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Primary and secondary nutrient status of salt affected soils of Siruguppa taluk in TBP irrigation command area, Karnataka

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Abstract

A study was conducted to assess the status of primary nutrients (available N, P_2O_5 and K_2O) and secondary nutrients (exchangeable Ca, exchangeable Mg and available S), and their relationship with soil properties in Siruguppa taluk of Ballari district using GPS and topographic sheets at a scale of 1:50,000. A total of 78 soil samples were collected from two depths (0-15 and 15-30 cm) during the summer of 2017 on a grid basis ($5' \times 5'$) from 13 grids comprising 39 sampling points. The collected soil samples were analyzed for primary and secondary nutrient status. Among the primary nutrients, the majority of surface and subsurface soil samples were categorized as low in available nitrogen (89.74 and 100%, respectively) with values below 280 kg ha^{-1} . In contrast, available phosphorus was predominantly in the high category ($>56.3 \text{ kg ha}^{-1}$), accounting for 94.87 and 87.17% of the surface and subsurface samples, respectively. Available potassium was also predominantly in the high category ($>336 \text{ kg ha}^{-1}$), comprising 87.17 and 61.53% of the surface and subsurface samples, respectively. Among the secondary nutrients, exchangeable calcium was predominantly in the medium category ($12.5\text{-}25 \text{ meq } 100 \text{ g}^{-1}$), accounting for 58.97% of the surface samples, whereas 48.71% of the subsurface samples were in the high category ($>25 \text{ meq } 100 \text{ g}^{-1}$). Exchangeable magnesium was predominantly in the medium category ($10.3\text{-}20.6 \text{ meq } 100 \text{ g}^{-1}$) in surface soils, accounting for 74.36% of the samples, while 51.28% of the subsurface samples were in the low category ($<10.3 \text{ meq } 100 \text{ g}^{-1}$). Available sulphur was predominantly in the high category ($>50 \text{ ppm}$), accounting for 76.92 and 74.36% of the surface and subsurface samples, respectively. The findings provide valuable information on the distribution of primary and secondary nutrients and may support site-specific nutrient management and sustainable soil fertility management in the study area.

Keywords: Primary nutrients, secondary nutrients, soil nutrient status, nutrient distribution, GPS, salt-affected soils

1. Introduction

Soil is one of the most valuable natural resources and plays a fundamental role in sustaining agricultural productivity. Salt-affected soils constitute one of the major forms of land degradation, in which soil productivity is reduced due to salinization ($EC > 4 \text{ dS m}^{-1}$), sodicity ($ESP > 15$), or a combination of both. Although all soils contain soluble salts, which may provide essential nutrients required for plant growth, excessive accumulation of salts in the active root zone adversely affects plant growth, yield, and quality. When salt concentrations exceed the tolerance threshold of crops, the soil becomes salt-affected and its productive capacity is considerably reduced. These soils are generally distinguished from normal soils by their higher concentration of soluble electrolytes and/or exchangeable sodium (Szabolcs, 1989) [39].

Excessive accumulation of salts in soil induces several forms of degradation, including soil particle dispersion, surface crusting, deterioration of soil structure, reduced porosity, and compaction. High salinity can also cause nutrient imbalances and may increase the uptake and accumulation of potentially toxic ions in plants (Priyadarshini, 2011) [16]. Based on their chemical characteristics, salt-affected soils are broadly classified as saline, sodic, and saline-sodic soils. In India, they are commonly grouped into saline and sodic (alkali) soils. According to reconciled estimates reported by CSSRI, Karnal, NRSA, and NBSS & LUP (2006) [11], approximately 6.73 million hectares of land in India were affected by salinity and sodicity, comprising about 3.77 million hectares of sodic soils and 2.96

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million hectares of saline soils. It was projected that approximately 11.7 million hectares would be affected by salinity and alkalinity by 2025. However, estimates of salt-affected areas vary considerably because remote-sensing-based assessments can be influenced by soil moisture, parent material, vegetation cover, and other surface characteristics (Mandal & Sharma, 2001)^[9].

Salt-affected soils exhibit considerable variation in their physical, chemical, and biological properties, resulting in differences in soil productivity among regions. Therefore, understanding the nature and extent of soil degradation in a particular area is essential for developing appropriate management and reclamation strategies. In the Tungabhadra Project (TBP) command area, soil salinity and waterlogging are major constraints to agricultural production. These problems have developed largely due to inappropriate land and water management practices and deviations from recommended cropping patterns over several decades. Approximately 96,215 ha, representing 26.5% of the total command area, have been reported to be salt-affected (Anonymous, 2012)^[1], with an estimated additional 1,000 ha becoming affected annually (IDNP, 2002)^[5]. Continuous monitoring of soil salinity and associated changes in soil properties is therefore essential for identifying areas undergoing degradation and for facilitating timely modification of management practices and implementation of appropriate reclamation measures.

Salt-affected soils, particularly those occurring in irrigated command areas, pose a serious challenge to sustainable agricultural production. These soils are characterized by excessive concentrations of soluble salts, including sodium chloride (NaCl), which adversely affect plant growth, soil structure, nutrient availability, and overall soil fertility. In irrigation command areas, salinization commonly develops when salts accumulate within the root zone as a consequence of irrigation, inadequate drainage, high evaporative demand, and rising groundwater levels. The accumulation of salts can restrict nutrient availability and ultimately reduce crop growth and productivity. Therefore, assessment of the availability of primary nutrients, namely nitrogen (N), phosphorus (P), and potassium (K), together with secondary nutrients such as calcium (Ca), magnesium (Mg), and sulfur (S), is essential for evaluating the fertility status and nutrient-supplying capacity of salt-affected soils.

The availability of these nutrients is strongly influenced by the degree of salinity and sodicity. Excess soluble salts can alter soil chemical conditions, affect nutrient equilibria, and interfere with nutrient absorption by plant roots, thereby resulting in nutrient deficiencies or imbalances. In particular, excessive sodium concentrations may interfere with potassium uptake because of competition between Na^+ and K^+ at the root surface, thereby affecting plant nutrition and physiological processes (Shahin *et al.*, 2009)^[22]. Furthermore, the accumulation of sodium can cause dispersion of soil particles and deterioration of soil structure, resulting in reduced infiltration, restricted aeration, and impaired water movement within the soil profile. These changes can further intensify the adverse effects of salinity and reduce the efficiency of nutrient uptake by crops (Munns & Tester, 2008)^[10].

Therefore, systematic assessment of the spatial distribution and availability of primary and secondary nutrients in salt-affected soils is important for developing site-specific nutrient management strategies. The use of GPS-based soil

sampling and spatial mapping can provide valuable information on the distribution of soil fertility parameters and help identify nutrient-deficient areas. Such information is particularly useful in irrigated command areas such as the Tungabhadra Project region, where salinity, sodicity, and waterlogging interact with soil fertility and crop productivity. In saline soils, the availability of nitrogen may be reduced because excessive salt concentrations can suppress microbial activity and disrupt important processes involved in the soil nitrogen cycle (Yusuf *et al.*, 2008)^[37]. High salinity can also inhibit biological nitrogen fixation by rhizobial bacteria, thereby affecting the nitrogen supply to leguminous crops. Phosphorus availability may likewise be reduced in salt-affected soils because of its interactions with calcium and magnesium and the formation of relatively less soluble phosphate compounds. Under saline conditions, phosphorus may precipitate or become associated with soil constituents, thereby reducing its availability for plant uptake (Zhao *et al.*, 2009)^[38]. Potassium is particularly important for maintaining plant water relations, enzyme activity, and tolerance to abiotic stress; however, excessive sodium can compete with potassium for uptake at the root surface, resulting in reduced potassium acquisition and potential potassium deficiency (Shahin *et al.*, 2009)^[22].

The availability of secondary nutrients, particularly calcium and magnesium, can also be affected by salinity and sodicity. High concentrations of sodium may alter the exchangeable cation balance and displace calcium and magnesium from soil exchange sites, thereby influencing their availability to plants. Calcium is especially important for maintaining soil aggregation and structural stability, as well as supporting plant cell-wall integrity. A reduction in exchangeable calcium can contribute to deterioration of soil structure, reduced aggregate stability, and impaired water infiltration. Magnesium, an essential component of chlorophyll and an important activator of several plant enzymes, may also become nutritionally limiting under unfavorable salt-affected conditions.

Effective management of nutrient status in salt-affected soils, particularly in irrigation command areas, requires regular assessment of soil fertility and appropriate site-specific interventions. The application of organic amendments can improve soil physical properties, microbial activity, and nutrient availability, while efficient irrigation and drainage management can reduce the accumulation of soluble salts in the root zone. Balanced application of fertilizers based on soil-test results is also essential to correct nutrient deficiencies and avoid unnecessary fertilizer inputs. In addition, the cultivation of salt-tolerant crop varieties can improve crop establishment, nutrient-use efficiency, and productivity under saline conditions. An integrated approach combining salinity management, balanced nutrient application, organic amendments, appropriate irrigation and drainage, and salt-tolerant crops is therefore essential for maintaining soil fertility and sustainable agricultural production in salt-affected areas.

2. Material and methods

Study Area

The Tungabhadra irrigation command area is an important agricultural region in Karnataka that provides irrigation facilities to crops grown in Ballari, Koppal, and parts of Raichur districts. The present study was conducted in Siruguppa taluk of Ballari district, located in the eastern part

of Karnataka. Ballari district extends between approximately 15°30' and 15°50' N latitude and 75°40' and 77°11' E longitude and covers 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. The taluk covers a geographical area of approximately 1,042 km² (Fig. 1). 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, to a limited extent, deep alluvial clayey soils. The region receives an average annual rainfall of approximately 658.3 mm. Agriculture is the predominant land-use activity, with major crops including paddy, sorghum (jowar), maize, cotton, and sugarcane. The availability of irrigation from the Tungabhadra command area supports intensive cultivation and makes the region particularly important for studying soil fertility and nutrient distribution in salt-affected soils.

Collection of soil samples and mapping of primary and secondary nutrients

Soil Sampling and Analysis

Soil samples were collected during April-May 2017 from the Siruguppa taluk of Ballari district using GPS and topographic sheets at a scale of 1:50,000. Sampling locations were selected on a grid basis at 5' × 5' intervals across 20 grids. Soil samples were collected from areas falling within the Tungabhadra Project (TBP) command, particularly those receiving irrigation from the Left Bank Canal. Samples were collected from four soil depths, namely 0-15, 15-30, 30-60, and >60 cm, using a soil auger. The collected soil samples were air-dried under shade, gently crushed using a pestle and mortar, and passed through a 2-mm sieve to remove coarse fragments and plant residues. The processed samples were subsequently stored in clean, labeled polythene bags until laboratory analysis. The samples were analyzed for primary nutrients, including available nitrogen (N), phosphorus (P₂O₅), and potassium (K₂O), and secondary nutrients, including exchangeable calcium (Ca), exchangeable magnesium (Mg), and available sulphur (S), following standard analytical procedures. An overview of salt-affected soils and the soil-sampling locations within the TBP command area is presented in Plates 1a and 1b.

3. Results and discussion

Characterization of soil samples of the study area

The soil pH, EC (dS m⁻¹), organic carbon content, and per cent distribution of soil samples are presented in Tables 1 and 2.

Soil pH (1:2.5)

The soil pH (1:2.5) at depths of 0-15, 15-30, 30-60, and >60 cm ranged from 7.48 to 8.96, 7.60 to 9.45, 7.68 to 9.12, and 7.70 to 8.90, respectively, with corresponding mean values of 8.00, 8.15, 8.20, and 8.24. The mean soil pH showed a slight increasing trend with increasing soil depth. As presented in Table 1, the mean soil pH at all depths in Siruguppa taluk was within the moderately alkaline category (pH 8.0-8.5) according to Brady and Weil (2007).

The slightly alkaline reaction of these soils may be attributed to the prevailing semiarid climate, the presence of basic parent material (*viz.*, gneissic complex), restricted

drainage, and relatively high levels of calcium carbonate and exchangeable bases (Ravi Kumar *et al.*, 2007) [19]. Regarding the percentage distribution of soil pH, approximately 78.57% of the samples at 30-60 cm depth to 89.74% of the samples at 0-15 cm depth were classified as mildly to moderately alkaline (Table 2). Priyadarshini (2011) [16] reported that approximately 45, 11, and 12% of surface soil samples from salt-affected soils of the Nellore and Gudur divisions of Nellore district, Andhra Pradesh, were mildly alkaline, moderately alkaline, and strongly alkaline (pH > 8.5), respectively.

The relatively lower pH observed in surface soils may be associated with the release of organic acids during the decomposition of organic matter (Bhadrapur and Seshagiri Rao, 1977) [3]. In contrast, the gradual increase in soil pH with depth may be attributed to the leaching and subsequent accumulation of exchangeable sodium and calcium carbonate at lower depths. Under conditions of low CO₂ availability, the formation and accumulation of sodium carbonate may further contribute to the higher pH observed in the subsoil layers (Shivakumar *et al.*, 2017; Sharma *et al.*, 2008) [24, 29]. Similar trends have been reported by Yeresheemi *et al.* (1997) [36] in salt-affected soils of the Upper Krishna Project in Karnataka, Balpande *et al.* (1996) [2] in degraded Vertisols of the Purna Valley in Maharashtra, and Mahendra (2007) [8] in soils of the Main Agricultural Research Station, Dharwad, Karnataka.

Soil EC (1:2.5)

The electrical conductivity (EC, 1:2.5) of the soil at depths of 0-15, 15-30, 30-60, and >60 cm ranged from 0.33 to 6.30, 0.25 to 7.60, 0.32 to 6.60, and 0.30 to 3.80 dS m⁻¹, respectively, with corresponding mean values of 1.69, 1.21, 1.47, and 1.22 dS m⁻¹. Unlike soil pH, the mean EC did not show a consistent trend with increasing soil depth. However, the surface soil samples generally recorded slightly higher EC values than the subsurface layers.

Overall, the mean EC values were below 4.0 dS m⁻¹ at all depths, indicating that the soils were generally non-saline at the time of sampling. However, the percentage distribution of EC values (Table 2) revealed that 2.56% of the samples at 15-30 cm depth and 7.69% of the samples at 0-15 cm depth had EC values exceeding 4.0 dS m⁻¹. These samples can be classified as saline at the time of sampling, indicating localized accumulation of soluble salts within the soil profile. The relatively higher proportion of saline samples in the surface layer may be associated with upward movement and accumulation of soluble salts under conditions of high evaporative demand and inadequate drainage.

Soil Organic Carbon

The mean soil organic carbon (OC) content was higher in the surface soil (0.92%) than in the subsurface soil (0.46%) of Siruguppa taluk (Table 1). Approximately 66.7% of the surface soil samples and 15.4% of the subsurface soil samples had OC contents in the high category (>0.75%), according to the soil-test fertility ratings of Tandon (2017) [33]. The higher OC content in surface soils may be attributed to the accumulation of root biomass, decomposition of previous crop residues, and the regular addition of farmyard manure (FYM) and other organic manures over the years. These inputs contribute to the enrichment of organic carbon in the surface layer compared with the lower soil depths.

The present findings are in agreement with those reported for the soils of Gangavathi taluk by Ravi Kumar *et al.* (2007) and Wijebandara *et al.* (2011)^[19, 35], who observed medium to high levels of organic carbon and attributed the relatively higher OC status to the incorporation of paddy stubbles in situ and the addition of organic manures to the soil.

Available nitrogen

Similar to organic carbon, the mean available N content was higher at surface (214.9 kg ha⁻¹) compared to sub-surface soils (119.2 kg ha⁻¹) in Siruguppa taluk (Table 3). However, the mean nitrogen contents were in the low category (<280 kg ha⁻¹) as per soil test fertility ratings (Tandon, 2017)^[33]. Nearly 89.74 per cent of surface samples in Siruguppa taluk (Table 4) were in low category. Though the organic carbon content of these soils generally is in high category, the low levels of available N observed in these soils could be due to the reasons that the nitrogen is vulnerable to losses viz., leaching, volatilization, denitrification process etc (Rao and Batra, 1983). The results are in line with Patel *et al.* (2017)^[13, 18] who also observed lower available N in salt affected soils of Dholka taluka of Bhal region in Gujarat.

Available phosphorus

Unlike available N, the mean available P₂O₅ content was higher at surface (231.3 kg ha⁻¹) compared to sub-surface (190.4 kg ha⁻¹) soil particularly in Siruguppa taluk (Table 3). Crop residue and organic matter on the surface might have favoured the solubilisation of insoluble phosphorus thus releasing more quantity on the surface (Chaudhary and Ghosh, 2006)^[4]. Further, in contrast to available P₂O₅, the per cent distribution of samples revealed that 94.9 (surface) and 87.2% (sub-surface) in Siruguppa taluk (Table 4) were in high category (>56.3 kg ha⁻¹) (Tandon, 2017)^[33] reflecting that the soils are amply supplied with phosphorus. Regular application of DAP and also poultry manure for paddy-paddy cropping system over the years might have resulted in build-up of sufficient phosphorus in these soils.

Available potassium

Similar to available N, the mean available K₂O content was higher in surface (506.4 kg ha⁻¹) compared to sub-surface (400.1 kg ha⁻¹) soils in Siruguppa taluk (Table 3). Similar to P₂O₅, the maximum per cent of surface (Table 4) (87.2) and sub-surface (61.5) samples had available K₂O content in high category (>336 kg ha⁻¹) as per soil test fertility ratings (Tandon, 2017)^[33]. Higher availability of potassium in these soils might be due to predominance of K rich micaceous minerals in the soils of arid and semi-arid regions (Kapoor *et al.*, 1981 and Ravi Kumar *et al.*, 2007)^[6, 19] and release of

K by dissolution of muscovite in sodic environment (Pal, 1985)^[12].

In general, slightly lower available N, P₂O₅ and K₂O content in subsurface soils compared to surface could be attributed to lower OC content, microbial activity etc., at lower layers. Exchangeable Calcium (Ca), Magnesium (Mg) and Available Sulphur (S) content and per cent distribution of surface and sub-surface samples of Siruguppa taluk is presented in Tables 3 and 4 respectively.

Exchangeable calcium

Irrespective of soil depths, the mean exchangeable Ca content was slightly low in surface (21.53 meq 100 g⁻¹) compared to sub-surface (23.76 meq 100 g⁻¹) soil in Siruguppa taluk, (Table 3). The maximum per cent of surface (58.97 meq 100 g⁻¹) and sub-surface (48.7 meq 100 g⁻¹) samples were in medium (12.5-25 meq 100 g⁻¹) to high (>25 meq 100 g⁻¹) in Siruguppa taluk (Table 4), as per soil test fertility ratings (Tandon, 2017)^[33].

Calcium usually dominates the exchange complex in soils of semiarid regions (Sharma *et al.*, 1996)^[27]. Similar results were reported by Surekha *et al.* (1997)^[30] in semi-arid climate of Andhra Pradesh, Sharma *et al.* (2004)^[25] in salt-affected soils of Southern Rajasthan and also by Ram *et al.* (2010)^[17] in flood prone soils of Eastern Rajasthan. The probable reason for higher concentration of exchangeable calcium at lower depth might be due to their greater solubility and leaching on account of irrigation (Pathak and Patel, 1980)^[15].

Exchangeable magnesium

Irrespective of soil depths, the mean exchangeable Mg content was high in surface (12.25 meq 100 g⁻¹) compared to sub-surface (10.18 meq 100 g⁻¹) soil in Siruguppa taluk (Table 3). The maximum per cent of surface (74.36 meq 100 g⁻¹) and sub-surface (51.28 meq 100 g⁻¹) samples were in medium (10.3-20.6 meq 100 g⁻¹) to low (<10.3 meq 100g⁻¹) category in Siruguppa taluk (Table 4), as per soil test fertility ratings (Tandon, 2017)^[33].

Available sulphur

The mean available sulphur in surface soil (236.8 ppm) was higher than the subsurface soil (160.9 ppm) in Siruguppa taluk (Table 3). The maximum per cent of surface (76.92) and sub-surface (74.36) samples had available sulphur content in high (>50 ppm) in Siruguppa taluk (Table 4), as per soil test fertility ratings (Tandon, 2017)^[33]. The higher content of available sulphur in these soils may be due to the presence of soluble salt present in the soil and addition of sulphur through fertilizer. Similar results were reported by Shivakumar *et al.* (2017)^[29] for salt affected soils of Vani Vilas command area of Hiriyur taluk, Chitradurga district.

Table 1: pH_(1:2.5), EC (dS m⁻¹) and organic carbon status in salt affected soils of Siruguppa taluk, Bellary district, Karnataka

Soil properties	Soil depth (cm)											
	0-15			15-30			30-60			60-90		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
pH	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 (dS m ⁻¹)	0.33	6.30	1.69	0.25	7.60	1.21	0.32	6.60	1.47	0.30	3.80	1.22
OC (%)	0.14	1.66	0.92	0.12	1.39	0.46	nd*					

Note: nd*= Not determined



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



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

Table 2: Per cent distribution of soil samples with respect to different ratings of soil pH, EC and organic carbon content of Siruguppa taluk

Soil Depth (cm)	pH			EC (dS m ⁻¹)			OC (%)		
	<7.5	7.5-8.5	>8.5	<2	2-4	>4	<0.5	0.5-0.75	>0.75
0-15	2.56 (1)	89.74 (35)	7.69 (3)	76.92 (30)	15.38 (6)	7.69 (3)	10.26 (4)	23.10 (9)	66.66 (26)
15-30	0	82.05 (32)	17.95 (7)	92.31 (36)	5.13 (2)	2.56 (1)	56.41 (22)	28.20 (11)	15.38 (6)
30-60	0	78.57 (22)	21.43 (6)	82.14 (23)	10.71 (3)	7.14 (2)	nd*		
60+	0	80.00 (16)	20.00 (4)	80.00 (16)	20.00 (4)	0			

Note: Values in parenthesis indicate number of samples nd*= Not determined

Table 3: Primary and secondary nutrient status in salt affected soils of Siruguppa taluk, Bellary district, Karnataka

Soil properties	Soil depth (cm)					
	0-15			15-30		
	Min.	Max.	Avg.	Min.	Max.	Avg.
Avail. N (kg ha ⁻¹)	15.68	338.69	214.86	43.90	235.20	119.25
Avail. P ₂ O ₅ (kg ha ⁻¹)	41.75	505.89	231.34	12.45	470.45	190.41
Avail. K ₂ O (kg ha ⁻¹)	157.49	952.22	506.43	189.52	883.32	400.07
Exch. Ca (meq 100g ⁻¹)	6.50	42.50	21.53	9.10	40.30	23.76
Exch. Mg (meq 100g ⁻¹)	2.60	20.20	12.25	0.70	22.10	10.18
Avail. S (ppm)	30.20	845.60	236.80	17.20	815.50	160.90

Table 4: Per cent distribution of soil samples with respect to different rating of primary and secondary nutrients in salt affected soils of Siruguppa taluk, Bellary district, Karnataka

Soil properties	Soil depth (cm)					
	0-15			15-30		
	Low	Medium	High	Low	Medium	High
Avail. N (kg ha ⁻¹)	89.74 (35)	10.26 (4)	0	100.00 (39)	0	0
Avail. P ₂ O ₅ (kg ha ⁻¹)	0	5.12 (2)	94.87 (37)	5.12 (2)	7.69 (3)	87.17 (34)
Avail. K ₂ O (kg ha ⁻¹)	0	12.82 (5)	87.17 (34)	0	38.46 (15)	61.53 (24)
Exch. Ca (meq 100g ⁻¹)	12.82 (5)	58.97 (23)	28.20 (11)	10.25 (4)	41.02 (16)	48.71 (19)
Exch. Mg (meq 100g ⁻¹)	25.64 (10)	74.36 (29)	0	51.28 (20)	46.15 (18)	2.56 (1)
Avail. S (ppm)	0	23.08 (9)	76.92 (30)	0	25.64 (10)	74.36 (29)

Note: Values in parenthesis indicate number of samples

	N	P ₂ O ₅	K ₂ O	Ca	Mg	S	Zn	Fe	Mn	Cu
	(kg ha ⁻¹)	(kg ha ⁻¹)	(kg ha ⁻¹)	(meq 100g ⁻¹)	(meq 100g ⁻¹)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Low	<280	<22.9	<129.6	<12.5	<10.3	<10	<1	<2.5	<5	<0.5
Medium	280-560	22.9-56.3	129.6-336	12.5-25	10.3-20.6	10-50	1-2.5	2.5-10	5-25	0.5-2.5
High	>560	>56.3	>336	>25	>20.6	>50	>2.5	>10	>25	>2.5

Conclusion

The study revealed that the mean soil pH at all depths in Siruguppa taluk fell within the moderately alkaline category (pH 8.0-8.5). Overall, the mean electrical conductivity (EC) values were below 4.0 dS m⁻¹ at all depths, indicating that the soils were generally non-saline. However, 7.69% of the surface soil samples (0-15 cm) and 2.56% of the subsurface soil samples (15-30 cm) collected from different grids of Siruguppa taluk recorded EC values exceeding 4.0 dS m⁻¹, indicating localized salinity at the time of sampling. The soils were predominantly characterized by medium to high organic carbon content. With respect to primary nutrients, the mean values indicated that the soils were low in available nitrogen (<280 kg ha⁻¹), whereas available phosphorus (>56 kg ha⁻¹) and potassium (>336 kg ha⁻¹) were in the high category. Among the secondary nutrients, the mean exchangeable magnesium content was in the medium category (10.3-20.6 meq 100 g⁻¹) in surface soils and in the low category (<10.3 meq 100 g⁻¹) in subsurface soils. The mean exchangeable calcium content was in the medium category (12.5-25.0 meq 100 g⁻¹), while the mean

available sulphur content was in the high category (>50 ppm) across the study area. Overall, the findings highlight the need for balanced and site-specific nutrient management, particularly for nitrogen and magnesium, along with regular monitoring of soil salinity to maintain soil fertility and sustain crop productivity in the TBP command area.

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