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Original Article

Soil Nutrient Index of the Semi-Arid Region of Kolar Taluk, Karnataka, India

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Abstract *- A study highlights the estimation of soil nutrient content of thirty-seven samples that were collected randomly in Kolar Taluk during the pre-monsoon season, 2022. Kolar Taluk lies geographically between 13° 02′ 03″ and 13°19′11″ Northern Latitudes and 77° 56′ 02″ and 78° 13′ 02″ eastern longitudes. The Organic Carbon, available Phosphorus, and Potassium were analyzed as per Standard Methods. The results of the soil fertility level showed little variation across different landforms. Organic matter and its decomposition rate differed among the soils. 2.4 to 3.4% of organic carbon. 97% had a higher level of Phosphorus with a range of 33.80 -511.13 kg/ha, whereas 54.05% were doubtful. The available potash supply is 113.42-279.05 kg/ha. ESP, SAR ratio indicated that the soils were found to be highly suitable for irrigation. The quality of Soil falls into the High-High-Low (HHL) category as per the nutrient index. This classification is primarily based on the amount of available Phosphorus, Organic Carbon, and Potassium, and these index values would help in the maintenance of soil fertility and suitable crops.*

Keywords *- Macro Nutrients, Nutrient Index Approach, SAR, ESP, Available Potash.*

1. Introduction

Fertility is the Soil's fundamental capability to provide nutrients in sufficient quantity and optimal proportions. In contrast, the yield of Soil reflects the Soil's ability to grow crops under precise maintenance practices, typically measured as yield. These properties of Soil are highly significant in the production of food, as they directly influence agricultural output. Evaluation of soil quality is crucial for sustainable agriculture, especially in regions affected by soil degradation. Adequate nutrient availability improves soil structure, aeration, and water holding capacity, thereby supporting efficient root growth and nutrient uptake. In contrast, nutrient deficiencies often result in visible crop symptoms and reduced productivity. Therefore, assessing soil fertility status is essential for identifying nutrient limitations and guiding appropriate management [9]. Regular replenishment of macro- and micronutrients, along with suitable soil amendments, is necessary to maintain soil health and an active, optimal crop yield. The ability of Soil to produce both commercial crops and the health of the Soil are essential. Whereas in irrigation, the compatibility of Soil and water is crucial; inappropriate irrigation practices can negatively impact the Soil's physicochemical properties. Thus, assessment of the land suitability to irrigate necessitates a comprehensive evaluation of Soil Properties, Land Terrain, and Quality of Irrigation water to be used [17]. A loss of Soil of a significant quantity of nutrients annually due to various factors such as cropping patterns, leaching, and erosion, etc. Soil testing is crucial as it provides insights into nutrient availability, providing the foundation for recommendations of fertilizer aimed at increasing crop yields. Also, it helps increase the application of excessive and haphazard fertilizers, fungicides, pesticides, and other substances, which can lead to the control of environmental pollution. By equipping farmers and planners with knowledge about appropriate application quantities, this approach enables accurate determination of soil testing and promotes more sustainable agricultural practices. A map of soil fertility for a specific area can be extremely valuable for farmers and planners [13,17]. The present study primarily focuses on soil sample testing of Kolar taluk, assessing the present situation of soil fertility, and provides farmers with information on nutrient availability, and it will serve as a foundation for developing fertilizer recommendations aimed at maximizing crop yields. Additionally, this data would help to maintain optimal soil fertility over the long term.

2. Materials and Methods

2.1. Study Areas

Kolar district is positioned in the south-eastern part of Karnataka State, Kolar taluk lies geographically stretch between 13^0 02′ 03″ and $13^0$19′11″ Northern Latitudes and 77^0 56′ 02″ and 78^0 13′ 02″ Eastern Longitudes (Fig 1), situated in the eastern Dry Agroclimatic zone of Karnataka, The climate of Kolar district is semi-arid. The district is built on granite, gneiss, schist, laterite, and alluvium. Basic dykes cut through the formations above them in several areas. The Kolar district has a varied topography, characterized by undulating plains, particularly in the northern and eastern regions, which lie within the Palar Basin. This area is well-suited for agriculture, benefiting from an elevation of around 849 - 1130m above the average level of the sea. Soil distribution varies with topography, comprising red sandy, red loamy, and lateritic soils. Approximately 73% of the land supports agriculture and horticulture, while the rest is used for pasture, forestry, mining, and ecological conservation.

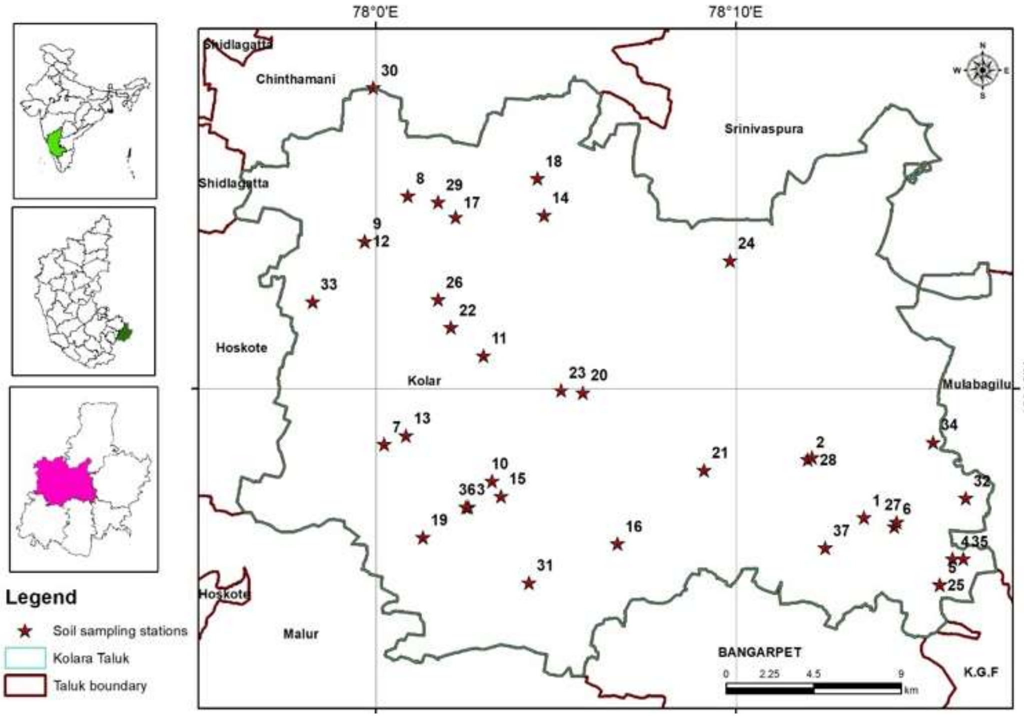

Fig. 1 Soil Sampling Locations Distribution Map of Kolar Taluk

2.2. Methodology

A total of 37 soil samples were collected from Kolar Taluk during the pre-monsoon season of 2022 (Figure 1). A used hand auger about 15-30 cm depth, following collection samples were made into powder using a wooden mallet and mortar. Allow samples to pass through a 2 mm filter to remove stones, roots, and other large particles further, filter through a 20-mesh sieve, and preserve in Polyethylene Bags, and each sample labelled as S1-S37. Soil parameters like pH and electrical conductivity were measured in the field using portable meters (HACH HQ30d multiparameter Kit) with 1: 5 soil-to-water ratio. Extract cations with 1N Ammonium Acetate at pH 7.0, and the leached samples were determined using the EDTA Titrimetric Method (Jackson 1973). The Walkley and black method is used to measure organic carbon and matter. Phosphorus was analysed by leaching the Soil with 0.002N.

Following Jackson (1973), the Chlorostannous reduced Phosphomolybdate Blue Colour method was used to determine the amount of Phosphorus in the extract. A Spectrophotometer was used to collect measurements at a wavelength of 690 nm. Irrigation quality parameters like Sodium Absorption Ratio and exchangeable Sodium Percentage were calculated using the equations given below.

$$\text{SAR= Exchangeable } \frac{Na}{\sqrt{\frac{Ca}{Mg}}/2} \quad (1)$$

$$\text{ESP= Exchangeable } \frac{Na}{Ca+Mg+K+Na} * 100 \quad (2)$$

2.2.1. Nutrient Index

To evaluate the soil fertility status in the study area, several indices were calculated based on organic carbon (%), available Phosphorus, and potash (kg/ha). Equation 3 was used to generate the Nutrient Index for the examined soil samples, and nutrient index values (OC, P, K)(I) <1.67 represent low, (II) between 1.67-2.33 show medium, and (III) > 2.33 indicate high fertility.

$$\text{Nutrient index} = \frac{(1*no.of\ samples\ in\ low\ category)+(2*no.of\ samples\ in\ medium\ category)+(3*no.of\ samples\ in\ high\ category)}{Total\ number\ of\ samples} \quad (3)$$

Soil reaction was classified as Acidic (pH< 6.0), Neutral (pH 6.0-8.0), and Alkaline (pH>8.0), corresponding to soil reaction indices I, II, and III, respectively. Electrical conductivity was grouped into normal (<1000 μs/cm) and injurious (>2000 μs/cm) classes and assigned salt indices I-II.

Organic carbon content was categorised as Low (<0.5%), Medium (o0.5-0.75%), and High (>0.75%) following nutrient indices I-II. Available Phosphorus was classified as Low (<22 kg/ha), Medium(22-54 kg/ha), and High (>54 kg/ha), while available Potassium was grouped as Low (<123 kg/ha), Medium (123-293 kg/ha), and High (>293 kg/ha).

The nutrient index was employed to categorize the fertility status of soils with respect to Organic Carbon (OC), available Phosphorus (P), and available Potassium (K). Nutrient index values less than 1.67 were classified as low, indicating deficient nutrient status and the need for corrective nutrient management practices. Values ranging from 1.67 to 2.33 were categorized as medium, reflecting moderate nutrient availability and the requirement for balanced fertilizer application to sustain soil productivity. Nutrient index values greater than 2.33 were considered high, signifying adequate to excess nutrient availability in Soil, where only maintenance inputs are generally recommended to ensure sustainable soil fertility management.

3. Results and Discussion

Analytical results obtained for 37 soil samples from Kolar Taluk are summarized in Table 1. The pH of the Soil is universally used to express hydrogen ion concentration, and it determines whether the Soil is acidic, Neutral, or Alkaline in nature [16,15]. While a pH range of 5.25-7.18 typically does not directly impact the growth of most crops, it significantly impacts the availability of vital nutrients. In the Kolar taluk, soil samples are demonstrating the presence of numerous soil types that are slightly Acidic to Neutral in nature. lowest pH recorded 5.25 in sample S3, while the highest was 7.18 in sample S31.

Table 1. Descriptive Statistical Analysis of Soil Samples

Sl.No	Parameters	Maximum	Minimum	Mean
1	pH	7.18	5.25	6.46
2	EC (μs/cm)	1282	49.1	333.67
3	% Ca	0.273	0.04	0.127
4	Exchangeable calcium	13.6	2	6.31
5	% Mg	0.136	0.005	0.047
6	Exchangeable Magnesium	11.221	0.4	3.864
7	% Na	0.0315	0.001	0.0098
8	Exchangeable sodium	1.3691	0.032	0.0098
9	%K	0.06	0.001	0.0232
10	Exchangeable Potassium	1.537	0.001	0.596
11	Available K2O (kg/ha)	309.39	0.26	119.92
12	P (ppm)	1.116	0.023	0.554
13	Available P2O5 (kg/ha)	511.128	10.717	254.13
14	OC %	3.4	2.4	2.8
15	OM%	5.8616	4.051	4.91
16	ESP	12.46	1.124	4.95
17	SAR	0.605	0.012	0.18

Electrical Conductivity (EC) serves as a measurement of a soil's carrying capacity of current, providing insights into the presence of soluble salts and the overall salinity of the Soil. Generally, lower EC values indicate lower salinity, while higher values suggest greater salinity. Although soil conductivity can be affected by a number of things, high EC values are typically associated with clay-rich soils, whereas sandy and gravelled soils tend to exhibit lower conductivities. This difference is largely due to the physical characteristics and form of the soil particles. EC values range from 49-1282, with the highest value found at S20, and the lowest EC found at S22.

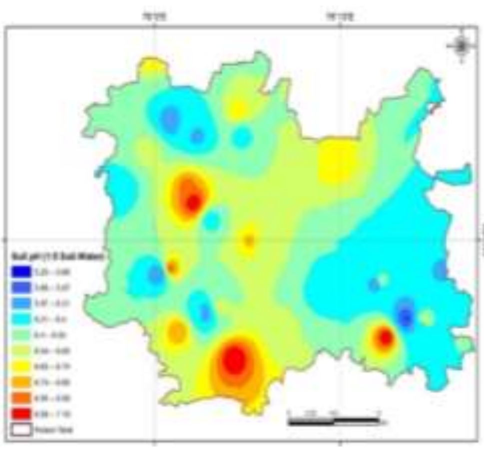

Fig. 2 pH values, Spatial Distribution in the Study Area.

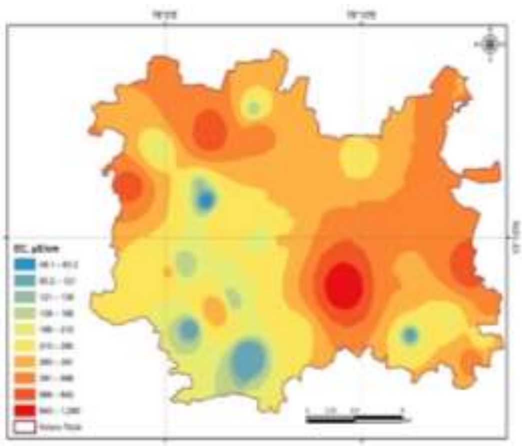

Fig. 3 Spatial Distribution of Electrical Conductivity in the Research Area

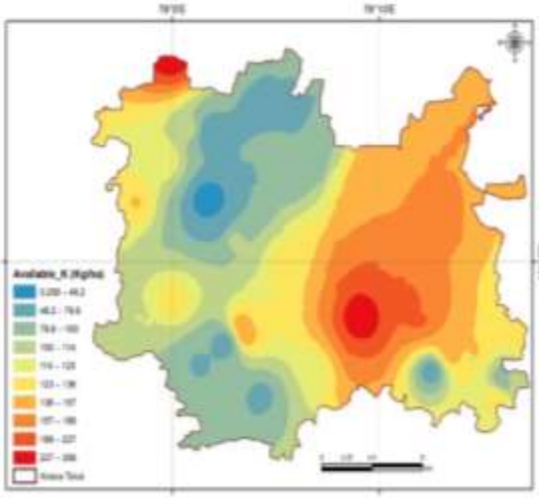

Fig. 4 Spatial Distribution Map of Available Potash in the Study Area

Exchangeable Calcium distribution in the study area varies between 2 and 13.6 meq/100g, the highest concentration found in sample no. S24. And the lowest value was found at sample S13. This significant variation indicates calcium availability in the study area. Exchangeable magnesium was measured in the study area, with values ranging from 0.4 to 11.2 meq/100g. These results were recorded at sample numbers S20-S35. The distribution of exchangeable sodium influences soil structure and plant growth. The maximum and minimum value found at samples S31 and S21 ranges from 0.032-1.36 meq/100g. At two to three percent of dry weight, it is the most prevalent metal cation in plant cells. The range of the exchangeable potassium values was 0.001 to 1.537 meq/100g. Sample S28 had the lowest value of 0.001 meq/100g, while sample S32 had the highest value of 1.537 meq/100g. Potassium (k) is an essential nutrient for plant growth. It controls Osmosis and maintains water balance [18.15].

Potassium removal by crops can be considerably high under typical field circumstances with sufficient nutrient input; it is sometimes equal to Nitrogen, and the uptake is three to four times that of Phosphorus. Moreover, it happens when too much K+ is absorbed without boosting crop yields. Although “required potassium” refers to the quantity of Potassium that is needed for best yields, any amount above this threshold is regarded as luxury consumption and results in wasteful nutrient removal. Available Potassium varies between 0.26 and 279.05 kg/ha; most of the samples fall under the doubtful category. About 54.05% (20 samples) values range from 113.42 to 279.05 kg/ha; this may not be sufficient for crop growth. Meanwhile, 45.94% (17 samples) were found to be deficient in potash. No sample fell into an adequate category (>280 kg/ha), indicating an overall low to marginal potassium status in the study area.

3.1. Percent Organic Carbon (OC), Percent Organic Matter (OM), and Available Phosphorus

OC plays an important role in soil health and fertility, and it varies from place to place based on factors like soil type, climate [5,15]. Determining the ideal amount of organic matter is complicated, as no universal value applicable to all plants or soils. Each species and soil type has unique requirements, making it essential to consider these variables when assessing organic matter needs for optimal plant growth. Percent organic carbon found in the range from 2.4% to 3.4%, reflecting fluctuating levels of organic materials and rates of decomposition.

Notably, 100% of the samples exhibited high organic carbon levels. Organic matter content ranges from 4.05 to 5.86. Phosphorus is a vital macronutrient in biological systems, making up 1% or more by weight of dry organic matter. It frequently acts as a confining element for the development of plants and is found in soil organic matter and inorganic matter. In Kolar Taluk, results are varied from 10.72 to 511.13 kg/ha (Figure 7). Notably, 2.70% of the soil samples were classified as having low phosphorus availability, while the remaining samples indicated abundant phosphorus levels(Muhr et al., 1965). Application of phosphorus-rich fertilizers tailored to specific crop needs can significantly enhance soil fertility and promote better plant growth, and is required for agricultural fields with low phosphorus content.

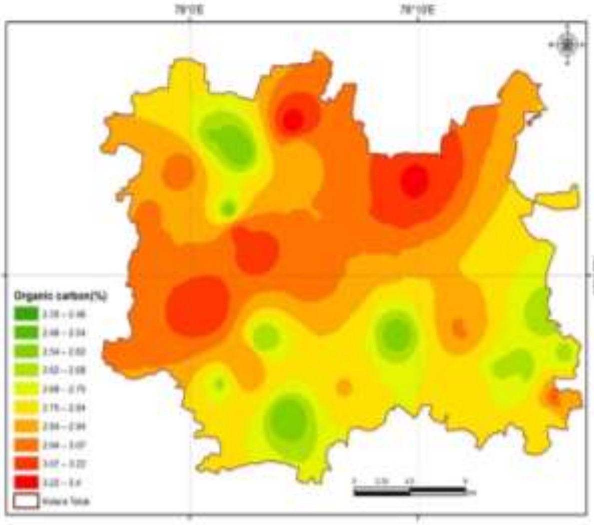

Fig. 5 Distribution of Percent Organic Carbon

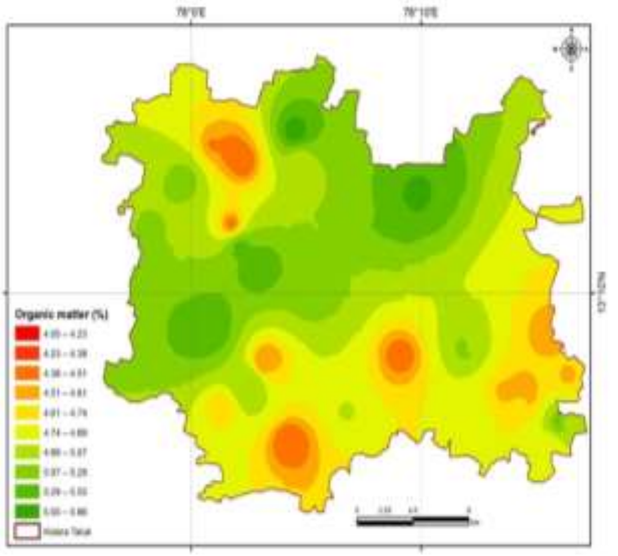

Fig. 6 Distribution of Percent Organic Matter

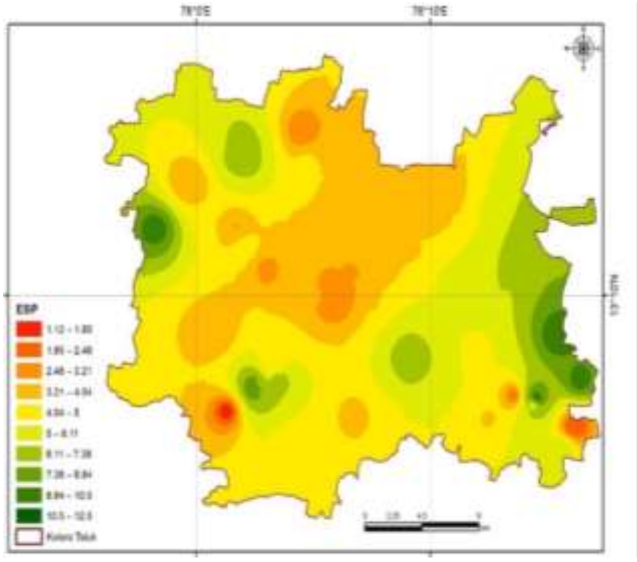

Fig. 8 Distribution Map of Exchangeable Sodium Percentage in the Study Area

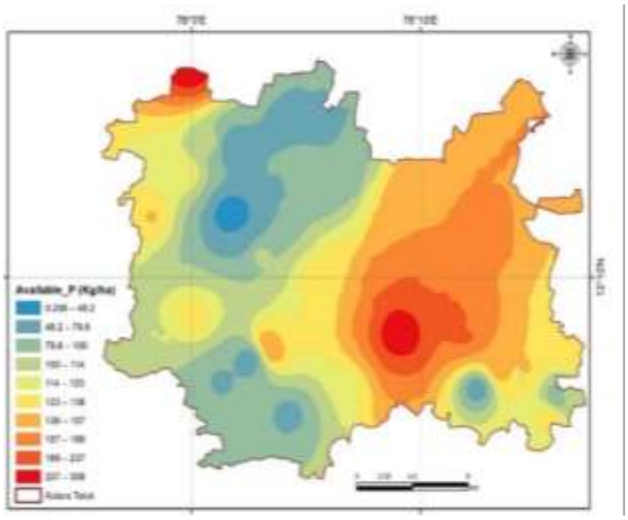

Fig. 7 Spatial Distribution of Available Phosphorus in Research Area

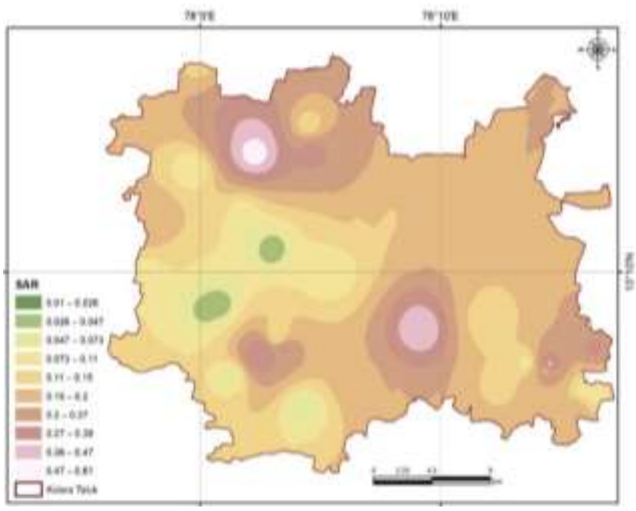

Fig. 9 Map of Sodium Absorption Ratio of the Spatial Distribution in the Kolar Taluk

3.2. Irrigational Quality Parameters

3.2.1. Exchangeable Sodium Percentage (ESP) and Sodium Absorption Ratio (SAR)

The Exchangeable Sodium Percentage (ESP) indicates the status of the Sodium saturation level of the Soil's adsorption/exchange complex. An ESP of 15 can result in pH levels of 8.5 or higher, while even higher ESP values can push the pH up to 10. Additionally, sodium can partially substitute for Potassium as part of their plant food. All the samples are <20, values range between 1.124 and 12.46, which indicates they are highly suitable for irrigation, well within the excellent category. (SAR) directly shows sodium hazard in Soil, ions of sodium replace the calcium and magnesium ions.

Based on SAR classification(TODD, 1959), .100% of samples were classified as the excellent category, which is all the samples show values <10, values range between 0.012 to 0.605, while no samples were seen in the good, fail, and poor categories. This suggests that the irrigation water is unlikely to provide sodium-related risks, hence fostering optimal soil conditions for agricultural activities.

3.2.2. Salinity

A salt-affected soil is characterized by its negative impact on crop growth due to the presence of soluble salts, whether in the form of anions or cations. These salts cannot be flushed from the upper soil layers due to insufficient rainfall. There are two types of salt-affected soils: saline and sodic. Electrical Conductivity (EC), which is measured in dS/m at 25°C, is commonly used to determine salinity.

The results presented in Table 2 indicate that the salinity values range from 0.4 to 12.82 dS/m, indicating good to crucial for soil quality (Figure 10). The low salinity levels suggest favourable conditions for agriculture.

Thus, in this region, the generation of biomass and economic output can be adversely affected by high concentrations of soluble salts, especially those exceeding 4 dS/m, which can also hinder seed germination and limit the growth of the majority of commercial crops.

Table 2. Crop Tolerance Groups and Salinity Conditions in Kolar Taluk.

Sl.No	EC (ds/m)	Category	Range (No. of samples; %)
1	< 0.7	All crops	0.4 to 0.50 (2; 5.40 %)
2	0.7 - 2.0	most crops	0.76 to 1.90 (14; 37.83 %)
3	2.0 - 10.0	salt-tolerant crops	2.07 to 9.18 (20; 54.05 %)
4	10.0 - 32.0	Most halophytes	12.82
5	33.0 >	No crops (seawater)	----------

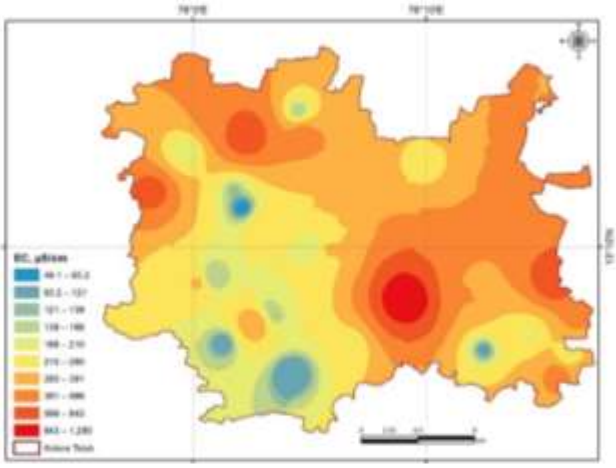

Fig. 10 Electrical Conductivity Value Spatial Distribution in the Kolar Taluk

3.3. Soil Fertility Assessment

A detailed analysis of both physical and chemical parameters shows significant insights into the soil quality of the study area. Overall, there are no significant issues, with only a few instances of slightly elevated salinity levels. Importantly, the region is characterised by fertile soils that supply a sufficient amount of vital nutrients, and there are almost no locations that are unsuitable for continuous irrigation.

In accordance with their soil pH, the soil samples were categorised as Soil Reaction Index classes I, II, and III (< 6.0, 6.0-8.0, and > 8.0), Acidity, Neutral, and >Neutral. Soil response index class I soil samples accounted for 13.51% of the total, while 86.48% fell into class II soil samples, indicating that the soils in the research area are neutral or slightly acidic, according to pH values ranging from 5.25 to 7.18. Sorting soil samples into three salt index classes according to conductivity values: (I)normal, < 1.0 dS/m, (II)critical, 1.0 - 2.0 dS/m, and(III) harmful, > 2.0 dS/m operates similarly. The results show that 5% of the samples have a normal salt concentration (Salt index category I), 37.83% have a salt index class II, and 56% have a salt index class III. On the other hand, the available potash and nutrient indices for %OC and available Phosphorus were computed independently. Most soil samples belonged to the high level of organic carbon, and their nutrient index values ranged from 2 to 3.4%. The nutritional index for available Phosphorus is 2.86, which is in the high range, and for available potash it is 1.46, which is low, according to most samples.

Table 3. Nutrient Indices and Summary of Soil Tests.

Soil Parameters	% samples			Nutrient Index
	Low	Medium	High	
OC (%)	---	---	100	5.55
Available K2O (kg/ha)	45.95	48.65	5.40	2.95
Available P2O5 (kg/ha)	2.70	---	97.3	5.45

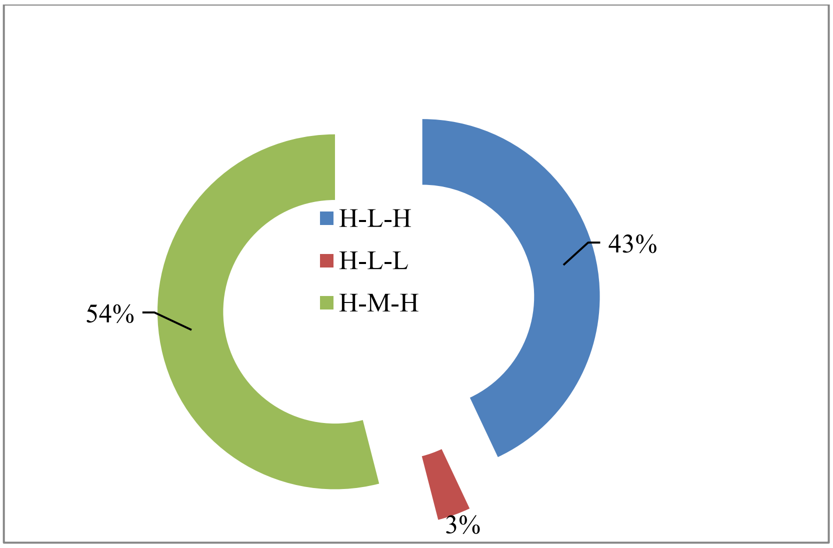

Fig. 11 Soil Fertility Categories in the Kolar Taluk (OC, Avail K, and Avail P)

The soil samples were categorized into three fertility groups based on available Potassium (K), Phosphorus (P), and Organic Carbon (OC), and these categories include High-Low-Low(HLL), High-Medium-High (HMH), and High-Low-High (HLH), with their percentage distribution illustrated in (Figure 11) using nutrient indices and the classification criteria values, namely high OC, P (3, 2.86), K (1.43), low. The overall nutrient status of the soil samples and the soils is classified as High-High-Low (HHL). This classification reveals a significant variability in soil fertility of the study area, contrasting with Verma et al. (2005) 's findings.

Conclusion

The study finds Low Levels of (K), High Levels of (P), and (OC). Irrigation quality parameters (such as ESP and SAR) showed that the soils fall into the excellent irrigation category.

Conflicts of Interest

"The authors (Ashwini K.B and K.L. Prakash) declare(Soil Nutrient Index of Semi-arid region of Kolar Taluk, Karnataka, India) in this article analyzed the primary) Data was measured (PRM); therefore, there is no conflict of interest."

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