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Characterization and mapping of salt affected soils of Siruguppa Taluk in Tungabhadra project irrigation command area, Karnataka

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Abstract

With the aid of GPS and topographic sheets, soil samples were collected on a grid basis ($5' \times 5'$, approximately 9×9 km) from Siruguppa Taluk of Bellary District, Karnataka. A total of 121 soil samples were collected from 20 grid points at four depths: 0-15, 15-30, 30-60, and >60 cm. In the surface soil (0-15 cm), pH (1:2.5), pHe, EC (1:2.5), and ECe ranged from 7.48 to 8.96, 6.98 to 8.10, 0.33 to 6.30 dS m^{-1} , and 0.69 to 14.50 dS m^{-1} , respectively, with corresponding mean values of 8.00, 7.50, 1.69, and 3.76 dS m^{-1} , respectively. Among the soluble cations, Na^+ was predominant, followed by $\text{Ca}^{2+} + \text{Mg}^{2+}$ and K^+ , while among the anions, Cl^- was predominant, followed by HCO_3^- and SO_4^{2-} . Approximately 28% of the surface soil samples had $\text{ECe} > 4.0 \text{ dS m}^{-1}$, indicating saline conditions. The proportion of samples with $\text{SAR} > 13$ was 30.8% at the surface depth.

At 15-30 cm depth, pH (1:2.5), pHe, EC (1:2.5), and ECe ranged from 7.60 to 9.45, 7.05 to 8.92, 0.25 to 7.60 dS m^{-1} , and 0.46 to 11.90 dS m^{-1} , respectively, with mean values of 8.15, 7.71, 1.21, and 2.42 dS m^{-1} , respectively. Approximately 8.0% of the samples had $\text{ECe} > 4.0 \text{ dS m}^{-1}$, while 33.33% had $\text{SAR} > 13$. At the lower depths, the mean ECe values at 30-60 and >60 cm remained below 4.0 dS m^{-1} ; however, 10.70% and 20.0% of the samples, respectively, had $\text{ECe} > 4.0 \text{ dS m}^{-1}$. Similar to the upper soil layers, Na^+ was the predominant soluble cation, followed by $\text{Ca}^{2+} + \text{Mg}^{2+}$ and K^+ , whereas Cl^- was the predominant anion, followed by HCO_3^- and SO_4^{2-} . The proportion of samples with $\text{SAR} > 13$ was 32.10% at 30-60 cm and 30.0% at >60 cm depth. Overall, the results indicated considerable spatial and vertical variation in soil salinity and sodicity across the Siruguppa Taluk, highlighting the need for appropriate monitoring and site-specific reclamation measures.

Keywords: GPS, pHe, ECe, SAR, Anions, Cations, Derived Parameters and Salt affected soil

Introduction

Soil is one of the most valuable natural resources upon which agricultural productivity largely depends. Salt-affected soils constitute an important category of degraded soils in which productivity is reduced due to salinity ($\text{EC} > 4 \text{ dS m}^{-1}$), sodicity ($\text{ESP} > 15$), or a combination of both. All soils contain varying amounts of soluble salts, many of which are essential for plant growth and serve as sources of nutrients. However, when the concentration of soluble salts in the active root zone exceeds critical thresholds, the growth, yield, and quality of most crops are adversely affected. Soils containing excessive concentrations of soluble salts and/or exchangeable sodium that impair their productive capacity are referred to as salt-affected soils. These soils commonly occur in association with non-saline soils but are characterized by relatively high concentrations of soluble electrolytes and/or exchangeable sodium (Szaboles, 1989).

Excessive salt accumulation can accelerate several soil degradation processes, including soil dispersion, surface crust formation, structural deterioration, and compaction, thereby reducing soil physical quality. High salinity may also cause nutrient imbalances and adversely affect plant growth by increasing the availability or accumulation of potentially toxic elements (Priyadarshini, 2011). Based on the dominant soil constraint, salt-affected soils are generally classified as saline, sodic, or saline-sodic soils. In India, these soils are broadly categorized into saline and sodic (alkali) soils.

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According to the reconciled estimates of CSSRI, Karnal, NRSA, and NBSS&LUP (2006), approximately 6.73 million hectares (M ha) of land in India was affected by salinity and sodicity, comprising 3.77 M ha of sodic soils and 2.96 M ha of saline soils. Earlier projections estimated that about 11.7 M ha could be affected by salinity and alkalinity by 2025. Estimates of the extent and spatial distribution of salt-affected soils vary among studies because remote-sensing-based assessments can be influenced by soil moisture, parent material, vegetation cover, and other surface and subsurface characteristics (Mandal and Sharma, 2001).

Salt-affected soils differ substantially from normal soils in their physical, chemical, and biological properties, and these differences directly influence soil productivity and crop performance. Therefore, accurate characterization and spatial assessment of salinity and sodicity at the local level are essential for identifying affected areas and developing appropriate soil, water, and crop management strategies for sustainable agricultural production.

Soil salinity and waterlogging are two major constraints affecting agricultural productivity in the Tungabhadra Project (TBP) command area, largely attributed to inappropriate land and water management practices and deviations from the recommended cropping pattern over several decades. Approximately 96,215 ha, accounting for about 26.5% of the total command area of 3.63 lakh ha, has been reported as salt affected (Anonymous, 2012), with an additional 1,000 ha reportedly becoming salt affected each year (IDNP, 2002). The continued expansion of salt-affected areas highlights the need for systematic monitoring of soil salinity and sodicity to assess temporal changes, anticipate further degradation, and facilitate timely modification of management practices and implementation of appropriate reclamation and rehabilitation measures.

Despite the extent and severity of the problem, ground-truth-based information on the characterization and spatial distribution of salt-affected soils in the TBP command remains limited, and comprehensive salinity base maps are lacking. Accurate delineation and characterization of salt-affected areas through systematic field sampling and laboratory analysis are therefore essential for obtaining reliable estimates of their extent and distribution.

A detailed assessment and spatial mapping of soil salinity and sodicity in the command area can provide valuable information for researchers, land managers, and policymakers to identify

affected areas, understand the spatial variability and potential factors contributing to salt accumulation, and develop appropriate management interventions. Such information is also essential for preventing further expansion of salt-affected soils and restoring their productivity through site-specific soil, water, drainage, and reclamation practices.

Materials and Methods

Study Area

The Tungabhadra irrigation command area in Karnataka provides irrigation facilities to agricultural crops in Bellary, Koppal, and parts of Raichur districts. The present study was conducted in Siruguppa Taluk of Bellary District, located in the eastern part of Karnataka. Bellary District extends between 15°30' and 15°50' N latitude and 75°40' and 77°11' E longitude, with a geographical area of approximately 8,447 km².

Siruguppa Taluk is situated at approximately 15°37'30.22" N latitude and 76°53'42.78" E longitude, with an average elevation of 373 m (1,223 ft) above mean sea level and a geographical area of approximately 1,042 km² (Fig. 1). The major soil types occurring in the area include medium-deep red gravelly clay soils, deep black clayey soils, deep black calcareous clayey soils, and deep alluvial clayey soils. The taluk receives an average annual rainfall of approximately 645 mm. The major crops cultivated in the area include paddy, sorghum (jowar), maize, cotton, and sugarcane.

The predominance of irrigated agriculture and the occurrence of diverse soil types make Siruguppa Taluk an important area for assessing the distribution and characteristics of salt-affected soils within the Tungabhadra irrigation command.

Collection of soil samples and mapping of salt affected soils

With the aid of GPS and toposheet (1:50000 scale), soil samples were collected on a grid basis (5' x 5') from Siruguppa (20 grids) taluk in Bellary district during April-May 2017. Generally, soil samples to a depth of 60+ cm at an increment of 0-15, 15-30 30-60 and 60+ cm were collected using auger from places which are in the command i.e., have irrigation facilities from the Left Bank Canal in the TBP command. The collected soil samples were air dried under shade, powdered with a pestle and mortar, sieved through 2 mm sieve and stored in polythene bags. These samples were analyzed for pH and EC (1:2.5), pH_e, EC_e, SAR, cation and anionic composition of saturation paste extract were determined by adopting standard analytical methods. The overview of the salt-affected soils and soil sample.

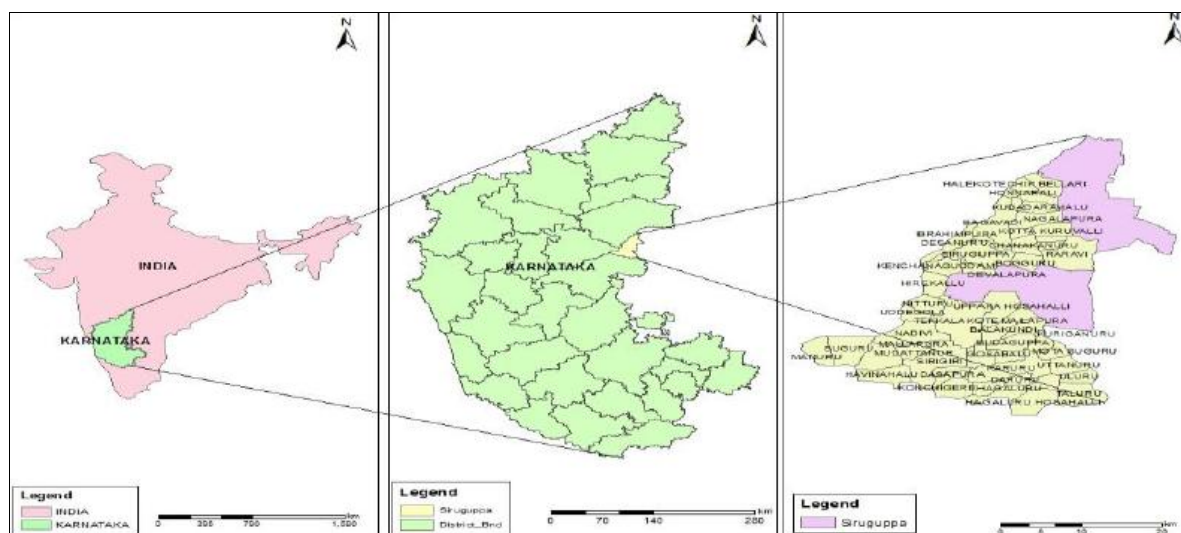


Fig 1: Location map of Siruguppa taluk

Collection in the TBP command area is shown in Plates 1a and 1b. The analyzed soil samples were interpolated for mapping of soil salinity and other properties by using Arc GIS Ver., 10.4 as per procedure detailed below:

Rectification of shape files of TBP command area
↓
Kriging according to the selected area
↓
Collecting information corresponding to the selected points
↓
Symbology according to mapping unit
↓
Descriptive analysis, area, map data and map layout

Statistical analysis

Various soil properties were tested for their correlation (r) with other properties as per the procedure by Snedecor and Cochran (1980) [20]. 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 indicates degree of association between two variables. If ‘r’ value is positive, two variables are positively correlated and it is negative, then two variables are negatively correlated. The significant of correlation coefficient was tested by t test. If table < calculated value then ‘r’ is significant and if table > calculated then it is non-significant.

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



Plate 1a: View of salt affected soils in TBP command area



Plate 1b: View of soil sampling in salt affected soils in TBP command

Results and discussion

Characterization of soil samples of the study area

Soil pH_(1:2.5) and pHe

Ionic composition of soluble salts and some other soil characteristics of salt affected soils are given in Table-1. In Siruguppa taluk of Bellary district the mean soil pH increased slightly with soil depth. Generally, the mean soil pH at all the depths of Siruguppa taluk was in the category of moderately alkaline (8.0 to 8.5) with pH ranging from 8.0 to 8.24 (Brady and Well, 2007). However, the mean pHe at all depths was in the category of mildly alkaline. Slight alkalinity of these soils could be attributed to semiarid climate, presence of basic parent material (viz., Gneissic complex), restricted drainage, high calcium carbonate and exchangeable bases (Ravi Kumar *et al.*, 2007)^[17].

As far as per cent distribution of pH and pHe is considered, in general about 78.57 (30-60 cm) to 89.74 (0-15 cm) and 50.00 (30-60 cm) to 69.20 (15-30 cm) in Siruguppa taluk were moderately alkaline in reaction (Table-2). Priyadarshini (2011) reported that about 45, 11 and 12 per cent of surface soil samples were mildly alkaline, moderately alkaline and strongly alkaline (> 8.5) respectively in soil reaction of salt affected soils of Nellore and Gudur divisions of Nellore district, Andhra

Pradesh.

The soil reaction (pHe) maps of surface and sub-surface soils of Siruguppa taluk is depicted in Fig.2a and 2b. The distribution of area under different categories of soil pHe as depicted in Fig. 2a, revealed that out of the total sampled area in Siruguppa taluk (76,648.9 ha) about 71,513.8 (98.43%) and 1,135.13 ha (1.60%) had pHe in the range of 6.98 to 7.50 and 7.50 to 8.10 respectively at surface soil (0-15 cm). At 15-30 cm (Fig. 2b), about 12,705.3 (17.48%) and 59,943.7 ha (82.51%) area had pHe in the range of 7.05 to 7.50 and 7.52 to 8.92 respectively.

Soil EC_(1:2.5) and ECe

Unlike soil pH, no consistent trend with depth was observed with respect to the mean EC_(1:2.5) and ECe of Siruguppa taluk soil samples, the mean EC and ECe ranging from 1.22 to 1.69 and 2.42 to 3.76 dS/m respectively (Table 1), though the surface samples generally had slightly higher values. Further, mean ECe at all depths were greater than respective EC_(1:2.5) values in Siruguppa taluks. Overall, the mean EC and ECe values were <4.0 dS m⁻¹ at all the depths in Siruguppa taluks reflecting that the soils are non-saline. However, looking at per cent distribution of ECe values (Table 2) varied from 28.30 (0-15 cm) to 7.70% (15-30 cm).

Table 1: Characterization of soil samples collected from Siruguppa taluk, Bellary district, Karnataka for soil salinity appraisal

Properties	Depth (cm)											
	0-15 cm			15-30 cm			30-60 cm			60+ cm		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
pH (1:2.5)	7.48	8.96	8.00	7.60	9.45	8.15	7.68	9.12	8.20	7.70	8.90	8.24
EC (1:2.5)	0.33	6.30	1.69	0.25	7.60	1.21	0.32	6.60	1.47	0.30	3.80	1.22
pHe	6.98	8.10	7.50	7.05	8.92	7.71	6.96	8.48	7.58	7.13	8.26	7.58
ECe (dS/m)	0.69	14.50	3.76	0.46	11.90	2.42	0.62	11.90	2.61	0.55	8.90	2.54
Cation (me l⁻¹)												
Ca+Mg	4.50	58.30	16.36	2.70	35.40	7.87	2.60	33.80	6.87	3.00	29.30	6.14
Na+	2.22	125	33.38	3.84	155.80	27.24	4.82	100	23.70	3.47	62.90	21.20
K+	0.07	0.72	0.28	0.04	0.36	0.16	0.02	0.50	0.13	0.03	0.16	0.07
Anion (me l⁻¹)												
HCO ₃ ⁻	5.50	13.50	8.95	5.00	13.60	7.69	3.21	35.40	8.19	3.50	19.60	8.91
Cl ⁻	10.50	124.50	25.44	3.50	27.50	13.0	4.20	96.80	18.80	7.50	55.20	15.70
SO ₄ ²⁻	0.09	1.76	0.85	0.11	2.35	0.59	0.20	2.50	0.72	0.10	2.02	0.62
SAR	1.18	37.50	11.30	2.99	37.04	13.48	4.07	27.60	11.70	2.31	29.40	11.90
(CO ₃ +HCO ₃)/(Cl+SO ₄)	0.09	0.93	0.44	0.28	2.42	0.65	0.10	0.86	0.55	0.03	0.65	0.19
Na/(Cl+SO ₄)	0.21	2.89	1.18	0.40	7.47	1.83	0.87	1.77	1.21	0.45	3.18	1.26

Table 2: Per cent distribution of soil properties of samples collected from Siruguppa taluk, Bellary district, Karnataka for soil salinity appraisal

Soil Depth (Cm)	pH			pHe			EC (dS/m)			ECe (dS/m)			(CO ₃ +HCO ₃)/(Cl+SO ₄)		Na/(Cl+SO ₄)		SAR	
	<7.5	7.5-8.5	>8.5	<7.5	7.5-8.5	>8.5	<2.0	2-4	>4	<2.0	2-4	>4	<1	>1	<1	>1	<13	>13
0-15	2.56 (1)	89.74 (35)	7.69 (3)	46.2 (18)	53.8 (21)	0	76.92 (30)	15.38 (6)	7.69 (3)	23.0 (9)	48.7 (19)	28.3 (11)	100 (39)	0	35.9 (14)	64.1 (25)	69.2 (27)	30.8 (12)
15-30	0	82.05 (32)	17.95 (7)	25.7 (10)	69.2 (27)	5.10 (2)	92.31 (36)	5.13 (2)	2.56 (1)	43.6 (17)	48.7 (19)	7.7 (3)	94.9 (37)	5.10 (2)	15.4 (6)	84.6 (33)	66.7 (26)	33.3 (13)
30-60	0	78.57 (22)	21.43 (6)	50.0 (14)	50.0 (14)	0	82.14 (23)	10.71 (3)	7.14 (2)	60.7 (17)	28.6 (8)	10.7 (3)	100 (28)	0	21.4 (6)	78.6 (22)	67.9 (19)	32.1 (9)
60+	0	80.00 (16)	20.00 (4)	35.0 (7)	65.0 (13)	0	80.00 (16)	20.00 (4)	0	65.0 (13)	15.0 (3)	20.0 (4)	100 (20)	0	35.0 (7)	65.0 (13)	70.0 (14)	30.0 (6)

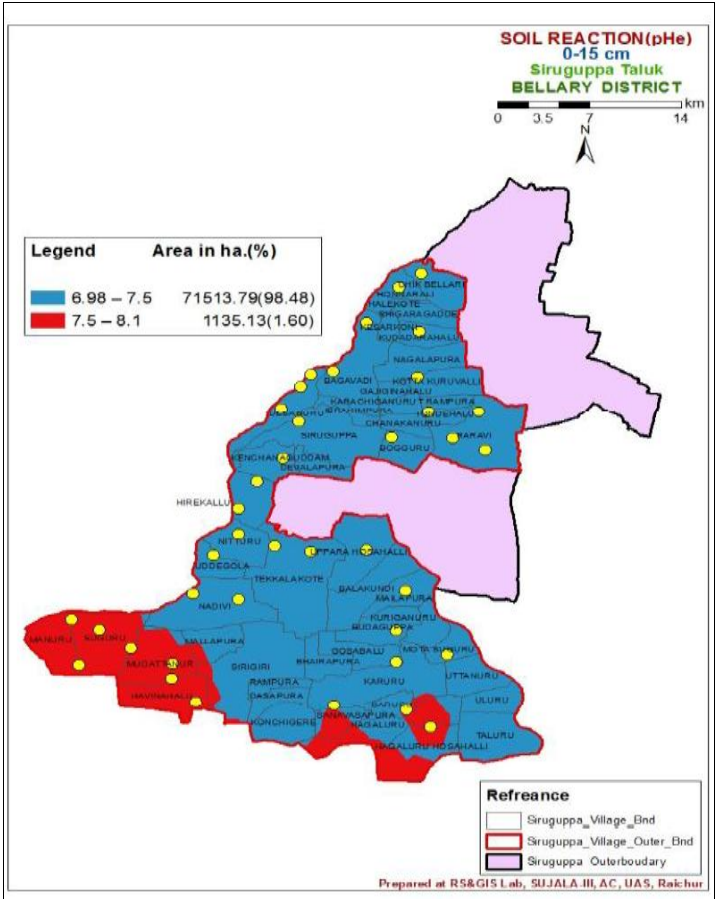


Fig 2a: pHe distribution map of surface soil (0-15 cm) in Siruguppa taluk

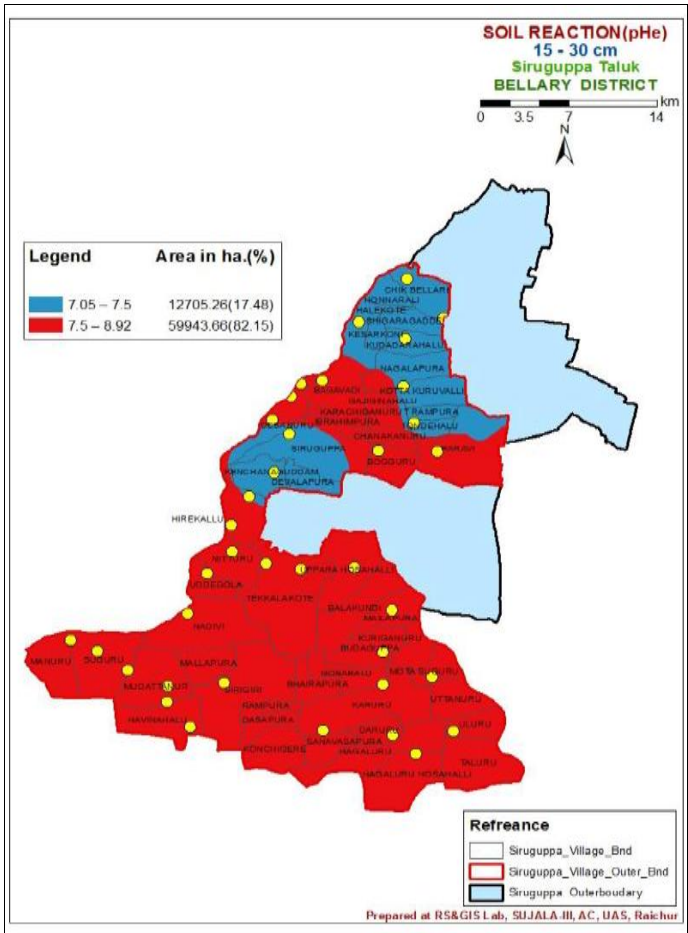


Fig 2b: pHe distribution map of sub-surface soil (15-30 cm) in Siruguppa taluk

In Siruguppa taluk were $>4 \text{ dS m}^{-1}$ reflecting that they are saline at the time of sampling.

The soil salinity (ECe) maps of surface and sub-surface soils of Siruguppa taluk is depicted in Fig.3a and 3b. The distribution of area under different categories of soil ECe as depicted in Fig. 3a, revealed that out of the total sampled area of Siruguppa taluk (72,648.92 ha) about 3.23 (0.004%), 60,523.40 (83.31%), 12,118.7 (16.68%), 2.12 (0.003%) and 1.20 ha (0.002%) had ECe in the range of 0.69 to 2.0, 2.0 to 4.0, 4.0 to 8.0, 8.0 to 12.0 and 12.6 to 14.5 dS m^{-1} respectively. At 15-30 cm, about 17.48, 82.51, 0.24 and 0.001% of total area had ECe in the range of 0.46 to 2.0, 2.0 to 4.0, 4.0 to 8.0 and 8.0 to 11.90 dS m^{-1} respectively (Fig. 3b).

A relatively higher ECe values in surface layer as compared to sub-surface soils may be ascribed to the upward movement of soluble salts due to capillary rise and deposition at the soil surface particularly during summer. Similar observations were made by Mohammad *et al.* (2017)^[13] and Priyadarshini (2011).

Cation and Anion

Cation and Anion Composition

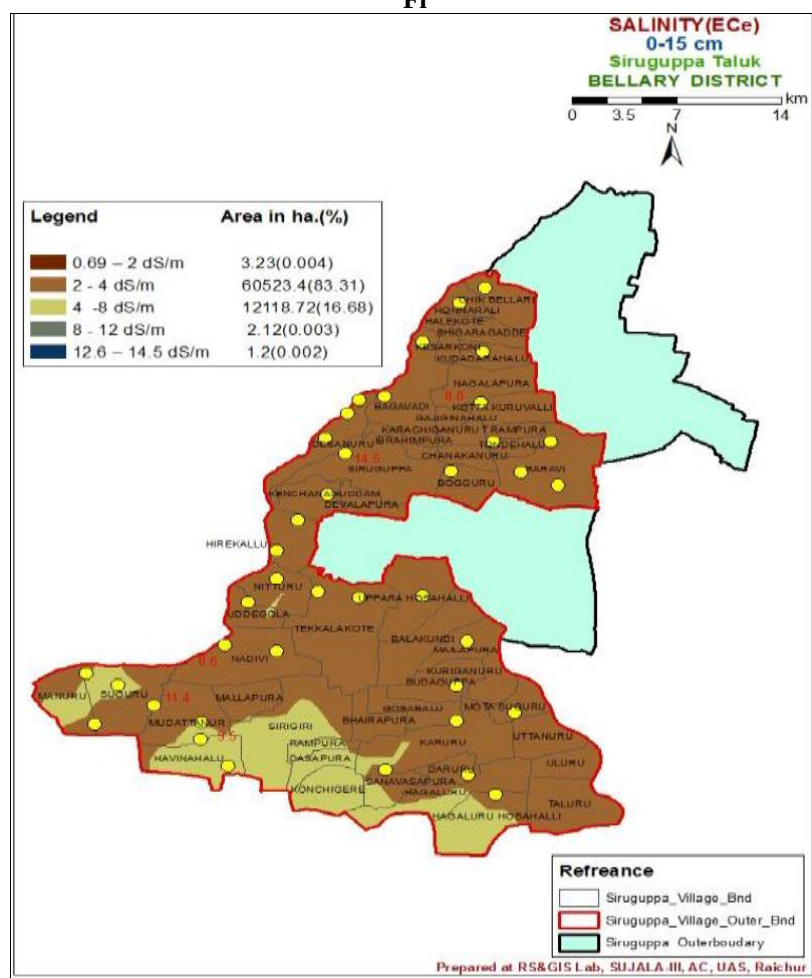
The mean concentrations of the major soluble cations, namely $\text{Ca}^{2+} + \text{Mg}^{2+}$, Na^+ , and K^+ , in the soil saturation extracts of Siruguppa Taluk were 16.36, 33.38, and 0.28 meq L^{-1} at 0-15 cm; 7.87, 27.24, and 0.16 meq L^{-1} at 15-30 cm; 6.87, 23.70, and 0.13 meq L^{-1} at 30-60 cm; and 6.14, 21.20, and 0.07 meq L^{-1} at $>60 \text{ cm}$ depth, respectively. The corresponding mean concentrations of the major anions, namely HCO_3^- , Cl^- , and SO_4^{2-} , were 8.95, 25.44, and 0.85 meq L^{-1} at 0-15 cm; 7.69,

13.00, and 0.59 meq L^{-1} at 15-30 cm; 8.19, 18.80, and 0.72 meq L^{-1} at 30-60 cm; and 8.91, 15.70, and 0.62 meq L^{-1} at $>60 \text{ cm}$ depth, respectively (Table 1).

Irrespective of soil depth, Na^+ was the predominant soluble cation, followed by $\text{Ca}^{2+} + \text{Mg}^{2+}$ and K^+ , while Cl^- was the predominant anion, followed by HCO_3^- and SO_4^{2-} . The relatively higher concentration of Na^+ may be attributed to its greater solubility and mobility compared with several other cationic salts (Sunitha *et al.*, 2010). The predominance of Na^+ and Cl^- indicates their important contribution to the soluble salt composition of the soils. Similar observations regarding the predominance of Na^+ among soluble cations have been reported by Panwar (2015), Sharma and Bhargava (1993), and Challa *et al.* (2000).

The concentrations of the major soluble cations generally showed a decreasing trend with increasing soil depth, particularly for $\text{Ca}^{2+} + \text{Mg}^{2+}$, Na^+ , and K^+ . Among the anions, Cl^- and SO_4^{2-} generally decreased with depth, whereas HCO_3^- showed relatively minor variation. The higher concentration of soluble ions in the surface layer may be associated with the upward movement of soil water through capillary rise followed by evapotranspiration during the dry summer period. Increased evapotranspiration under semi-arid conditions can promote the upward movement and accumulation of soluble salts in the near-surface soil layer. Mohammad *et al.* (2017)^[13] and Scott and Smith (1987) similarly reported that, under irrigated conditions in arid and semi-arid regions, alkali cations may accumulate near the soil surface as a result of capillary movement and evaporation.

Fi



3a: ECE distribution map of surface soil (0-15 cm) in Siruguppa taluk

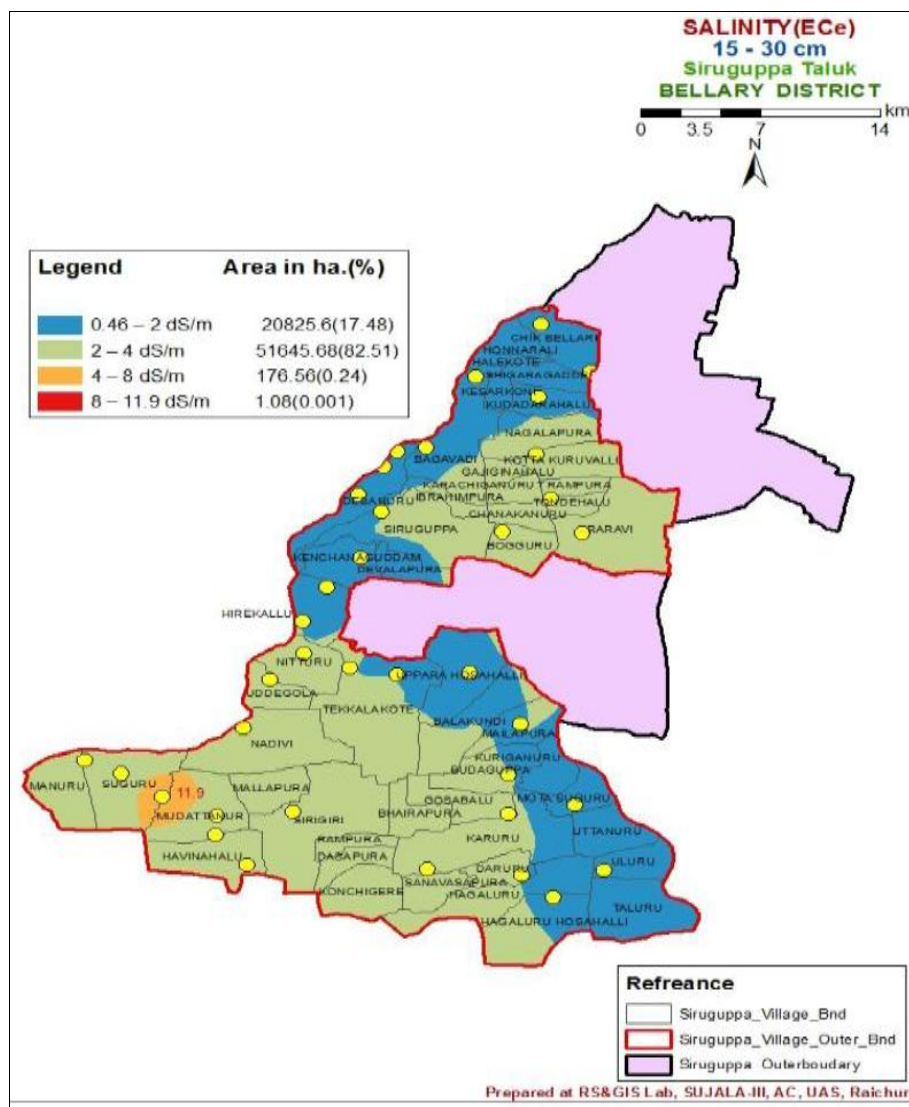


Fig 3b: ECe distribution map of sub-surface soil (15-30 cm) in Siruguppa taluk

$(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$ and $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ Ionic Ratios and Their Spatial Distribution

Irrespective of soil depth, the mean $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$ ratio was <1 at all depths in Siruguppa Taluk (Table 1). Based on the percentage distribution of samples, only 5.10% of the samples at 15-30 cm depth had a ratio >1 (Table 2). In contrast, the mean $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ ratio was generally >1 and ranged from 1.18 to 1.83 across the different soil depths, except at 15-30 cm (Table 1). The proportion of samples having a $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ ratio >1 ranged from 64.1% at 0-15 cm to 84.6% at 15-30 cm depth (Table 2).

Unlike ECe, which reflects the overall concentration of soluble salts, the ionic composition and derived ionic ratios provide additional information on the relative dominance of sodium and alkaline ions and the potential tendency towards sodicity. According to Chhabra (2003), soils in which either $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- + \text{SO}_4^{2-})$ and/or $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-}) >1$ may be considered to have an alkaline or sodicity tendency. Conversely, when both ratios are <1 , the soils may be classified as saline irrespective of their pH and SAR. These criteria should be interpreted in conjunction with ECe, pH, SAR, and other soil chemical properties when assessing the salinity and sodicity status of soils.

The spatial distribution of the mean $(\text{CO}_3^{2-} + \text{HCO}_3^-) / (\text{Cl}^- +$

$\text{SO}_4^{2-})$ ratio in surface and subsurface soils of Siruguppa Taluk is presented in Fig. 4a and 4b. At the surface depth (0-15 cm), nearly 100% of the total mapped area (72,648.92 ha) was classified within the <1 ratio category. Although approximately 5% of the samples recorded values >1 , these isolated values were grouped within the <1 category during spatial interpolation in ArcGIS. At 15-30 cm depth, approximately 90.04% and 9.96% of the area had ionic ratios <1 and >1 , respectively (Fig. 4b).

The spatial distribution of the mean $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ ratio in surface and subsurface soils is shown in Fig. 5a and 5b. At the surface depth, approximately 20.58% of the total mapped area had a ratio <1 , whereas 79.41% had a ratio >1 . At 15-30 cm depth, approximately 6.56% and 93.43% of the area had $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-})$ ratios <1 and >1 , respectively (Fig. 5b).

The predominance of areas with $\text{Na}^+ / (\text{Cl}^- + \text{SO}_4^{2-}) >1$, particularly at the 15-30 cm depth, indicates a substantial sodium dominance in the soluble salt composition of the Siruguppa soils. This spatial pattern, together with the observed SAR values, suggests that several parts of the study area may have a potential tendency towards sodicity and therefore warrant regular monitoring and appropriate soil-water management and reclamation measures.

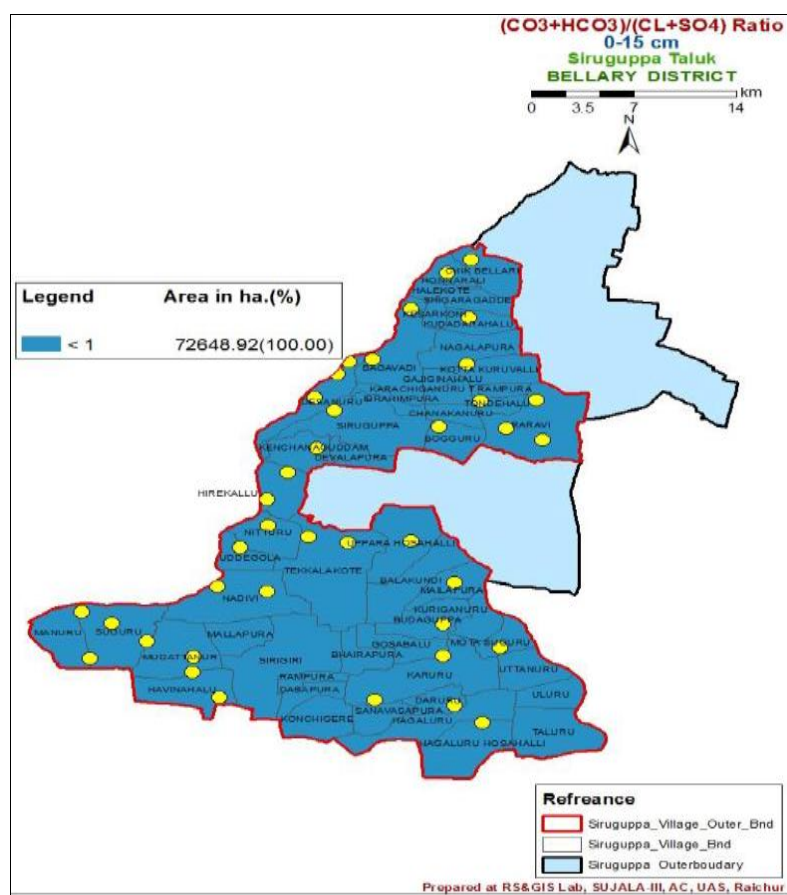


Fig 4a: (CO₃+HCO₃)/(Cl+SO₄) ionic ratio distribution map of surface soil (0-15 cm) in Siruguppa taluk

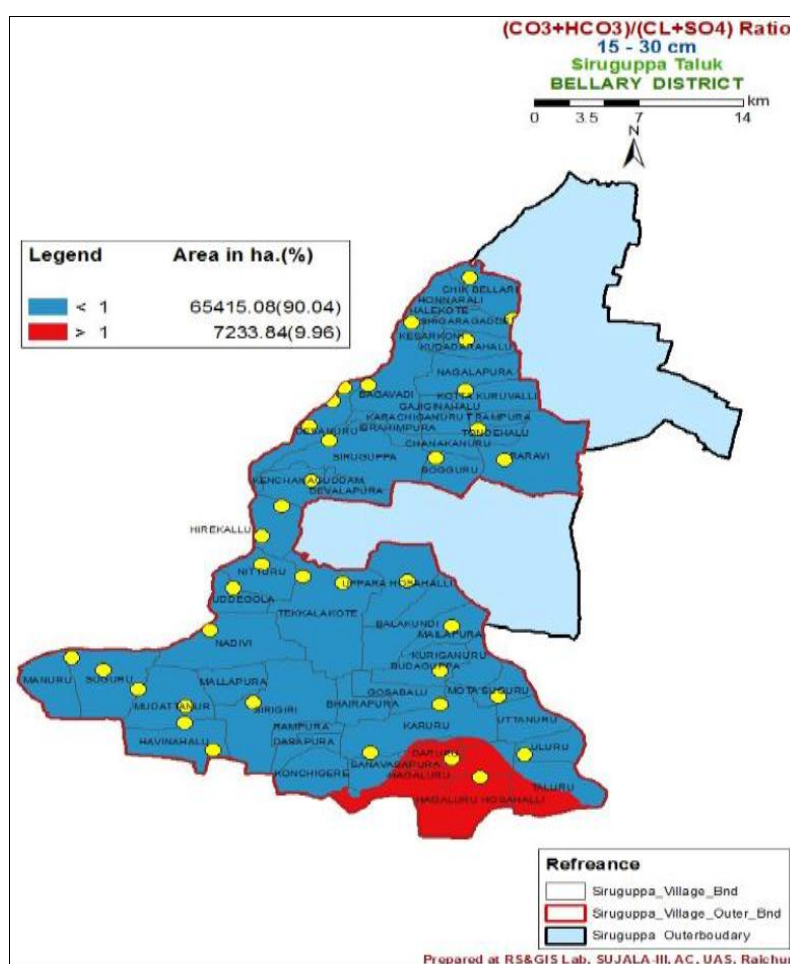
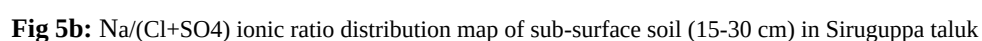
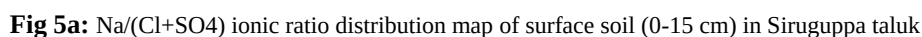


Fig 4b: (CO₃+HCO₃)/(Cl+SO₄) ionic ratio distribution map of sub-surface soil (15-30 cm) in Siruguppa taluk



Sodium Adsorption Ratio (SAR)

The mean SAR values of the soils of Siruguppa Taluk were 11.30, 13.48, 11.70, and 11.90 at 0-15, 15-30, 30-60, and >60 cm depths, respectively (Table 1). Based on the percentage distribution of samples (Table 2), 30.0-33.3% of the samples recorded SAR values >13 across the different soil depths, with the highest proportion observed at 15-30 cm depth (33.3%) and the lowest at >60 cm depth (30.0%). The relatively higher SAR values in the subsurface layers, particularly at 15-30 cm depth, indicate a potential tendency for sodium accumulation in the subsoil. Such accumulation may contribute to the development of sodicity, particularly where soluble salts are leached from the upper soil layers without adequate drainage and calcium replacement. Similar observations have been reported by Sharma (2002), Balpande *et al.* (1996) [2], and Challa *et al.*

(2000).

The spatial distribution of SAR in the surface and subsurface soils of Siruguppa Taluk is presented in Fig. 6a and 6b. At the surface depth (0-15 cm), approximately 75.56%, 23.65%, 0.78%, and 0.003% of the total mapped area (72,648.92 ha) had SAR values in the ranges of 1.17-13.0, 13.0-20.0, 20.0-30.0, and 30.0-37.47, respectively. At 15-30 cm depth, approximately 53.96%, 29.74%, 16.20%, and 0.04% of the area had SAR values in the ranges of 2.98-13.0, 13.0-20.0, 20.0-30.0, and 30.0-37.03, respectively (Fig. 6b). Because of their very limited spatial occurrence, the maximum SAR values of 37.47 at 0-15 cm and 37.03 at 15-30 cm were grouped within the 20.0-30.0 class during spatial interpolation and mapping.

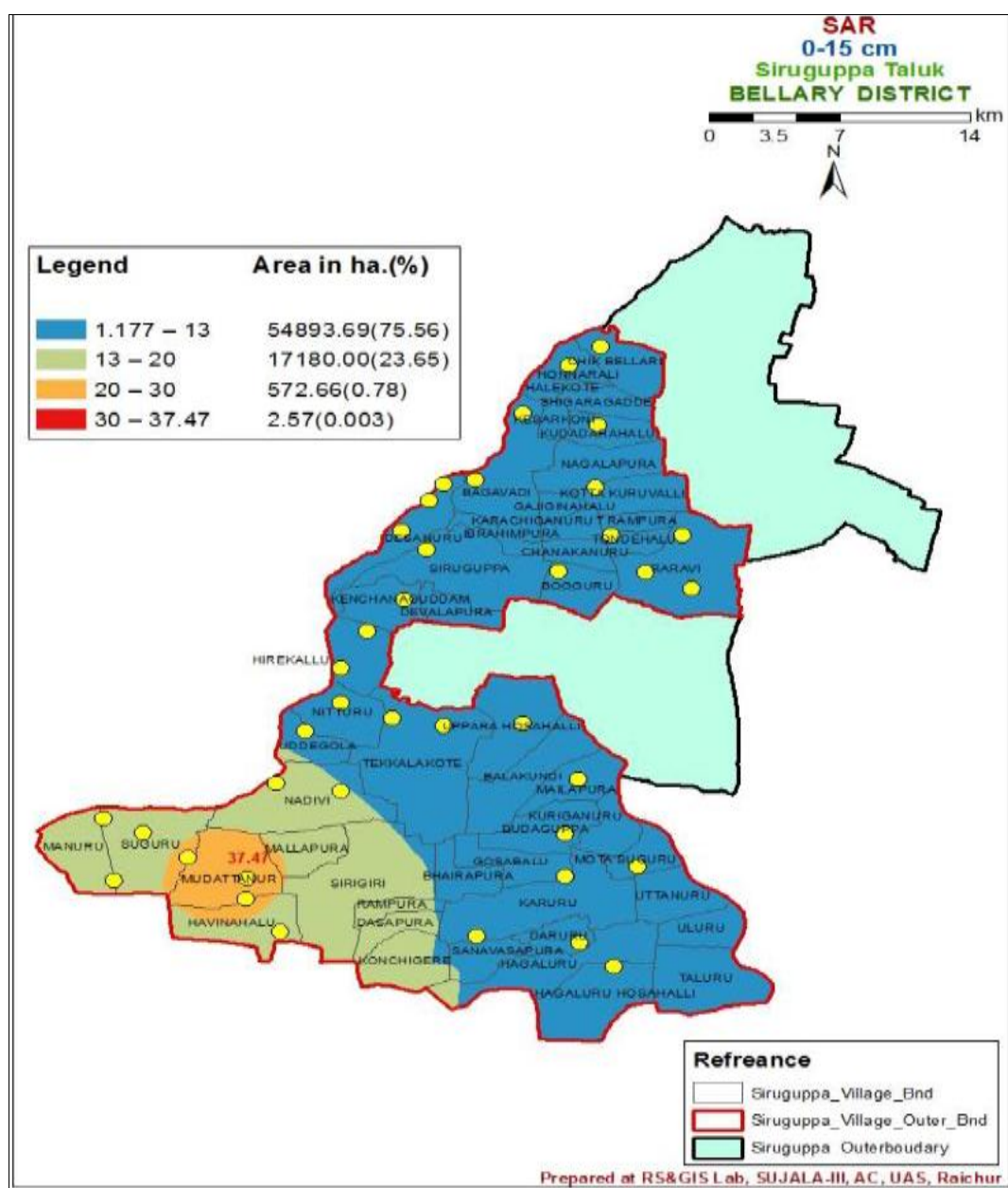


Fig 6a: SAR distribution map of surface soil (0-15 cm) in Siruguppa taluk

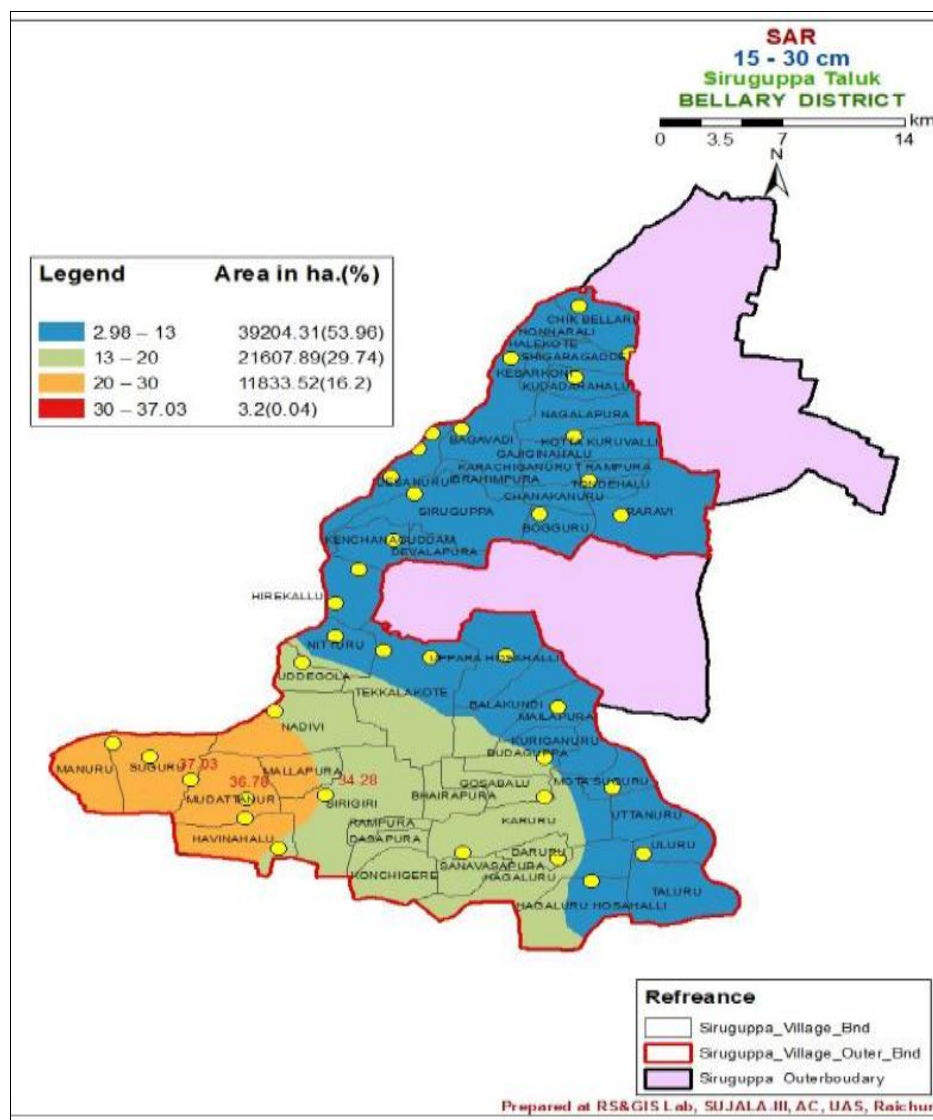


Fig 6b: SAR distribution map of sub-surface soil (15-30 cm) in Siruguppa taluk

Conclusion

The study revealed that approximately 28.3% of the surface soil samples (0-15 cm) collected from different grids in Siruguppa Taluk had $EC_e > 4.0 \text{ dS m}^{-1}$, indicating saline conditions at the time of sampling. In the subsurface layers, approximately 8-20% of the samples recorded EC_e values $> 4.0 \text{ dS m}^{-1}$, demonstrating that salinity was also present at different depths. The occurrence of elevated SAR values further indicated a potential sodicity hazard, with approximately 31% of the surface soil samples having $SAR > 13$. At subsurface depths, 30-33.3% of the samples also recorded $SAR > 13$, with the highest proportion occurring at 15-30 cm depth.

Overall, the results indicate that both salinity and sodicity are important soil constraints in parts of Siruguppa Taluk, with considerable variation across soil depths and sampling locations. The observed distribution of EC_e and SAR highlights the need for systematic monitoring and site-specific management practices, including improved drainage, appropriate irrigation and leaching management, and suitable soil reclamation measures, to prevent further deterioration and sustain agricultural productivity in the Tungabhadra irrigation command.

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