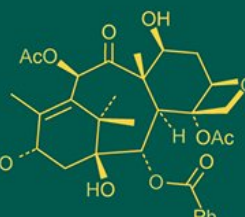


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Correlation study on salt affected soils of Siruguppa and Hospet Taluks in Tungabhadra project irrigation command area, Karnataka

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Abstract

The present investigation aimed to assess the Pearson correlation coefficients between soil properties and derived salinity parameters in soils collected from Siruguppa and Hospet Taluks of the Tungabhadra Project (TBP) irrigation command area. In Siruguppa Taluk, soil pHe showed no significant correlation with ECe, SAR, or other derived parameters at either the 0-15 or 15-30 cm soil depths. ECe exhibited a significant positive correlation with $\text{Na}^+(\text{Cl}^- + \text{SO}_4^{2-})$ and a significant negative correlation with $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$ at both depths, whereas its correlation with SAR was significantly negative only at 0-15 cm depth. SAR showed a significant positive correlation with $\text{Na}^+(\text{Cl}^- + \text{SO}_4^{2-})$ and a significant negative correlation with $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$ at both depths.

In Hospet Taluk, soil pHe exhibited significant positive correlations with ECe, SAR, and $\text{Na}^+(\text{Cl}^- + \text{SO}_4^{2-})$ at both 0-15 and 15-30 cm depths, while its correlation with $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$ was significantly negative only at 15-30 cm depth. ECe showed significant positive correlations with SAR and significant negative correlations with $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$ at both depths. SAR was significantly positively correlated with $\text{Na}^+(\text{Cl}^- + \text{SO}_4^{2-})$ at both depths and significantly negatively correlated with $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$ at 0-15 cm depth. Furthermore, $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$ showed a significant negative correlation with $\text{Na}^+(\text{Cl}^- + \text{SO}_4^{2-})$ at 0-15 cm depth. Overall, the correlation analysis demonstrated depth- and location-dependent relationships among soil pHe, ECe, SAR, and the derived ionic ratios, providing insights into the salinity and sodicity characteristics of soils in the TBP irrigation command.

Keywords: Pearson correlation coefficient; salt-affected soils; soil salinity; sodium adsorption ratio; saturation paste extract

1. Introduction

Soil salinity is a major environmental constraint affecting soil quality, agricultural productivity, and sustainable crop production, particularly in regions influenced by irrigation and natural salinization. The accumulation of soluble salts in soil can alter its physical, chemical, and biological properties, thereby adversely affecting plant growth and crop yield (Szaboles, 1989) [7]. Soil salinity and waterlogging are two major constraints in the Tungabhadra Project (TBP) command area, which have developed over the decades due to inappropriate land and water management practices and deviations from the recommended cropping pattern. Approximately 96,215 ha, accounting for about 26.5% of the total command area of 3.63 lakh ha, has been reported to be salt affected (Anonymous, 2012) [1], with an estimated additional 1,000 ha becoming salt affected annually (IDNP, 2002).

Understanding the relationships among soil properties and salinity-related parameters is essential for evaluating the development and severity of salt-affected conditions. Correlation analysis provides a useful statistical approach for quantifying the strength and direction of associations between soil properties and derived indicators of salinity and sodicity. Important soil parameters associated with salt-affected conditions include pH, electrical conductivity (EC), pH of the soil extract (pHe), electrical conductivity of the saturation extract (ECe), sodium adsorption ratio (SAR), and selected ionic ratios. Among these, ECe is widely used to assess the concentration of soluble salts in soil, while SAR provides an indication of the relative abundance of sodium in relation to calcium and magnesium and is therefore an important indicator of sodicity hazard.

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The ionic composition of the soil solution provides additional information on the nature and relative dominance of soluble ions. The ratios $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$ and $\text{Na}^+/(\text{Cl}^- + \text{SO}_4^{2-})$ can be used to assess the relative contribution of carbonate-bicarbonate and sodium ions in relation to chloride and sulphate. These derived parameters, when interpreted together with ECe, pH, and SAR, can provide a better understanding of the chemical characteristics and potential salinity or sodicity tendencies of soils (Gupta *et al.*, 1989)^[4].

The relationships among these parameters may vary with soil depth and geographic location because of differences in irrigation, drainage, evaporation, soil properties, and salt movement within the soil profile. Therefore, evaluating their correlations can help identify closely associated soil characteristics and improve interpretation of salinity and sodicity indicators. Such information is particularly important in irrigated command areas where prolonged irrigation and inadequate drainage can promote the accumulation and redistribution of soluble salts.

In this context, the present study was undertaken to assess the correlation coefficients between soil properties and selected derived parameters of salinity and sodicity in the soils of Siruguppa and Hospet Taluks of the Tungabhadra Project irrigation command area. The study specifically examined the relationships of pHe, ECe, SAR, and the ionic ratios $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$ and $\text{Na}^+/(\text{Cl}^- + \text{SO}_4^{2-})$ at different soil depths. The findings are expected to improve understanding of the interrelationships among salinity-related soil properties and provide a scientific basis for monitoring, management, and reclamation of salt-affected soils in the TBP command area.

2. Materials and methods

Study Area

The Tungabhadra irrigation command area in Karnataka provides irrigation facilities for agricultural crops in Bellary, Koppal, and parts of Raichur districts. The present study was conducted in Siruguppa and Hospet Taluks, located in Bellary district. Bellary district extends from southwest to northeast and is situated in the eastern part of Karnataka. Geographically, the district lies between 15°30' and 15°50' N latitude and 75°40' and 77°11' E longitude, covering an area of approximately 8,447 km².

Siruguppa Taluk is located at 15°37'30.22" N latitude and 76°53'42.78" E longitude, with an average elevation of 373 m (1,223 ft) and a geographical area of 1,042 km². Hospet Taluk lies at approximately 15°16'00" N latitude and 76°24'00" E longitude, with an average elevation of 479 m (1,572 ft) and a geographical area of 934 km². The major soil types occurring in the study area include medium-deep red gravelly clay soils, deep black clayey soils, deep black calcareous clayey soils, and deep alluvial clayey soils. The average annual rainfall of Hospet and Siruguppa Taluks is 658.3 and 645.0 mm, respectively. The major crops cultivated in these taluks include paddy, sorghum (jowar), maize, cotton, and sugarcane.

Collection and Analysis of Soil Samples

Soil samples were collected during April-May 2017 with the aid of a Global Positioning System (GPS) and topographic sheets at a scale of 1:50,000. Sampling was carried out on a 5' × 5' grid basis, covering 20 grids in Siruguppa Taluk and 15 grids in Hospet Taluk. Soil samples were collected from

agricultural areas within the Tungabhadra Project command area receiving irrigation water from the Left Bank Canal.

Samples were collected using an auger from four soil depths, namely 0-15, 15-30, 30-60, and >60 cm (60+ cm). The collected samples were air-dried under shade, gently powdered using a pestle and mortar, passed through a 2 mm sieve, and stored in clean polythene bags until analysis. The soil samples were analyzed for pHe, electrical conductivity of the saturation extract (ECe), sodium adsorption ratio (SAR), and the cationic and anionic composition of the saturation paste extract. All analyses were carried out using standard analytical procedures described by Richards (1954)^[5].

Statistical Analysis

The correlation coefficients (r) of soil properties with the derived parameters of salinity were worked out by following the procedure outlined by Snedecor and Cochran (1980)^[6].

Karl Pearson correlation coefficient (product moment correlation coefficient)

$$r = \frac{\sum xy - n\bar{x}\bar{y}}{\sqrt{(\sum x^2 - n\bar{x}^2)(\sum y^2 - n\bar{y}^2)}}$$

Where,

- r = correlation coefficient
- x and y are variables
- n = no. of observations in x and y

The 'r' value describes how strongly two variables are related. Two variables are positively linked if the r' value is positive; conversely, if it is negative, two variables are negatively connected.

The significant of correlation coefficient was tested by t test.

If $t_{\text{table}} < t_{\text{calculated}}$ value then 'r' is significant and if $t_{\text{table}} > t_{\text{calculated}}$ then it is non-significant.

$$t_{\text{calculated}} (|t|) = \frac{r}{\sqrt{(1 - r^2)/(n - 2)}}$$

3. Results and Discussion

Correlation Coefficients of Soil Properties in Saturation Paste Extracts from Siruguppa Taluk

The Pearson correlation coefficients between soil properties and derived salinity parameters were calculated and are presented in Table 1. Soil pHe showed no significant correlation with ECe, SAR, or any of the other derived parameters at either the 0-15 or 15-30 cm soil depths. ECe exhibited a significant positive correlation with $\text{Na}^+/(\text{Cl}^- + \text{SO}_4^{2-})$, with correlation coefficients of $r = 0.541$ and 0.836 at 0-15 and 15-30 cm depths, respectively. In contrast, ECe showed a significant negative correlation with $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$, with $r = -0.696$ and -0.398 at the corresponding depths. ECe also exhibited a significant negative correlation with SAR ($r = -0.776$) at the 0-15 cm depth.

SAR showed a significant positive correlation with $\text{Na}^+/(\text{Cl}^- + \text{SO}_4^{2-})$, with $r = 0.769$ and 0.793 at 0-15 and 15-30 cm depths, respectively. Conversely, SAR exhibited a significant negative correlation with $(\text{CO}_3^{2-} + \text{HCO}_3^-)/(\text{Cl}^- + \text{SO}_4^{2-})$, with $r = -0.565$ and -0.379 at the respective depths. The positive association between SAR and the sodium ionic ratio indicates that greater relative sodium dominance was associated with higher SAR values. Similar relationships

between salinity-related soil parameters have been reported by Chhabra (2003)^[2] and Gupta and Abrol (1990)^[4].

Correlation Coefficients of Soil Properties in Saturation Paste Extracts from Hospet Taluk

The Pearson correlation coefficients between soil properties and derived salinity parameters for Hospet Taluk are presented in Table 2. Soil pH_e exhibited significant positive correlations with E_{Ce} ($r = 0.410$ and 0.332), $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ ($r = 0.414$ and 0.446), and SAR ($r = 0.565$ and 0.573) at 0-15 and 15-30 cm depths, respectively. In contrast, pH_e showed a significant negative correlation with $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$ ($r = -0.336$) at the 15-30 cm depth only.

E_{Ce} showed significant positive correlations with SAR, with $r = 0.639$ and 0.395 at 0-15 and 15-30 cm depths, respectively. Conversely, E_{Ce} exhibited significant negative correlations with $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$, with $r = -0.391$ and -0.463 at the respective depths. SAR was significantly negatively correlated with $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$ ($r = -0.527$) at 0-15 cm depth, whereas it showed significant positive correlations with $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$, with $r = 0.690$ and 0.914 at 0-15 and 15-30 cm depths, respectively. Furthermore, $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$ showed a significant negative correlation with $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ ($r = -0.326$) at the surface depth only.

Overall Relationship among Salinity Parameters

Table 1: Correlation coefficient of saturated paste extract of soil sample parameters collected from Siruguppa taluk, Bellary district, Karnataka.

Properties	Depth									
	0-15 cm					15-30 cm				
	pH _e	E _{Ce}	SAR	$(\text{CO}_3 + \text{HCO}_3) / (\text{Cl} + \text{SO}_4)$	$\text{Na} / (\text{Cl} + \text{SO}_4)$	pH _e	E _{Ce}	SAR	$(\text{CO}_3 + \text{HCO}_3) / (\text{Cl} + \text{SO}_4)$	$\text{Na} / (\text{Cl} + \text{SO}_4)$
pH _e	1	-0.117	0.235	0.177	0.229	1	-0.071	0.289	0.195	0.153
E _{Ce}		1	-0.776**	-0.696**	0.541**		1	-0.153	-0.398*	0.836**
SAR			1	-0.565**	0.769**			1	-0.379*	0.793**
$(\text{CO}_3 + \text{HCO}_3) / (\text{Cl} + \text{SO}_4)$				1	-0.207				1	-0.158
$\text{Na} / (\text{Cl} + \text{SO}_4)$					1					1

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Table 2: Correlation coefficient (r) of saturated paste extract of soil sample parameters collected from Hospet taluk, Bellary district, Karnataka.

Properties	Soil depth (cm)									
	0-15					15-30				
	pH _e	E _{Ce}	SAR	$(\text{CO}_3 + \text{HCO}_3) / (\text{Cl} + \text{SO}_4)$	$\text{Na} / (\text{Cl} + \text{SO}_4)$	pH _e	E _{Ce}	SAR	$(\text{CO}_3 + \text{HCO}_3) / (\text{Cl} + \text{SO}_4)$	$\text{Na} / (\text{Cl} + \text{SO}_4)$
pH _e	1	0.410*	0.565**	-0.171	0.414*	1	0.332*	0.573**	-0.336*	0.446**
E _{Ce}		1	0.639**	-0.391*	0.039		1	0.395*	-0.463**	0.266
SAR			1	-0.527**	0.690**			1	-0.269	0.914**
$(\text{CO}_3 + \text{HCO}_3) / (\text{Cl} + \text{SO}_4)$				1	-0.326*				1	-0.079
$\text{Na} / (\text{Cl} + \text{SO}_4)$					1					1

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

4. Conclusion

The study revealed that soil pH_e exhibited significant positive correlations with SAR and $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$, particularly in Hospet Taluk, at both investigated soil depths. The sodium adsorption ratio (SAR) also showed a significant positive correlation with $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ in both Siruguppa and Hospet Taluks, indicating a strong association between relative sodium dominance and sodicity-related conditions. A considerable proportion of

Overall, soil pH_e did not show significant correlations with the salinity-related parameters in Siruguppa Taluk, whereas in Hospet Taluk it exhibited significant positive correlations with E_{Ce} at both 0-15 and 15-30 cm depths ($r = 0.410$ and 0.332 , respectively). According to Gupta *et al.* (1989)^[3], an increase in soil pH with increasing salinity may occur in alkaline soils because of the presence of alkaline salts, particularly carbonates and bicarbonates of sodium. In Hospet Taluk, approximately 30% of the samples, averaged across the investigated depths, had a $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$ ratio greater than 1, indicating a relatively greater contribution of carbonate and bicarbonate ions compared with chloride and sulphate in these samples.

Soil pH_e also showed significant positive correlations with SAR and $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ in Hospet Taluk at both investigated depths. Across both taluks, E_{Ce} generally showed significant negative correlations with $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$, indicating an inverse association between overall soluble salt concentration and the relative contribution of carbonate and bicarbonate ions. Similarly, SAR exhibited a significant positive correlation with $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ in both taluks and at both depths. This relationship is consistent with the role of sodium dominance in influencing sodicity-related soil conditions and indicates that higher relative sodium abundance was associated with higher SAR values in the studied soils.

soil samples from Hospet Taluk exhibited $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$ and $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ ratios greater than 1, suggesting a potential tendency toward sodicity in these soils. Therefore, timely monitoring and appropriate reclamation and soil-water management practices are necessary to prevent further deterioration and maintain the productivity of the TBP irrigation command area.

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