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# Effect of subsurface drainage on physico-chemical properties of saline vertisol under TBP command

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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 bulk density (BD) and maximum water holding (MWHC) capacity of pre-drainage soil samples was ranged from 1.20 to 1.67 Mg $m^{-3}$ and 39.91 to 51.62 percent respectively and BD was reduced in post-drainage soil samples i.e., 1.22 to 1.63 Mg $m^{-3}$ while there is a increase in MWHC of post-drainage soil samples i.e., 41.68 to 51.92 percent. Similarly the mean values of pH, Ec, TSS and ESP of pre-drainage soil samples was 7.80 to 8.48, 15.70 to 26.00 dS $m^{-1}$, 3.82 to 6.32 and 9.49 to 24.14 percent respectively, while it was in reduced in post-drainage soil samples i.e., 7.52 to 8.40, 9.46 to 20.16 dS $m^{-1}$, 2.30 to 4.90 and 8.39 to 19.27 percent for pH, Ec, TSS, and ESP respectively. The mean values of exchangeable cations i.e., Ca+Mg, Na and K of pre-drainage soil samples was 35.20 to 46.97 meq 100 $g^{-1}$, 4.74 to 12.46 meq 100 $g^{-1}$ and 0.46 to 0.66 meq 100 $g^{-1}$ respectively and it was reduced in post-drainage soil samples i.e., 30.48 to 42.70 meq 100 $g^{-1}$, 3.48 to 8.49 meq 100 $g^{-1}$, 0.48 to 0.74 meq 100 $g^{-1}$ for Ca+Mg, Na and K respectively.

**Keywords:** Subsurface drainage, physico-chemical, saline vertisol, TBP command

## 1. Introduction
Crop productivity in India is hampered not just by drought, but also by the indiscriminate use of existing irrigation water. Irrigation in key areas of arid and semi-arid countries has often resulted in an increase in the water table, resulting in waterlogging and salinization. Soil salinity and waterlogging have spread around the world, affecting millions of hectares of arable land in over a hundred countries and posing a threat to long-term agricultural productivity. Saline soils covered 2.95 million hectares in India. Out of which Karnataka has 1893 acres of salty soils, accounting for 0.06 percent of the country's total (Sharma *et al.*, 2015) [12]. Reclamation of these soils was necessary to increase food grain production at the national level in order to feed the country's rapidly rising population. 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.

### 1.1 Objective
To assess the effect of subsurface drainage on physico-chemical properties of saline vertisol

## 2. Materials and Methods
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 27.4 ºC. Summer season is very hot with temperatures rising to 42 ºC 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 percent of the average annual rainfall.

### 2.1 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 physico-chemical analysis. The physical analysis included estimating bulk density and maximum water holding capacity and chemical analysis included estimating pH, Ec, total soluble salts, exchangeable Ca+ Mg, Na, K and ESP. 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.

### 2.2 Soil physical properties
#### 2.2.1 Bulk density
Bulk density of soil was determined by core method as described by Black (1965) [2] and expressed in Mg $m^{-3}$.

#### 2.2.2 Water holding capacity (WHC)
The water holding capacity of soil was determined by Keen's cup method as described by Piper (1966) [9] and expressed in percent.

### 2.3 Soil chemical properties
#### 2.3.1 Soil reaction (pH)
Soil pH was determined in 1:2.5 soil: water suspension using digital pH meter (Systronics make, Model No. 802) having glass electrode as described by Jackson (1973) [4].

#### 2.3.2 Electrical conductivity (EC)
Electrical conductivity was measured in 1:2.5 soil: water suspension as described by Jackson (1973) [4] using digital conductivity meter 304 and expressed as dS $m^{-1}$ at 25 °C.

#### 2.3.3 Total soluble salts (%)
The total soluble salts in saturation extract of soil samples is estimated by using the below formula:

$$\text{TSS}(\%) = \text{ECe} \times \frac{640}{10000}$$

Where
ECe is in dS $m^{-1}$

### 2.4 Exchangeable cations
After the extraction of water soluble cations, the left over soil sample was further used for the extraction of exchangeable cations. The neutral *N* ammonium acetate was used as an extract ant at 1:5 soil to solution ratio.

#### 2.4.1 Exchangeable calcium and magnesium
The concentrations of Ca and Mg in the extract were determined by EDTA titration method as outlined by Jackson (1973).

#### 2.4.2 Exchangeable potassium and sodium
The concentrations of K and Na in the extract were determined by using a flame photometer, Systronics -128 as outlined by Jackson (1973) [4].

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

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

## 3. Result and Discussion
### 3.1 Impact of subsurface drainage (SSD) on soil physical characteristics
#### 3.1.1 Bulk density (Mg $m^{-3}$) and Maximum water holding capacity (%)
The analysis results pertaining to Bulk density (BD) and Maximum water holding capacity (MWHC) of pre and post drainage soil samples are presented in Table 1. In general, among the pre-drainage soil samples the BD values ranged from 1.20 to 1.67 Mg $m^{-3}$ while MWHC values ranged from 39.91 to 51.62 percent irrespective of soil depths. The results revealed that the mean values for BD of pre-drainage soil samples drawn from 0-30, 30-60, 60-90 and 90-120 cm soil depth are 1.31, 1.37, 1.43 and 1.49 Mg $m^{-3}$ respectively showing a slight increase in soil BD values with soil depth while the mean values of MWHC 42.46, 44.15, 46.24 and 47.64 percent respectively showing a slight increasing trend with the soil depth (Table 1a).
On the other hand, in the case of post SSD soil samples, in general the BD values ranged from 1.22 to 1.63 Mg $m^{-3}$ while MWHC values ranged from 41.68 to 51.92 percent irrespective of soil depths. While mean results indicated comparatively less mean values of BD (Mg $m^{-3}$) and more MWHC (%) in all the respective soil depths *i.e*., 1.28, 1.33, 1.39, 1.45 and 44.17, 45.80, 47.25 and 48.03 for 0-30, 30-60, 60-90 and 90-120 cm respectively when compared to pre-drainage condition (Table 1b). The estimations of bulk density (BD) of various soil samples have indicated that SSD had impacted in lowering the soil bulk density significantly in surface soil depths only. In the case of sub surface soil depths, there was also lowering of BD due to SSD but it was non-significant. The lower value of BD of soil in post-drainage soils samples may be attributed to the removal of salts in a greater extent from surface depths. Similarly, Bharambe *et al*. (2001) [1] have reported lower values of BD in SSD installed plots and higher BD values in control plots.
The SSD positively impacted the maximum water holding capacity (MWHC) of surface soil samples significantly while sub surface soil sample non-significantly. Moreover, the water holding capacity of soil samples taken at lower depth are generally higher than the surface soils. This may be attributed to higher clay content, soil texture, porosity *etc*., Similar observations were also reported by Challa and Gaikwad (1987) [3].
The comparative analyses of BD and MWHC of pre and post-drainage soil samples using paired t test is given in Table 2. The $t_{cal}$ values for BD and MWHC are 2.48, 1.82, 1.84, 1.42 and -2.14, -1.23, -0.91 and -0.43 respectively for the soil depths *viz*., 0-30, 30-60, 60-90 and 90-120 cm. It is clear that significant changes are happened only in surface soil depths, *i.e*., a decrease in soil BD and an increase in MWHC owing to

the impact of SSD.

**Table 1:** Effect of SSD on bulk density (Mg $m^{-3}$) and maximum water holding capacity (%) recorded in soil samples collected from different sampling points

| Soil depth (cm) | BD | | | MHWC | | |
|---|---|---|---|---|---|---|
| | a) Pre-drainage | | | | | |
| | Min. | Max. | Mean | Min. | Max. | Mean |
| | | | | | | |
| 0-30 | 1.20 | 1.42 | 1.31 | 39.91 | 44.53 | 42.46 |
| 30-60 | 1.28 | 1.50 | 1.37 | 40.33 | 47.30 | 44.15 |
| 60-90 | 1.30 | 1.54 | 1.43 | 42.98 | 49.37 | 46.24 |
| 90-120 | 1.36 | 1.67 | 1.49 | 43.89 | 51.62 | 47.64 |
| b) Post-drainage | | | | | | |
| 0-30 | 1.22 | 1.32 | 1.28 | 41.94 | 46.91 | 44.17 |
| 30-60 | 1.25 | 1.48 | 1.33 | 41.68 | 48.63 | 45.80 |
| 60-90 | 1.29 | 1.52 | 1.39 | 43.89 | 50.31 | 47.25 |
| 90-120 | 1.36 | 1.63 | 1.45 | 44.03 | 51.92 | 48.03 |

**Tables 2:** Comparison of bulk density and maximum water holding capacity of pre-drainage and post-drainage soil samples using paired t-test

| Soil depth (cm) | BD | | MHWC | |
|---|---|---|---|---|
| | $t_{cal}$ | $t_{cri}$ | $t_{cal}$ | $t_{cri}$ |
| 0-30 | 2.48* | 1.86* | -2.14* | 1.86* |
| 30-60 | 1.82 | | -1.23 | |
| 60-90 | 1.84 | | -0.91 | |
| 90-120 | 1.42 | | -0.43 | |

### 3.2 Impact of subsurface drainage (SSD) on soil chemical characteristics

#### 3.2.1 pH and EC

The analysis results pertaining to pH and EC of pre and post drainage soil samples are presented in Table 3. In general, among the pre-drainage soil samples the pH values ranged from 7.80 to 8.48 while EC values ranged from 15.70 to 26.00 dS $m^{-1}$ irrespective of soil depths. The mean values for pH of pre-drainage soil samples were 8.12, 8.29, 8.32, 8.38 while the mean EC was 21.64, 20.62, 19.22, 17.90 dS $m^{-1}$for soil depths *viz*., 0-30, 30-60, 60-90 and 90-120 cm respectively (Table 3a). Thus, showing a trend of slight increase in soil pH and a slight decrease in soil EC with the increase in soil depth.

On the other hand, in the case of post SSD soil samples, in general the pH values ranged from 7.52 to 8.40 while EC values ranged from 9.46 to 20.16 dS $m^{-1}$ irrespective of soil depths. Moreover, there were moderate changes in post-drainage results. The mean pH values comparatively increased with the soil depths *i.e*., 7.87, 8.20, 8.27 and 8.31 while there was a quite noticeable decrease in soil EC *i.e*., 13.31, 15.89, 17.43 and 18.20 dS $m^{-1}$for 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively (Table 3b).

The analysis results of post-drainage soil samples have indicated a significant reduction in soil pH values when compared to the pre-drainage soil samples (Fig. 1). The impact is quite significant in surface soil depths and narrows down with increase in the soil depth. The observed reduction in soil pH values owing to post SSD could be attributed to the leaching of soluble sodium and bicarbonates. Similar observations were also have been reported by Shrikanta (2015) [13]. While the analysis results of post-drainage soil samples have indicated a significant reduction in soil EC values when compared to the pre-drainage soil samples (Fig. 1b). In post-drainage soil samples the soil EC reduced with the soil depth up to 90 cm but there after there was a quite higher soil EC in post SSD soil samples when compared to pre-SSD. This observation can be attributed to leaching of salts from the upper layers and their accumulation in the lower depth of 90-120 cm. Similar results were also reported by Patil *et al*. (2016) [8].

The distribution of surface soil pH and EC in the entire study area before and after SSD is depicted in the map (Fig. 2).

The paired t-test (Table 4) revealed that SSD had significantly impacted and decreased the soil pH in all the depths while the decrease in soil EC was significant in all the depths with the exception of 90-120 cm which had comparatively higher EC than the pre SSD but the increase was non-significant (Table 3a & 3b).

**Table 3:** Effect of SSD on pH and EC (dS $m^{-1}$) recorded in soil samples collected from different sampling points

| Soil depth (cm) | pH (1:2.5) | | | EC (1:2.5) | | |
|---|---|---|---|---|---|---|
| | a) Pre-drainage | | | | | |
| | Min. | Max. | Mean | Min. | Max. | Mean |
| **0-30** | 7.80 | 8.25 | 8.12 | 19.86 | 26.00 | 21.64 |
| 30-60 | 8.21 | 8.35 | 8.29 | 18.56 | 23.40 | 20.62 |
| 60-90 | 8.27 | 8.39 | 8.32 | 17.68 | 21.60 | 19.22 |
| 90-120 | 8.31 | 8.48 | 8.38 | 15.70 | 19.87 | 17.90 |
| b) Post- drainage | | | | | | |
| 0-30 | 7.52 | 8.12 | 7.87 | 9.46 | 15.25 | 13.31 |
| 30-60 | 8.14 | 8.26 | 8.20 | 14.89 | 17.55 | 15.89 |
| 60-90 | 8.20 | 8.34 | 8.27 | 15.23 | 19.60 | 17.43 |
| 90-120 | 8.24 | 8.40 | 8.31 | 17.00 | 20.16 | 18.20 |

**Table 4:** Comparison of pH and EC of pre-drainage and post-drainage soil samples using paired t-test

| Soil depth (cm) | pH | | EC | |
|---|---|---|---|---|
| | $t_{cal}$ | $t_{cri}$ | $t_{cal}$ | $t_{cri}$ |
| 0-30 | 5.51* | 1.86* | 12.87* | 1.86* |
| 30-60 | 3.36* | | 8.31* | |
| 60-90 | 3.30* | | 6.23* | |
| 90-120 | 2.80* | | -0.39 | |

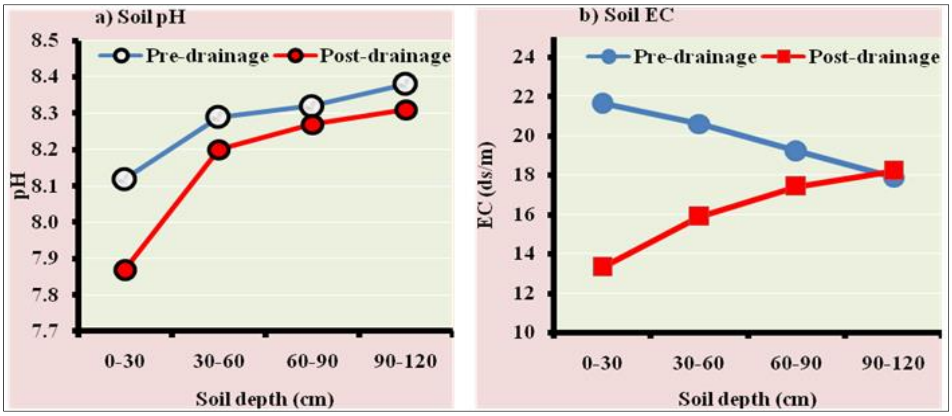


**Fig 1:** Influence of SSD on soil pH and EC observed at different soil depths

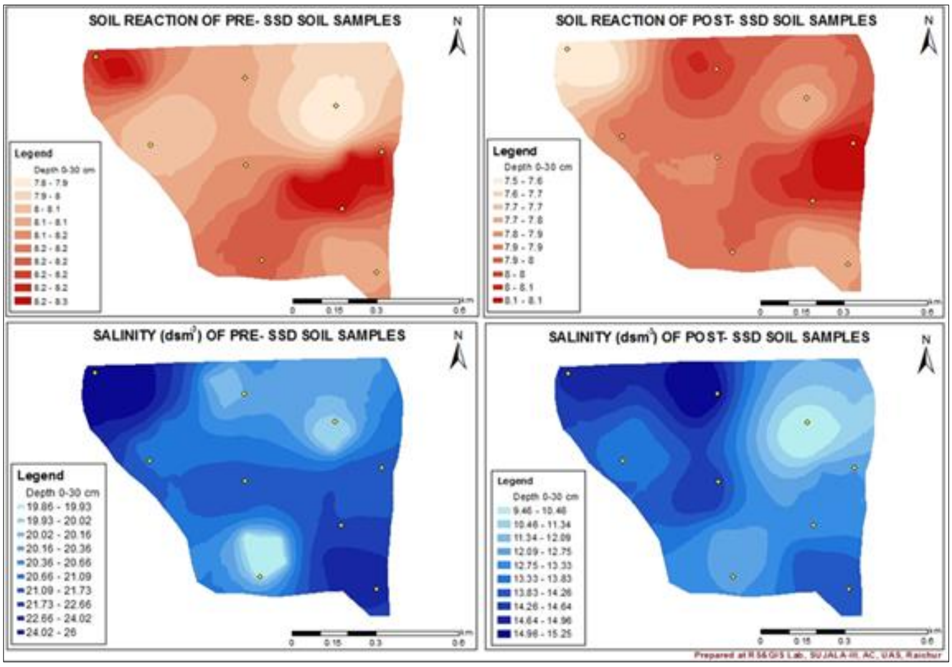


**Fig 2:** Map showing variation in pH and EC of pre and post-drainage soil samples of study area produced by Krigging

### 3.3 Total soluble salts percent (TSS)

The analyses results pertaining to TSS (%) of pre and post drainage soil samples are presented in Table 5. In general, among the pre-drainage soil samples the TSS (%) values ranged from 3.82 to 6.32 irrespective of soil depths. The results revealed that the mean values for TSS of pre-drainage soil samples drawn from 0-30, 30-60, 60-90 and 90-120 cm soil depths were 5.26, 5.02, 4.67 and 4.35 percent respectively, showing a slight decrease with the soil depth (Table 5a).

On the other hand, in the case of post SSD soil samples, in general the TSS (%) values ranged from 2.30 to 4.90 irrespective of soil depths. While the analyses of soil samples from post SSD work have indicated a decrease in mean values of TSS (%) in all soil depths, except in 90-120 cm *i.e.*, 3.24, 3.86, 4.24, 4.43 for 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively (Table 5b).

The SSD positively impacted by reducing the total soluble salts of post-drainage soil samples in all the depths than TSS of corresponding depths of pre-drainage soil samples with the exception of 90-120 cm soil depth wherein salts got accumulated more when compared to pre-drainage soil samples. The reduction in TSS of post-drainage soil samples is due to the leaching and accumulation of salts in lower depths.

The comparative analysis of TSS (%) content of pre and post-drainage soil samples using paired t-test (Table 6) revealed that that SSD had significantly impacted and decrease in soil TSS was significant in all the depths with the exception of 90-120 cm which had comparatively higher TSS than the pre SSD but the increase was non-significant (Table 6a & 6b).

**Table 5:** Effect of SSD on total soluble salts (%) recorded in soil samples collected from different sampling points

| Soil depth (cm) | TSS | | |
|---|---|---|---|
| | a) Pre-drainage | | |
| | Min. | Max. | Mean |
| 0-30 | 4.83 | 6.32 | 5.26 |
| 30-60 | 4.51 | 5.69 | 5.02 |
| 60-90 | 4.30 | 5.25 | 4.67 |
| 90-120 | 3.82 | 4.83 | 4.35 |
| b) Post-drainage | | | |
| 0-30 | 2.30 | 3.71 | 3.24 |
| 30-60 | 3.62 | 4.27 | 3.86 |
| 60-90 | 3.70 | 4.77 | 4.24 |
| 90-120 | 4.13 | 4.90 | 4.43 |

**Table 6:** Comparison of TSS of pre-drainage and post-drainage soil samples using paired t-test

| Soil depth (cm) | TSS | |
|---|---|---|
| | $t_{cal}$ | $t_{cri}$ |
| 0-30 | 12.87* | 1.86* |
| 30-60 | 8.31* | |
| 60-90 | 6.23* | |
| 90-120 | -0.39 | |

### 3.4 Exchangeable cations

The concentration of exchangeable cations in the pre-drainage soil samples of study area followed the order of Ca+Mg >Na >K. The analysis data on exchangeable Ca+Mg, Na and K content of pre and post drainage soil samples are presented in Table 7. In general, among the pre-drainage soil samples the exchangeable Ca+Mg values ranged from 35.20 to 46.97 meq 100 $g^{-1}$, the Na values ranged from 4.74 to 12.46 meq 100 $g^{-1}$, while K values ranged from 0.46 to 0.66 meq 100 $g^{-1}$ irrespective of soil depths. The results revealed that the mean values for exchangeable cations of pre-drainage soil samples were 42.32, 41.04, 39.45, 41.95 meq 100 $g^{-1}$ for Ca +Mg, 10.68, 7.58, 6.03, 6.13 meq 100 $g^{-1}$ for Na and 0.60, 0.54, 0.56, 0.51 meq 100 $g^{-1}$ for K in soil samples drawn from 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively. Thus, showing a trend of slight decrease in exchangeable Na with increase in soil depth while, there was no clear trend in the case of Ca+Mg and K (Table 7a).

On the other hand, in the case of post SSD soil samples, in general the exchangeable Ca+Mg values ranged from 30.48 to 42.70 meq 100 $g^{-1}$, the Na values ranged from 3.48 to 8.49 meq 100 $g^{-1}$, while K values ranged from 0.48 to 0.74 meq 100 $g^{-1}$ irrespective of soil depths. The comparison of mean values of pre and post SSD soil samples revealed that post SSD soils retained lesser concentration of exchangeable Ca+Mg and Na in all the soil depths *i.e*., 34.91, 35.70, 37.22, 38.47 meq 100 $g^{-1}$ and 4.74, 5.18, 5.67, 6.09 meq 100 $g^{-1}$ and there was a moderate change in mean values of exchangeable K *i.e.*, 0.68, 0.56, 0.58 and 0.54 meq 100 $g^{-1}$ in 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively (Table 7b).

The exchangeable Ca +Mg and Na content were more during pre-drainage conditions whereas SSD has positively impacted in reducing the exchangeable cations in post-drainage soil samples (Fig. 3 and 4). This reduction in soil exchangeable cations could be attributed to the leaching effect and draining of water from the field. On the other hand, the results of mean exchangeable potassium ($K^+$) values revealed that there was a slight increase in the potassium content in the post-drainage soil samples when compared to pre-drainage soil samples. This might be due to application of potassic fertilizers to the field by farmers during paddy cultivation. This observation is in conformity with the findings of Pradeepa (2017) [11].

The distribution of surface soil exchangeable Ca+Mg and Na in the entire study area before and after SSD is depicted in the map (Fig. 4).

The comparative analysis of exchangeable Ca+Mg, Na and K content of pre and post-drainage soil samples using paired t test is presented in Table 8. The results revealed that there was significant difference between the values of soil exchangeable Ca+Mg, Na and K of soil samples drawn at different depths. Among the cations studied, Ca+Mg significantly varied in all the four soil depths, Na in first three soil depths but is non-significant at 90-120 cm soil depth, while K values indicated significant differences in all the soil depths with comparatively higher exchangeable K values in post-drainage soils than the pre-drainage, a sign of soil improvement.

**Table 7:** Effect of SSD on exchangeable cations (meq 100 $g^{-1}$) recorded in soil samples collected from different sampling points

| Soil depth (cm) | Ca+Mg | | | Na | | | K | | |
|---|---|---|---|---|---|---|---|---|---|
| | **a) Pre-drainage** | | | | | | | | |
| | Min | Max. | Men | Min. | Max. | Mean | Min. | Max. | Mean |
| 0-30 | 38.57 | 46.97 | 42.32 | 8.96 | 12.46 | 10.68 | 0.53 | 0.66 | 0.60 |
| 30-60 | 36.15 | 45.18 | 41.04 | 6.20 | 9.28 | 7.58 | 0.49 | 0.61 | 0.54 |
| 60-90 | 35.20 | 43.84 | 39.45 | 4.98 | 7.47 | 6.03 | 0.50 | 0.61 | 0.56 |
| 90-120 | 38.57 | 45.18 | 41.95 | 4.74 | 7.97 | 6.13 | 0.46 | 0.56 | 0.51 |
| **b) Post-drainage** | | | | | | | | | |
| 0-30 | 30.48 | 39.14 | 34.91 | 3.48 | 6.48 | 4.74 | 0.59 | 0.74 | 0.68 |
| 30-60 | 32.41 | 39.47 | 35.70 | 4.13 | 7.32 | 5.18 | 0.49 | 0.66 | 0.56 |
| 60-90 | 33.75 | 42.70 | 37.22 | 4.65 | 7.99 | 5.67 | 0.53 | 0.64 | 0.58 |
| 90-120 | 35.06 | 42.70 | 38.47 | 5.01 | 8.49 | 6.09 | 0.48 | 0.60 | 0.54 |

**Table 8:** Comparison of exchangeable cations of pre-drainage and post-drainage soil samples using paired t-test

| Soil depth (cm) | Exchangeable cations | | | | | |
|---|---|---|---|---|---|---|
| | Ca+Mg | | Na | | K | |
| | $t_{cal}$ | $t_{cri}$ | $t_{cal}$ | $t_{cri}$ | $t_{cal}$ | $t_{cri}$ |
| 0-30 | 28.70* | 1.86* | 45.58* | 1.86* | -12.81* | 1.86* |
| 30-60 | 17.39* | | 22.02* | | -2.58* | |
| 60-90 | 4.89* | | 3.10* | | -4.10* | |
| 90-120 | 10.99* | | 0.15 | | -3.28* | |

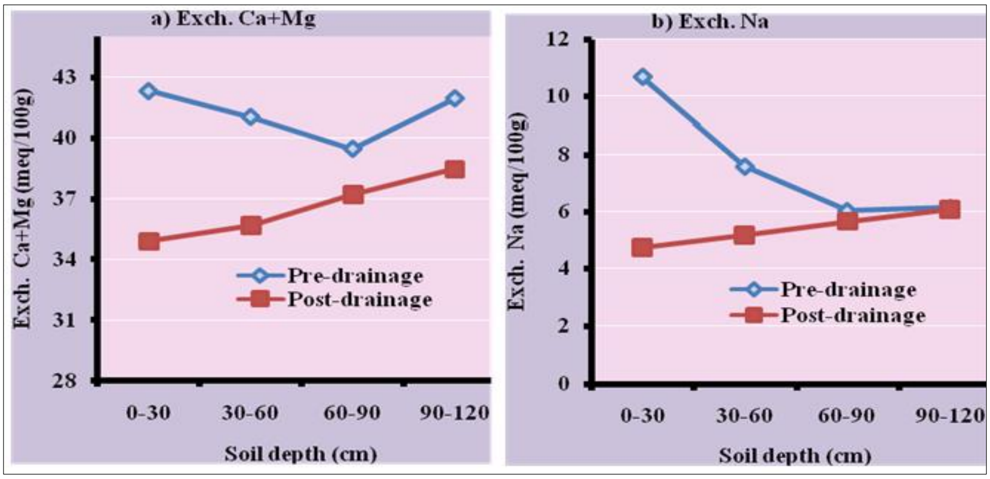


**Fig 3:** Influence of SSD on exchangeable Ca+Mg and Na cations observed at different soil depths

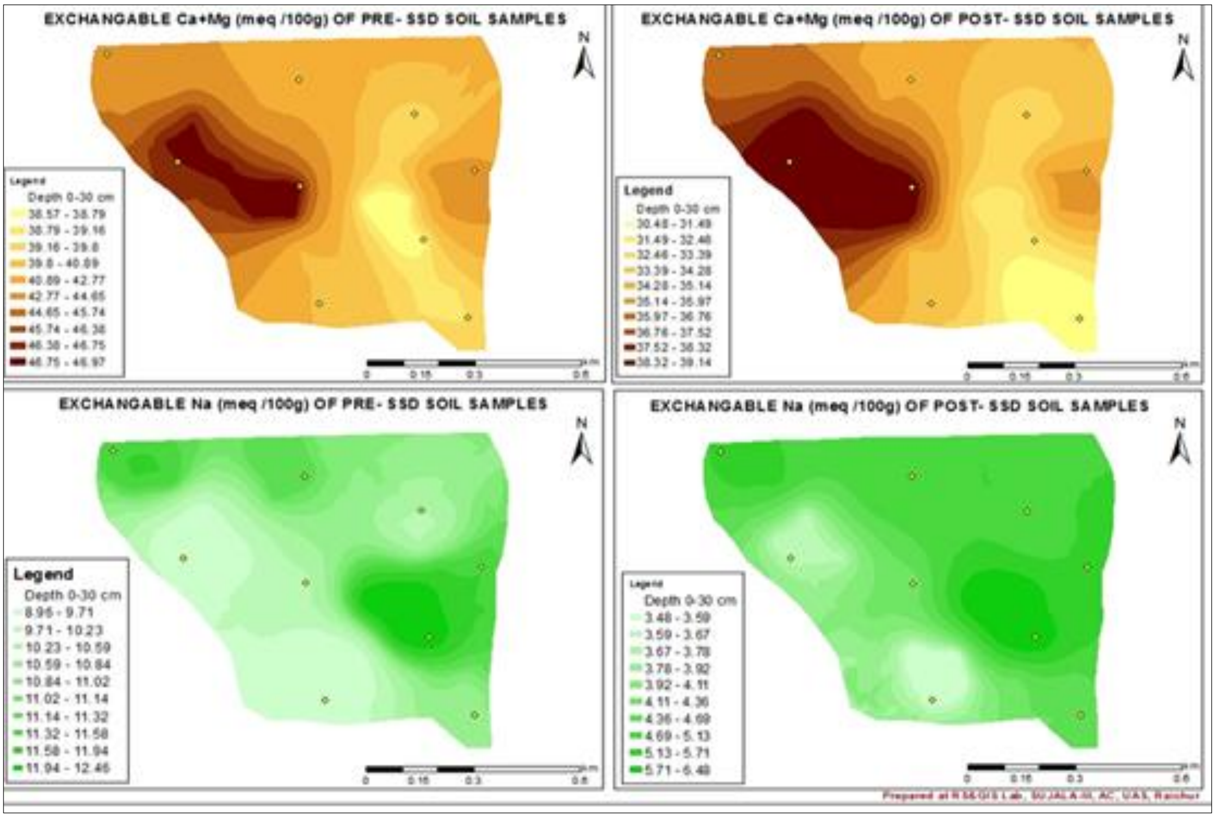


**Fig 4:** Map showing variation in exchangeable Ca+Mg and Na cations of pre and post-drainage soil samples of study area produced by Krigging

### 3.5 Exchangeable sodium percentage

The analysis results pertaining to exchangeable sodium percentage (ESP) of pre and post-drainage soil samples are presented in Table 9. In general, among the pre-drainage soil samples the ESP values ranged from 9.49 to 24.14 percent irrespective of soil depths. The mean values ESP were 19.98, 15.46, 13.13 and 12.63 percent respectively for 0-30, 30-60, 60-90 and 90-120 cm soil depths (Table 9a). Thus, ESP of soil samples showing a slight decrease with the soil depth in pre-drainage soils. Thus in the case of pre-drainage the ESP of soil decreased with soil depth.

On the other hand, in the case of post SSD soil samples, in general the ESP values ranged from 8.39 to 19.27 percent irrespective of soil depths. The results indicated a noticeable decrease in soil ESP with increasing in soil depth when compared to the pre SSD soil samples *i.e.*, 11.80, 12.53, 13.06 and 13.53 percent for 0-30, 30-60, 60-90 and 90-120 cm soil depth respectively (Table 9b.). The result indicated a noticeable percentage impact of SSD on ESP of soil sample from 0-30 and 30-60 cm depths, while the impact was marginal at 60-90 cm soil depth and negative at 90-120 cm depth.

The analysis results of post-drainage soil samples have recorded lower ESP than the pre-drainage soil samples in all the soil depths with the exception of 90-120 cm soil depth (Fig. 5). The reduction in ESP was due to the SSD system, which helped in leaching of sodium and removal of salts along with leachate. After the provision of SSDs, the salts from the upper layers pushed downwards by leaching to deeper layers and to the lateral drain so accumulation of sodium might have taken place in 90-120 cm soil depth. It should be noted that this observation is only after first paddy crop following the installation of SSD. In subsequent years there may be complete removal of salts with little chance for accumulation. These results were in agreement with the findings of Pradeep *et al.* (2005) [10] and Kamble *et al.* (2006) [5].

The distribution of surface soil ESP in the entire study area before and after SSD is depicted in the map (Fig. 6).

The paired t-test (Table 10) revealed that SSD had significantly impacted and the ESP was significantly decreased in all the depths with the exception of 60-90 and 90-120 cm which had comparatively higher ESP than the pre SSD but the increase was non-significant.

**Table 9:** Effect of SSD on ESP recorded in soil samples collected from different sampling points

| Soil depth (cm) | ESP | | |
|---|---|---|---|
| | a) Pre-drainage | | |
| | Min. | Max. | Mean |
| 0-30 | 16.35 | 24.14 | 19.98 |
| 30-60 | 11.98 | 20.19 | 15.46 |
| 60-90 | 10.10 | 17.30 | 13.13 |
| 90-120 | 9.49 | 16.95 | 12.63 |
| b) Post-drainage | | | |
| 0-30 | 8.39 | 16.50 | 11.80 |
| 30-60 | 9.41 | 18.16 | 12.53 |
| 60-90 | 10.05 | 18.67 | 13.06 |
| 90-120 | 10.70 | 19.27 | 13.53 |

**Table 10:** Comparison of ESP of pre-drainage and post-drainage soil samples using paired t-test

| Soil depth (cm) | ESP | |
|---|---|---|
| | $t_{cal}$ | $t_{cri}$ |
| 0-30 | 54.14* | 1.86* |
| 30-60 | 19.80* | |
| 60-90 | 0.29 | |
| 90-120 | -1.80 | |

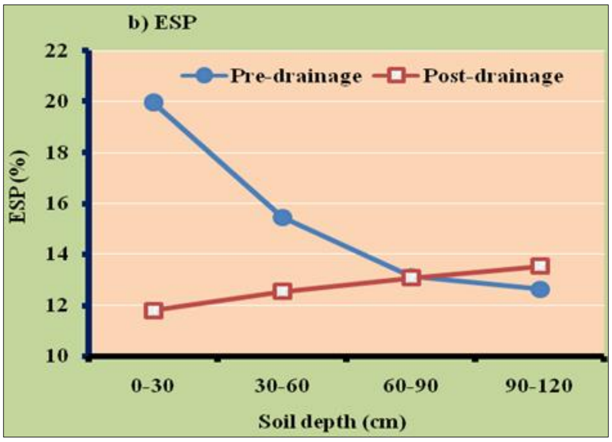


**Fig 5:** Influence of SSD on soil SAR and ESP observed at different soil depth

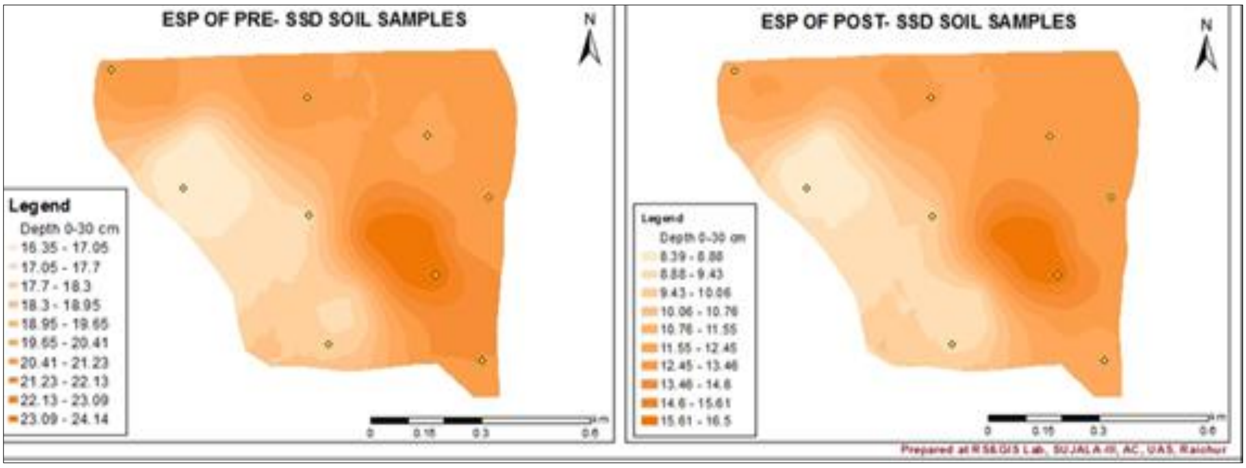


**Fig 6:** Map showing variation in SAR and ESP of pre and post-drainage soil samples of study area produced by Krigging

## 4. Conclusion

There is a moderate change in the soil properties of post-SSD soils. The soil bulk density of post-drainage soil samples was less than that of pre-drainage soil samples while the maximum water holding capacity of post-drainage soil samples were comparatively more than that of pre-drainage soil samples. However, the impact was more in surface soil depths when compared to the below depths. The soil pH and electrical conductivity of post-drainage soil samples were reduced significantly when compared to pre-drainage soil samples in all respective corresponding soil depths. The provision of SSD positively impacted soil properties such as sodium adsorption ratio and TSS of post-drainage soil samples in all the depths by leaching of water soluble salts as well as exchangeable sodium.

## 5. Competing interests

Authors have declared that no competing interests exist.

## 6. References

1. Bharambe PR, Shelke DK, Jadhava G, Vaishnava VG, Oza SR. Management of salt affected vertisols with subsurface drainage and crop residue in corporation under soyabean-wheat cropping system. J Indian Soc. Soil Sci. 2001;46(1):24-29.
2. Black CA. Methods of soil analysis, Part 1. American Soc. Agron., Madison, Wisconsin, USA 770. 1965.
3. Challa O, Gaikwad MS. Water relation characteristics of major soils of Dadra and Nagar Havali. J Indian Soc. Soil Sci. 1987;35:118-120.
4. Jackson ML. Soil Chemical Analysis. Prentice Hall of India. Pvt. Ltd., New Delhi; c1973.
5. Kamble BM, Chougule BA, Rathod, SD, Rathod PK. Improvement of salt affected-water logged soils in western Maharashtra through subsurface drainage (SSDs) system. Asian J Bio. Sci. 2006;1(2):64-67.
6. Kumar A, Kushwaha KK, Singh S, Shivay YS, Meena MC, Nain L. Effect of paddy straw burning on soil microbial dynamics in sandy loam soil of Indo-Gangetic Plains. Environ. Technol. Innov. 2019;16:100469.
7. Liu TX, Ji XE. Effect of crop straw burning on soil organic matter and soil microbes. Soil. (in Chinese with English abstract). 2003;35:347-348
8. Patil R, Balakrishnan P, Satish KU, Srinivasa RGV, Channabasavanna AS, Rajkumar H. Impact of subsurface drainage system on soil chemical properties and crop yield in Upper Krishna Command. Int. J Agric. Sci. 2016;8(51):2202-2205.
9. Piper CS. Soil and Plant Analysis, Hans Publishers, Bombay; c1966. p. 368.
10. Pradeep HM, Hebsur NS, Gali SK, Koti RV. Effect of subsurface drainage and amendments on soil physical and chemical properties of black soils of Ghataprabha command area. Karnataka J Agric. Sci. 2005;18(3):953-958.
11. Pradeepa CM. Performance evaluation and modelling studies of existing subsurface drainage systems in Upper Krishna project command area, Karnataka. M. Sc. Thesis.

Univ. Agric. Sci. Raichur (India); c2017.
12. Sharma DK, Thimmappa K, Chinchmalatpure R, Anil, Mandal AK, Yadav RK, *et al*. Assessment of production and monetary losses from salt-affected soils in India. Technical Bulletin (05), ICARCSSRI, Karnal; c2015.
13. Shrikanta G. Performance evaluation of subsurface drainage system in mallapur village of Tungabhadra command area. M. Sc. Thesis, Univ. Agric. Sci. Raichur (India); c2015.