Soil properties, land use and livelihood options in salt-affected areas of YSR Kadapa district, Andhra Pradesh, India

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A study was conducted to assess the soil properties, land use and livelihood options of salt-affected areas in YSR Kadapa district, Andhra Pradesh, India during 2020. One hundred and fifty-eight soil samples in salt-affected mandals were collected at two depths, viz. 0–30 cm and 30–60 cm at 79 locations. They were analysed for different physical and chemical properties. Sandy loam texture was predominant in 56.96% of samples and 35.44% of subsurface samples. This was followed by sandy clay loam in 18.98% surface and 34.20% subsurface samples. pH_2 of soil varied from 7.5 to 10.6 and 7.3 to 10.6 for the surface and subsurface soils respectively. ECe was in the range 0.4 –46.0 dS m^{-1} in surface soils and 0.4–33.0 dS m^{-1} in the subsurface soils. Residual sodium carbonate of the surface soils was in the range –63.8 to 47.8 meq/l and it was –51.6 to 68.6 meq/l for subsurface samples. Sodium adsorption ratio ranged from 0.78 to 70.0 on the surface and from 0.52 to 65.3 in subsurface soils. Exchangeable sodium percentage range from 0.9 to 80.5 and 0.6 to 75.1 in the surface and subsurface soil samples respectively. Cation exchange capacity 3.17 to 43.26 cmol (p^+) kg^{-1} characterized surface soils, while values 5.94 to 63.51 cmol (p^+) kg^{-1} characterized subsurface soils. The problem soils, namely saline, saline-alkali and alkali soils, were present under various land-use categories.

Keywords: Land use, livelihood options, salinity stress, salt-affected areas, soil properties.

SALT-AFFECTED soils are common in arid and semiarid regions due to low rainfall and high evapotranspiration. It has been estimated that around 50% of arable land would be salt-affected in India by 2050. Salt-affected soils of the world account for 952.2 million hectares (m ha)[1]. An area of 6.74 m ha in India suffers from salt accumulation, of which 3.78 m ha is sodic while 2.96 m ha is saline[2]. In Andhra Pradesh (AP), 12,081 ha of saline, 271,389 ha of sodic and 83,882 ha of saline-sodic soils are distributed[3]. The estimated area of salt-affected soils in the Kadapa district, AP, is spread over 19,628 ha (ref. 4). Salinity stress impacts seed germination, reduces plant density and growth rate, resulting in smaller leaves, shorter stature of plants, limiting nutrient absorption, reducing water and nutrient availability and finally crop failure[5]. Soil salinity may be tackled by two approaches. (i) By reclaiming salt-affected soils and (ii) by managing salt-tolerant crops, improving agroforestry techniques and utilizing natural vegetation as an alternative livelihood. Therefore, a study was conducted to assess the soil properties and land use by farmers in salt-affected areas of the YSR Kadapa district, AP.

Geographically, this district lies between 13°43′ and 15°14′N lat, 77°55′ and 79°29′E long, covering a 15,359 sq. km geographical area. It is bordered by the SPSR Nellore district to the east, Anantapur district to the west, Chittoor district to the south, and Kurnool and Prakasam districts to the north. The annual rainfall of the district varies from 502 mm in the western part adjacent to the Anantapur and Chittoor districts to 927 mm in the eastern part adjacent to the Nellore district during the southwest and northeast monsoons. The maximum temperature varies from 34°C to 40°C in summer while the minimum temperature varies from 25°C to 35°C during winter. Salt-affected soils are distributed in the southwestern part of the district, which receives less rainfall (Figure 1).

Material and methods

Seventy-nine locations from 17 mandals having salt-affected soils, viz. Sambepalli, Rayachoti, Ramapuram, Veeraballi, Lakkireddipalli, Chakrayapeta, Vemula, Pulivendula, Thondur, Kondapuram, Mylavaram, Peddamodium, Mydukuru, B. Koduru, Valluru, Kadapa and Pendlimarri were selected for the study. Soil samples were separately collected from two depths, viz. 0–30 and 30–60 cm. Location coordinates for each sampling site were determined using handheld GPS. Soil samples were processed using standard procedure and analysed for various physical characteristics and chemical composition. Saturation paste extract (1 : 1) was obtained by following the standard procedure[6] and used to analyse soluble ions. pH was determined potentiometrically using a pH meter in 1 : 2 soil water suspension prepared from saturated soil paste[7]. Electrical conductivity was determined using a conductivity bridge[8]. Chlorides (Mohr’s method),

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Figure 1. Sample locations in YSR Kadapa district, Andhra Pradesh, India.

carbonates and bicarbonates were determined by the double indicator method and calcium and magnesium by versenate titration method adopting standard procedures[9]. Sodium and potassium were determined by flame photometry[9]. Analysis of particle size was carried out by international pipette method using sodium hexametaphosphate as the dispersing agent[10]. The textural class was determined using USDA textural triangle. To determine cation exchange capacity (CEC), a known weight of the soil was saturated with 1.0 N sodium acetate (pH 8.2), followed by the leaching of excess sodium acetate with 95% ethanol. Neutral ammonium acetate (1.0 N) was used to displace the adsorbed sodium. A flame photometer was used to determine sodium concentration in the leachate. The calculated CEC was expressed in cmol (p^+) kg^{-1} soil[11]. The sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were calculated using the following equations[9]: $SAR = Na/((Ca^{2+} + Mg^{2+})/2)^{0.5}$ and $RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$. In these equations, Na^+, Ca^{2+}, $Mg^{2+}CO_3^{2-}$, HCO_3^-, Ca^{2+} and Mg^{2+} (milli equivalent per litre (meq/l)). The exchangeable sodium percentage (ESP) of soils was computed by the following equation[12].

$$ESP = \frac{\begin{pmatrix}\text{Exchangeable sodium}\\ \text{(cmol (p}^+\text{) kg}^{-1}\text{ soil)}\end{pmatrix}}{\begin{pmatrix}\text{Cation exchange capacity}\\ \text{(cmol (p}^+\text{) kg}^{-1}\text{ soil)}\end{pmatrix}} \times 100.$$

Based on the physico-chemical properties, soils were classified into different salt-affected categories[9].

SPSS 20.0 was employed to analyse the analytical data using the Pearson correlation coefficient matrix to know significant variations between the soil physico-chemical properties. Descriptive statistics was computed using Microsoft Excel (Microsoft, WA, USA) spreadsheet. Soil physico-chemical properties were classified into different categories by following the standard ratings[13], soil salinity[14] and salt-affected soils[9].

Results and discussion

Characteristics of salt-affected soils

Texture: The surface soils of the study area were dominantly sandy loam (56.96%). Other types of surface soils were sandy clay loam (15%), loamy sand (8%), loam (8%) and clay loam (3%). In the subsurface (below 30 cm), textural classes of soil encountered were sandy loam (35.44%), sandy clay loam (34.20%), loamy sand (12.70%), clay loam (10.13%), loam (3.8%), sandy clay (2.53%) and sand (1.2%; Table 1). Elevation may have a positive relationship with sand and negative with silt and clay particles which might be due to the transportation and accumulation of finer particles within the soil along with the rainwater and based

Table 1. Soil textural classes

Textural class	Surface (0–30 cm) No. of samples	Surface (0–30 cm) Percentage	Subsurface (30–60 cm) No. of samples	Subsurface (30–60 cm) Percentage
Sandy loam	45	56.96	28	35.44
Sandy clay loam	15	18.98	27	34.20
Loamy sand	8	10.13	10	12.70
Loam	8	10.13	3	3.80
Clay loam	3	3.80	8	10.13
Sandy clay	0.0	0.00	2	2.53
Sand	0.0	0.00	1	1.20

Table 2. pH and the respective reaction of soils

Reaction class	pH range	Surface (0–30 cm) No. of samples	Surface (0–30 cm) Percentage	Subsurface (30–60 cm) No. of samples	Subsurface (30–60 cm) Percentage
Neutral	6.6–7.3	1	1.27	1	1.27
Slightly alkaline	7.4–7.8	0	0.00	0	0.00
Moderately alkaline	7.9–8.4	28	35.44	22	27.85
Strongly alkaline	8.5–9.0	5	6.33	10	12.66
Very strongly alkaline	9.1–10.6	45	56.96	46	58.23

Table 3. ECe and degree of salinity hazard in soils

Soil salinity class	ECe (dS m^{-1})	Surface soil (0–30 cm) No. of samples	Surface soil (0–30 cm) Percentage	Subsurface soil (30–60 cm) No. of samples	Subsurface soil (30–60 cm) Percentage
Non-saline	0–2	30	37.97	33	41.77
Slightly saline	2–4	15	18.99	14	17.72
Moderately saline	4–8	17	21.52	13	16.46
Strongly saline	8–16	9	11.39	16	20.25
Very strongly saline	>16	8	10.13	3	3.80

on the slope at lower elevation points during geologic formation of the study area[15].

Soil reaction: This varied from neutral (pH 6.6–7.3) to very strongly alkaline (pH 9.1–10.6) in both surface and subsurface soils. Slightly alkaline soils were not found in both the depth ranges studied. Most soils at both depths were found to be strongly alkaline, followed by moderately alkaline. Neutral and strongly alkaline soils were less in proportion (Table 2). The high pH of soils could be due to higher amounts of carbonates, bicarbonates and sodium ions in them[16].

Electrical conductivity: Salinity is expressed on the basis of electrical conductivity values of the soil. The electrical conductivity (1 : 1 saturated soil water extract) ranged from 0.4 to 46.0 dS m^{-1} on the surface and from 0.4 to 33.0 dS m^{-1} in the subsurface soils. About 40% of the soil samples at both depth ranges were non-saline (<2 dS m^{-1}). Slightly saline to very strongly saline soils (>2dS m^{-1}) were about 60% (Table 3). This might be due to the geochemical disintegration of rocks and parent material, capillary rise of brackish groundwater and lack of leaching, high evapotranspiration due to arid and semi-arid climatic conditions, and low rainfall resulting in the lack of vegetation to cover the soil in the region[17].

Soluble ion concentration: The dominance of Na^+ (57.08 meq/l), Cl^- (27.38 meq/l), Ca^{2+} (4.69 meq/l) and HCO_3^- (4.39 meq/l) ions was observed in the near-surface (0–30 cm) soil. In the subsurface soil (30–60 cm), the dominance of Na^+ (57.77 meq/l), Cl^- (7.08 meq/l) and HCO_3^- (5.25 meq/l) was observed (Table 4). Presence of Na^+, Cl^- and HCO_3^- ions indicates the development of saline, saline alkali and alkali soils at both depths in the study area. It is evident that excess quantities of CO_3^{2-} and HCO_3^- over Ca^{2+} and Mg^{2+} reduce the activity of calcium and magnesium by its precipitation in soil solution due to evaporation of moisture and encourages Na^+ ion activity. The excess sodium ions replace the calcium and magnesium ions during exchange which deteriorates the soil structure[2].

Cation exchange capacity and exchangeable sodium percentage: CEC of the soil varied with its texture and depth. The presence of most reactive particles in the soil has a major influence on CEC. In the surface soil, the CEC values ranged from 3.17 to 43.26 cmol (p^+) kg^{-1} with a mean value of 16.64 cmol (p^+) kg^{-1}. ESP ranged from 0.9 to 80.5, with a

Table 4. Soluble ion content in saturated paste extract of salt-affected soils in YSR Kadapa district, Andhra Pradesh (AP), India

	Surface (0–30 cm)		Subsurface (30–60 cm)	
Parameter (meq/l)	Range	Mean	Range	Mean
CO_3^{2-}	0.0–9.6	0.29	0.0–28.2	1.14
HCO_3^-	0.6–41.4	4.39	0.0–42.4	5.25
Cl^-	0.8–255	27.38	0.3–76.2	7.08
Ca^{2+}	1.2–44	4.69	0.4–16.8	2.84
Mg^{2+}	0.0–20.4	1.12	0.4–45.6	1.95
Na^+	2.0–479	57.08	1.77–396	57.77
K^+	0.13–1.09	0.33	0.16–0.86	0.29

Table 5. Exchangeable sodium percentage (ESP) and degree of alkali hazard

		No. of samples			
		Surface (0–30 cm)		Subsurface (30–60 cm)	
Approximate ESP	Alkali hazard	No. of samples	Percentage	No. of samples	Percentage
Up to 15	None to slight	36	45.57	42	53.16
15–30	Slight to moderate	15	18.99	20	25.32
30–50	Moderate to high	19	24.05	13	16.46
50–70	High to very high	7	8.86	3	3.80
>70	Extremely high	2	2.53	1	1.27

Table 6. Physico-chemical properties of soils collected from salt-affected areas of YSR Kadpa district, AP

	pH_2		pH_e		ECe (dS m^{-1})		EC2		RSC		SAR		ESP		CEC (cmol(p^+) kg^{-1})	
Depth (cm)	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
0–30	7.5–10.6	9.34	7.2–9.7	8.19	0.4–46	5.96	0.07–10.6	2.03	–63.8–47.8	–1.43	0.78–70.0	20.4	0.9–80.5	23.49	3.17–43.26	16.64
30–60	7.3–10.6	9.46	6.9–9.8	8.25	0.4–33	5.25	0.05–9.6	2.01	–51.6–68.6	1.58	0.52–65.3	16.10	0.6–75.1	18.51	5.94–63.51	28.93

RSC, Residual sodium carbonate; SAR, Sodium adsorption ratio; CEC, Cation exchange capacity.

mean value of 23.49 in the surface soil. In the subsurface soil, CEC ranged from 5.94 to 63.51 cmol (p^+) kg^{-1} with a mean value of 28.93 cmol (p^+) kg^{-1}, while ESP ranged from 0.6 to 75.1 with a mean value of 18.51 (Tables 5 and 6).

In the surface soils (0–30 cm deep), ESP < 15 was recorded in 45.57% of the samples and ESP >15 in the rest. In the subsurface soils (30–60 cm deep) ESP <15 was recorded in 53.16% and ESP >15 was recorded in 46.84% of the samples. This indicates that the exchangeable sodium is slightly more dominant in the surface soil than the subsurface soil, leading to the deterioration of soil aggregate stability and poor aeration and drainage. These are common features of sodic soils. ESP of the soil decreases with depth[6].

Residual sodium carbonate and sodium adsorption ratio: SAR was in the range 0.78–70 with a mean value of 20.4, and 0.52–65.3 with a mean value of 16.10 in the surface and subsurface soils respectively, indicating the dominance of sodium in surface samples compared to the subsurface soil samples. The RSC ranged from –63.8 to 47.8 with a mean value of –1.43 for the surface soil samples, and from –51.6 to 68.6 with a mean value of 1.58 for the subsurface soil samples (Table 6). The high residual sodium carbonate (RSC) values indicate the dominance of carbonate and bicarbonate ions in the soil solution, leading to the development of sodic soils at a few locations in the study area[16].

Relation between pH_2 and pH_e

The pH_2 (1 : 2 soil water suspension) was greater than pH_e (1 : 1 saturated soil water extract). pH_2 of the soil is the real indicator of soil reaction[6] (Figure 2 and Table 6). The mean value of pH_2 of soil samples indicates that pH of the surface soil is less than that of subsurface soil. Similar results have been reported in sweet orange-growing sandy loam to sandy clay loam soils of Kadapa district, AP[18]. The lower pH of surface soil might be due to organic matter and dominance of crystallized neutral salts, viz. $CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$, NaCl and Na_2SO_4. The higher pH in the subsurface soil might be due to the dominance of carbonate and bicarbonate ions.

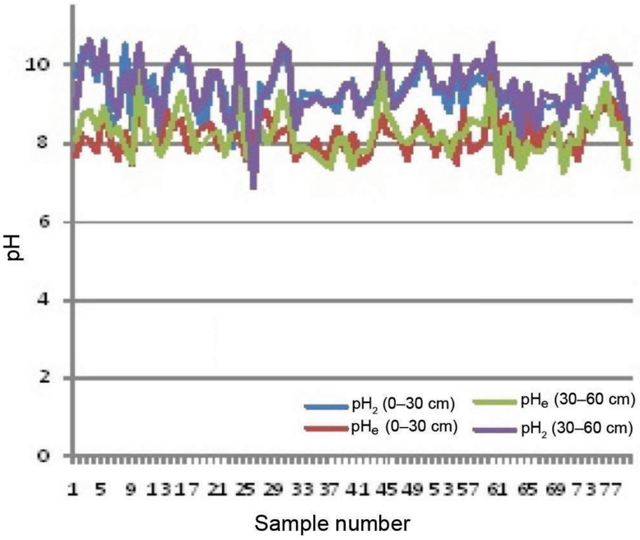

Figure 2. Relationship between pH_2 and pH_e.

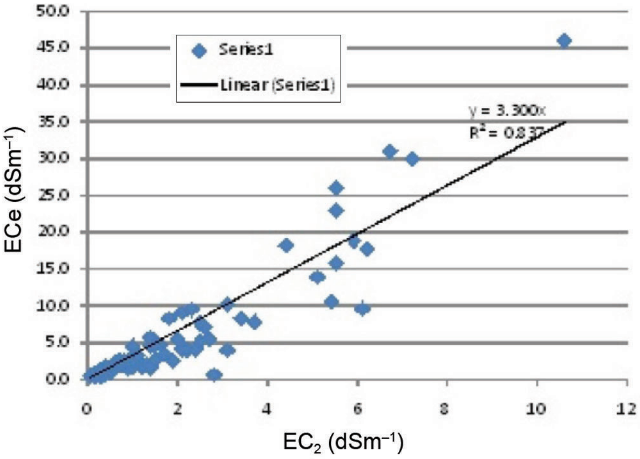

Figure 3. Relationship between EC_2 and ECe.

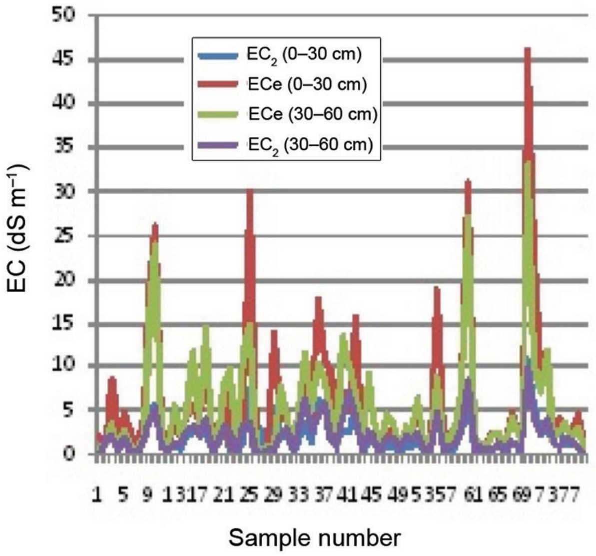

Figure 4. Relationship between ECe and EC_2.

Relation between EC_2 and ECe

ECe (1 : 1 saturated soil water extract) was greater than EC_2 (1 : 2 soil water suspension) of the soil. ECe of the soil was 3.3 times greater than the EC_2 (Figure 3). ECe of soil is the real indicator of salt content in salt-affected soils[19]. Figure 4 and Table 6 indicate that higher salt content is found in surface soils. This may be due to the movement of salts to the surface through capillary rise under semiarid climatic conditions in Kadapa district, AP[18].

Land use – soil features

The soils are mostly under the barren category due to a lack of sufficient and regular distribution of rainfall for cultivation. The tanks get occasionally filled with water (say once in 2–3 years). In those years, rice was cultivated to a small extent under tank-fed irrigation. Other crops, namely, jowar, cotton, horse gram, castor, gingelly, coriander, mango, jamun and sapota are cultivated under rainfed conditions, and using tubewell water.

Land use – vegetation – livelihood options

Crops like rice, jowar, cotton, horsegram, castor, gingelly, coriander, mango, jamun, sapota and the weeds, namely, *Abutilon inidcam*, *Achiranthus aspera*, *Aristolochia bracteata*, *Calotrophis gigantea*, *Cassia auriculata*, *Celosia argentia*, *Chloris barabata*, *Chrozphora rottleri*, *Cissus quadrangularis*, *Cleome viscosa*, *Commelina benalensis*, *Cressa critica*, *Corchorus acutangulus*, *Croton sparsiflorus*, *Cyperus rotundus*, *Cynodon doctylan*, *Datura stamonium*, *Euphorbia hirta*, *Leucas aspera*, *Nicotiana plumbaginifolia*, *Parthenium hysterophorus*, *Solanum xanthocarpum*, *Solanum nigrum*, *Tribulas terrestris*, *Xanthium strumanium*, *Tephrosia purpurea* and trees, namely, *Acasia nilotica*, *Albizia lebbeck*, *Azadiracta inidca*, *Borassus flabellifer*, *Limonia assidissima*, *Phoenix sylvestris*, *Pongamia pinnata*, *Prosopis julifera*, *Prosopis cineraria*, *Tamarindus indica*, *Tectona grandis*, *Ziziphus jujube* grown in the study area. Agriculture alone does not provide livelihood security to farmers. Crop failure is common in salt-affected soils. Taking advantage of native trees and grasses, the farmers have taken to sheep and goat-rearing, dairy, backyard poultry and firewood production. They have also taken to agroforestry, developing orchards, charcoal-making, and producing tamarind, neem, palmyra and date-palm sugar for their livelihood.

Conclusion

The soils of the study area carry a high abundance of Na^+, Cl^-, HCO_3^- and CO_3^{2-} ions at the surface and shallow subsurface. These have given rise to saline, alkali and saline-alkali soils. Soils are ruined by salts making them less productive and even non-productive for many crops, and the area is barren most of the time. Salinity has a major impact on the livelihood of farmers. Not being able to grow crops, the farmers diversified into dairy, poultry and horticultural activities.

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Received 9 November 2021; re-revised accepted 26 August 2022

doi: 10.18520/cs/v123/i9/1136-1141