence of SSD on water soluble Ca+Mg and Na cations observed at different soil depths.

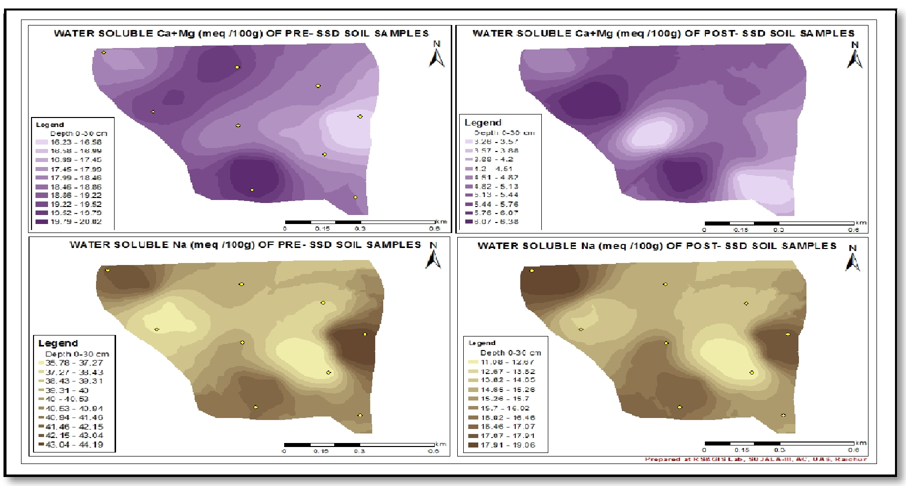

Fig. 2. Map showing variation in water soluble Ca+Mg and Na cations of pre and post-drainage soil samples of study area produced by Krigging.

Table 2: Comparison of water soluble cations of pre-drainage and post-drainage soil samples using paired t-test.

Soil depth (cm)	Water soluble cations					
	Ca+Mg		Na		K	
	t_{cal}	t_{cri}	t_{cal}	t_{cri}	t_{cal}	t_{cri}
0-30	37.22*	1.86*	72.07*	1.86*	12.26*	1.86*
30-60	15.44*		25.12*		7.46*	
60-90	8.78*		13.21*		6.67*	
90-120	3.68*		5.33*		4.38*	

The distribution of surface soil water soluble Ca+Mg and Na in the entire study area before and after SSD is depicted in the map (Fig. 3).

Sodium adsorption ratio (SAR). The analyses results pertaining to SAR of pre and post drainage soil samples are presented in Table 3. In general, among the pre-drainage soil samples the SAR values ranged from 8.23 to 14.41 irrespective of soil depths. The results revealed that the mean values for SAR of pre-drainage soil samples drawn from 0-30, 30-60, 60-90 and 90-120 cm soil depths were 10.31, 10.29, 11.52 and 10.90 respectively and results were not showing any definite trend with an increase in depth of the soil under study (Table 3).

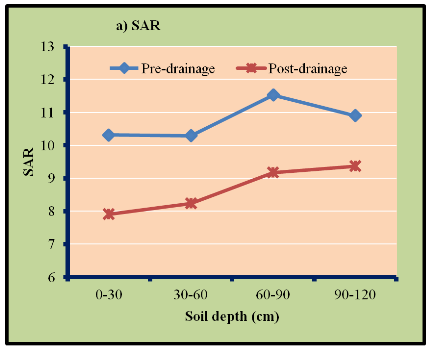

Fig. 3. Influence of SSD on soil SAR observed at different soil depths.

Table 3: Effect of SSD on sodium adsorption ratio (SAR) recorded in soil samples collected from different sampling points.

Soil depth (cm)	SAR		
	a) Pre-drainage		
	Min.	Max.	Mean
0-30	9.21	12.10	10.31
30-60	8.53	12.50	10.29
60-90	8.81	14.41	11.52
90-120	8.23	13.73	10.90
	b) Post-drainage		
0-30	5.46	9.92	7.90
30-60	6.55	10.65	8.24
60-90	7.46	12.19	9.17
90-120	7.97	12.09	9.37

On the other hand, in the case of post SSD soil samples, in general the SAR values ranged from 5.46 to 12.19 irrespective of soil depths. While the analyses of soil samples from post SSD work have indicated a decrease in mean values of SAR in all soil depths *i.e.,* 7.90, 8.24, 9.17 and 9.37 for 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively (Table 3b). The reduction in SAR of post-drainage soil samples is due to the leaching and accumulation of salts in lower depths (Fig. 3). These results are in conformation with the findings of Doddamani *et al.* (1995) wherein they observed the decrease in SAR values after the installation of subsurface drainage.

The comparative analysis of SAR content of pre and post-drainage soil samples using paired t-test (Table 4) revealed that that SSD had significantly impacted and decreased the soil SAR in all the depths.

The distribution of surface soil SAR in the entire study area before and after SSD is depicted in the map (Fig. 4).

Table 4: Comparison of SAR and TSS of pre drainage and post-drainage soil samples using paired t-test.

Soil depth (cm)	SAR	
	t_{cal}	t_{cri}
0-30	6.24*	1.86*
30-60	4.26*	
60-90	4.09*	
90-120	3.05*	

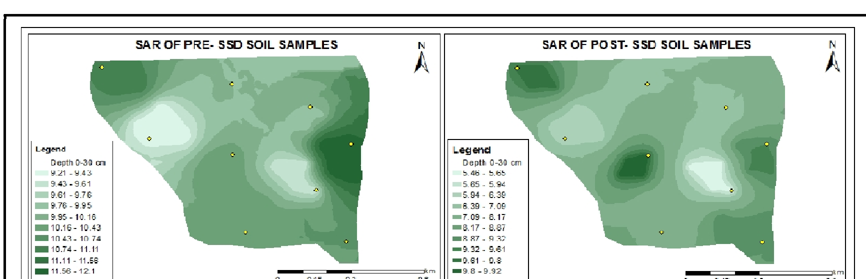

Fig. 4. Map showing variation in SAR of pre and post-drainage soil samples of study area produced by Krigging.

Water soluble anions. The concentration of water soluble anions in the pre and post-drainage soil samples of study area followed the order of $Cl^- > SO_4^{2-} > HCO_3^-$. It is clear that chloride and sulphate were the dominant anions in the water extract of soil samples. The results pertaining to water soluble Cl^-, SO_4^{2-} and HCO_3^- of pre and post drainage soil samples are presented in Table 5. In general, among the pre-drainage soil samples the Cl^- values ranged from 37.14 to 65.76 meq 100 g^{-1}, the SO_4^{2-} values ranged from 18.39 to 37.86 meq 100 g^{-1} and the HCO_3^- values ranged from 2.13 to 3.12 meq 100 g^{-1} irrespective of soil depths. The results revealed that the mean values for water soluble anions in pre-drainage soil samples were 61.98, 58.45, 53.71 and 42.14 meq 100 g^{-1} for Cl^-, 21.66, 25.02, 30.12, 32.81 meq 100 g^{-1} for SO_4^{2-} and 2.85, 2.77, 2.64, 2.40 meq 100 g^{-1} for HCO_3^- in soil samples drawn from 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively (Table 5a). Thus, water soluble Cl^- and HCO_3^- showing a trend of slight decrease while SO_4^{2-} is not showing any definite trend with the increase in soil depth.

On the other hand, in the case of post SSD soil samples, in general the Cl^- values ranged from 19.95 to 38.13 meq 100 g^{-1}, the SO_4^{2-} values ranged from 10.82 to 31.55 meq 100 g^{-1} and the HCO_3^- values ranged from 1.27 to 1.72 meq 100 g^{-1} irrespective of soil depths. And results revealed that the concentration of water soluble anions was reduced in all the soil depths when compared to the values in corresponding soil depths of pre-drainage samples. The mean values for water soluble anions of post-drainage soil samples were 22.14, 29.26, 32.57, 35.12 meq 100 g^{-1} for Cl^-, 12.74, 18.40, 23.17, 27.34 meq 100 g^{-1} for SO_4^{2-} and 1.43, 1.54, 1.49, 1.62 meq 100 g^{-1} for HCO_3^- for 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively showing an increasing trend with the soil depth (Table 5b). The reduction in water soluble anions in post-drainage soil samples (Fig. 5a and 5b), was due to the SSD system, which helped in leaching of water soluble anions along with leachate. Thus indicating the positive effect of SSD in removal of salts throughout the profile soil depth. Similar results were reported by Anand, (2003).

Table 5: Effect of SSD on water soluble anions (meq 100 g^{-1}) content of 1:5 soil: water extract recorded in soil samples collected from different sampling point.

Soil depth (cm)	Cl^-			SO_4^{2-}			HCO_3^-		
	(a) Pre-drainage								
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
0-30	55.86	65.76	61.98	18.39	25.49	21.66	2.53	3.12	2.85
30-60	52.79	61.98	58.45	21.23	29.13	25.02	2.46	3.03	2.77
60-90	48.28	56.86	53.71	25.48	34.96	30.12	2.34	2.88	2.64
90-120	37.14	45.76	42.14	29.76	37.86	32.81	2.13	2.62	2.40
(b) Post-drainage									
0-30	19.95	23.49	22.14	10.82	14.99	12.74	1.27	1.56	1.43
30-60	26.40	31.04	29.26	15.61	21.42	18.40	1.36	1.68	1.54
60-90	28.13	35.54	32.57	19.60	26.89	23.17	1.32	1.63	1.49
90-120	30.95	38.13	35.12	24.80	31.55	27.34	1.55	1.72	1.62

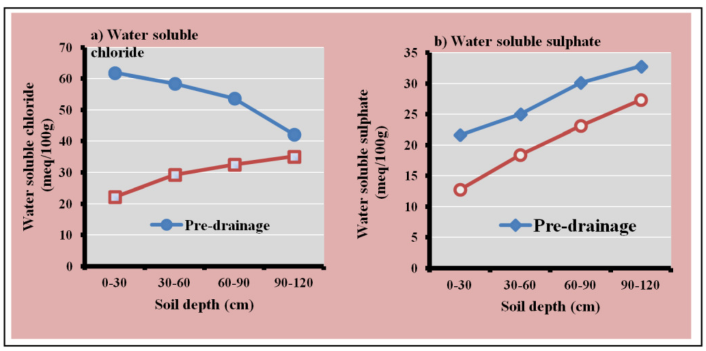

Fig. 5. Influence of SSD on water soluble chloride and sulphate anions observed at different soil depths.

The comparative analyses of water soluble anions of pre and post-drainage soil samples using paired t test is given in Table 6. From the table it is clear that SSD had impacted significant changes in the water soluble concentration of anions throughout the profile depth.

The distribution of surface soil water soluble Cl^- and SO_4^{2-} in the entire study area before and after SSD is depicted in the map (Fig. 6).

Table 6: Comparison of water soluble anions of pre-drainage and post-drainage soil samples using paired t-test.

Soil depth (cm)	Water soluble anions					
	Cl^-		SO_4^{2-}		HCO_3^-	
	t_{cal}	t_{cri}	t_{cal}	t_{cri}	t_{cal}	t_{cri}
0-30	54.59*	1.86*	38.18*	1.86*	39.15*	1.86*
30-60	49.84*		33.10*		32.08*	
60-90	40.08*		33.57*		25.05*	
90-120	37.52*		28.47*		15.09*	

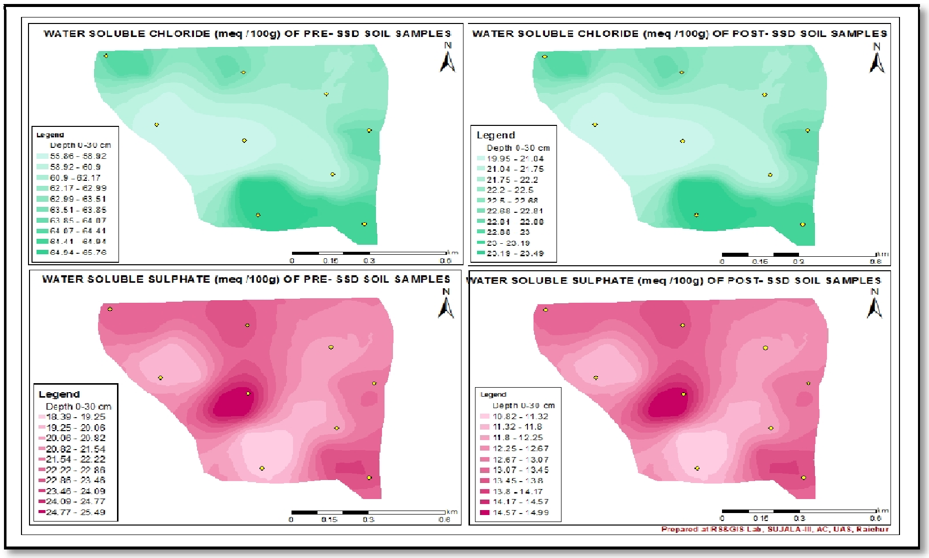

Fig. 6. Map showing variation in water soluble chloride and sulphate anions of pre and post-drainage soil samples of study area produced by Krigging.

FUTURE SCOPE

As subsurface drainage system leaches out excess water soluble salts from the soil, there is also apprehension about the significant loss of nutrients if we keep the SSD in operation for a long time.

Therefore, future research should focus on:

1. Long term impact of SSD on nutrient losses from soils
2. Feasibility study of controlled SSD system to sustain the efficient management of salt affected soils over a period of time

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Conflict of Interest. None.

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