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Soil Fertility Assessment and Management Strategies for Sustainable Agriculture in Chikkanayakanahalli Block of Karnataka, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Soil testing is essential for determining the availability of nutrients within the soil, which indicates fertilizer recommendations aimed at optimizing crop yields. Soil test summaries are indispensable reference tools for the scientific management of soil. A total of 113 surface soil samples were randomly collected from farmers field across nine villages in the Chikkanayakanahalli block to assess the fertility status of the soil. From the above study observed that the soils in the Chikkanayakanahalli block of Tumkur district in Karnataka State exhibit a range from moderately

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acidic to Slightly alkaline (5.24 to 8.02) pH levels, characterized by normal electrical conductivity (0.08 to 0.23 dSm^{-1}) and low organic carbon content (0.11 to 0.54%) with a few exceptions. The assessment of available macronutrients indicated a low to medium in nitrogen (104.7 to 340.5 kg ha^{-1}), whereas phosphorus (12 to 68 kg ha^{-1}) and potassium (53.5 to 407.5 kg ha^{-1}) levels varying from low to high. Additionally, the evaluation of available micronutrients revealed that all soil samples were either deficient to sufficient in iron (0.98 to 2.81 mg kg^{-1}) and manganese (0.23 to 3.94 mg kg^{-1}), whereas recorded sufficient to excessive levels of zinc (0.86 to 9.72 mg kg^{-1}) and copper (1.55 to 17.58 mg kg^{-1}). The findings of this research highlight the urgent need for intensive soil nutrient management due to the overexploitation of soil resources. The declining levels of critical parameters such as organic carbon suggested that the necessitating prompt action for the sustainable management of soil resources.

Keywords: Chemical; macronutrients; micronutrients; sustainable soil management.

1. INTRODUCTION

Soils vary considerably in their characteristics and behaviour. The land resources of the nation represent its most invaluable and revered asset. They serve as the primary source to produce food, fiber, fuel, and numerous other essential goods necessary for fulfilling the needs of both humans and animals. Nevertheless, these resources are under significant threat of decline due to relentless human activities and uses that exceed their natural capacity. Land degradation is recognized as one of the most critical global challenges (Shafnas *et al*. 2023).

As the global population continues to rise, the demand for food is also increasing, necessitating a corresponding rise in food production despite the constraints of limited land availability. This situation has resulted in intensified agricultural practices and the widespread application of chemical fertilizers (Srinivas & Krishnamurthy, 2017). In Karnataka, approximately 27.4 percent of the total geographical area is experiencing degradation, primarily due to water erosion, salinization, and other anthropogenic activities. To satisfy the food grain requirements of the population over the next decade, it is essential to enhance current production levels by nearly 50 percent. This increase must be achieved through improved productivity, with future yields expected to arrive from vertical expansion rather than horizontal increase in net cropping area (Prashantha & Chikkaramappa, 2017).

Soil is a critical factor in establishing the sustainable productivity of an agro-ecosystem. The productivity of soil is primarily influenced by its capacity to provide essential nutrients to plants. Soil fertility is a key determinant of nutrient availability for plants, which in turn affects crop yields. Key elements such as pH, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and micronutrients significantly influence both soil fertility and crop production (Gautam *et al*., 2025). Assessing the fertility status of the soil can help identify soil-related limitations, including nutritional deficiencies, that may impact crop productivity. It plays a crucial role in the effective application of fertilizers and other agricultural inputs (Basavaraja, *et al*., 2016). The proper understanding of the soils is therefore, necessary for its best possible use to ensure sustainable agriculture. In this context, the Chikkanayakanahalli tehsil of Tumkur district in Karnataka was selected to investigate the soil characteristics, classification, and soil organic carbon stock in soils vulnerable to land degradation.

2. MATERIALS AND METHODS

Study area: Tumkur district is in the southeastern region of Karnataka and is positioned between the latitudes of 12° 45" and 14° 30" North, and the longitudes of 76° 15" and 77° 45" East. This district is administratively segmented into ten taluks, encompassing a total area of 1,064,755 hectares. It shares its boundaries with Anantapur district of Andhra Pradesh to the northeast, Kolar and Bangalore districts to the east, Mandya district to the south, and Chitradurga, Chickmagalur, and Hassan districts to the west. The ten taluks within the district are Tumkur, Gubbi, Kunigal, Turuvekere, Chikkanayakanahalli, Tiptur, Sira, Madhugiri, Pavagada, and Koratagere. To study soil fertility, Chikkanayakanahalli taluk was selected. This taluk is situated in the southeastern part of Karnataka and is defined by its geographical coordinates of 13° 24" and 13° 15" North latitudes and 76° 56" and 77° 46" East longitudes. It covers an area of 113000 hectares

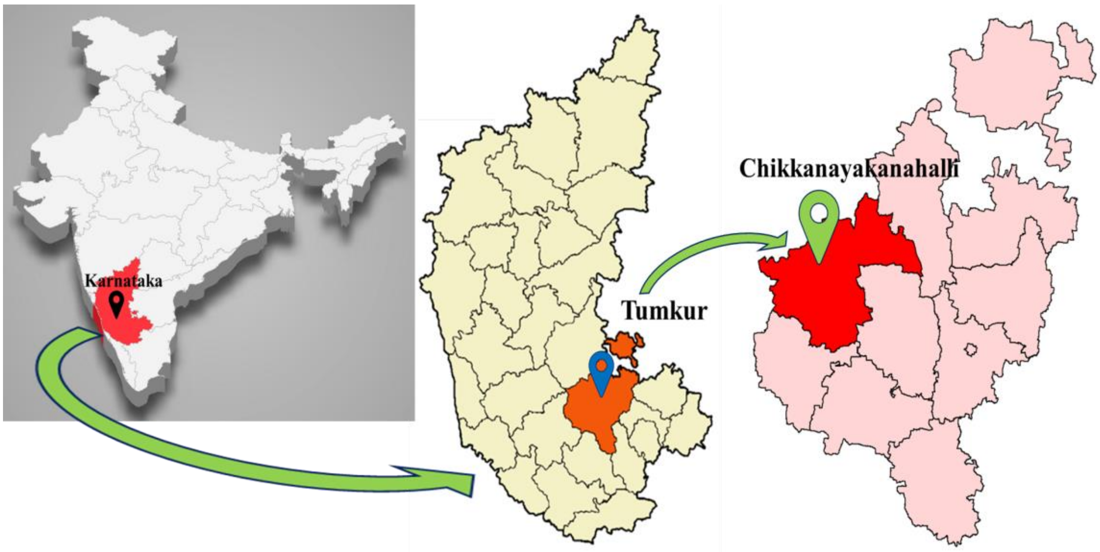

Fig. 1. Location Map of Study Area

and falls within the central dry zone. Out of total area 63557 ha area is net sown with 1.18 cropping intensity and 39.3 % area is under irrigation. Ragi, other cereals, minor millets, pulses, oilseeds, fruits and vegetables are the principal crops of this area (Vittala, 2017). The predominant landforms include granite, gneiss, and schist, characterized by dykes and laterized parent material, which contribute to the development of well-drained, somewhat excessive, or moderately well-drained soils. The normal annual rainfall of Chikkanayakanahalli tehsil is 681mm.

Study Details: The 113 surface soil samples were collected from the farmers field at Bheemasandra, Halli Timlapur, Handanakere, Huchchanalli, Kengalapur, Puradakatte, Ramaghatta, Sabbenahalli and Takkalupalya villages of Chikkanayakanahalli block of Tumkur, Karnataka. Surface composite soil samples were collected from 0-15 cm layer. The soil samples were air-dried, ground (< 2 mm) and analysed for chemical and fertility parameters. The pH (1:2.5) and electrical conductivity (EC) (1:2.5) of soils water suspension were measured using standard procedures as described by Jackson (1973). Soil organic carbon (OC) was determined using the Walkley-Black method (Nelson & Sommers 1996). Available nitrogen (N) was estimated by modified alkaline permanganate method (Sahrawat & Burford,1982). Available phosphorous of the acid soils was determined by Brays No. 1 method as outlined by Bray and Kurtz (1945) and Olsen's method (Olsen & Sommers, 1982) was used for neutral to alkaline soils. Available potassium (K) was determined using the neutral normal ammonium acetate method (Helmke & Sparks, 1996). Micronutrients (Fe, Zn, Cu and Mn) were extracted by DTPA using the procedure and determined by Atomic Absorption Spectrophotometer (Lindsay & Norvell, 1978). Organic carbon content, available N, P_2O_5 and K_2O in soil was interpreted as low, medium and high. Whereas, DTPA extractable zinc (Zn), iron (Fe), copper (Cu) and manganese (Mn) interpreted as deficient, sufficient and excess.

3. RESULTS AND DISCUSSION

Physico-chemical properties of soil: The 113 soil samples collected from Chikkanayakanahalli block of Tumkur district were analysed for their physico-chemical properties of soil and the data is presented in Table 1 and discussed under the following subheads.

Soil Reaction (pH): The analysis of 113 soil samples indicated a pH range from 5.24 to 8.02, with an average pH of 6.62 (Table 2). The findings showed that the villages of Bheemasandra and Kengalapur exhibited the highest pH level at 8.02, while the lowest pH recorded was 5.24 in Halli Timlapur village. Additionally, the mean pH of the soil samples from Halli Timlapur was lowest at 6.31, whereas the samples from Takkalupalya had the highest mean pH of 6.92.

Table 1. Range and mean of chemical properties of soils in Chikkanayakanahalli block of Tumkur district

Sr. No.	Villages	pH	EC (dSm^{-1})	OC (%)
1	Bheemasandra	5.82 - 8.02 (6.80)	0.10 - 0.18 (0.14)	0.20 - 0.45 (0.32)
2	Halli Timlapur	5.24 - 6.96 (6.31)	0.10 - 0.16 (0.13)	0.29 - 0.45 (0.38)
3	Handanakere	5.36 - 7.14 (6.44)	0.09 - 0.16 (0.12)	0.20 - 0.45 (0.32)
4	Huchchanalli	5.82 - 7.36 (6.80)	0.08 - 0.17 (0.12)	0.27 - 0.45 (0.36)
5	Kengalapur	5.71 - 8.02 (6.44)	0.08 - 0.18 (0.13)	0.11 - 0.54 (0.37)
6	Puradakatte	5.76 - 7.14 (6.51)	0.09 - 0.19 (0.12)	0.20 - 0.48 (0.33)
7	Ramaghatta	5.94 - 7.68 (6.75)	0.09 - 0.23 (0.12)	0.11 - 0.48 (0.33)
8	Sabbenahalli	5.81 - 7.31 (6.60)	0.08 - 0.19 (0.13)	0.11 - 0.48 (0.34)
9	Takkalupalya	6.08 - 7.86 (6.92)	0.09 - 0.15 (0.11)	0.23 - 0.48 (0.32)
Range and mean	Range	5.24 – 8.02	0.08 – 0.23	0.11 – 0.54
of 113 soil samples	Mean	6.62	0.12	0.34

Table 2. Soil Reaction (pH)

pH (Ratings)	Range	No. of samples	Samples (%)
Extremely acidic	< 4.0		
Strongly acidic	4.1 – 5.0		
Moderately acidic	5.1 – 6.0	22	19.5
Slightly acidic	6.1 – 6.5	29	25.6
Neutral	6.6 – 7.5	55	48.7
Slightly alkaline	7.6 – 8.0	7	6.2
Moderately alkaline	8.1 – 9.0		
Strongly alkaline	9.1 – 10.0		
Very strongly alkaline	> 10.1		

The soil reaction ratings data proposed by Banger and Zende (1978) is displayed in Table 2. Among the 113 soil samples analysed, 22 samples representing 19.5%, were classified as moderately acidic (5.1-6.0), while 29 samples were identified as slightly acidic (6.1-6.5). Additionally, 55 samples, accounting to 48.7%, were categorized as neutral (6.6-7.5) and only 7 samples fall under slightly alkaline (7.6-8.0). Overall, the soil samples predominantly classified as moderately acidic. Soil pH plays a crucial role in determining the solubility and accessibility of essential nutrients for plants. Each nutrient has a specific pH range that optimizes its availability. For example, nitrogen, in the form of nitrate (NO^{3-}), is most accessible in soils with a pH between 6.0 and 7.5. Conversely, phosphorus is most available in soils with a pH range of 6.0 to 7.0, while potassium remains relatively accessible across a broader pH spectrum (5.5 to 8.0). In addition to influencing nutrient availability, soil pH directly affects crop growth by impacting root development and microbial activity. Different crops have distinct pH preferences, and maintaining soil pH within these ideal ranges can significantly boost crop yields. Effective management of soil pH requires regular monitoring and the application of amendments to keep pH levels suitable for the desired crops. Liming is a widely used method to increase soil pH in acidic conditions, utilizing materials such as limestone (calcium carbonate) or dolomite (calcium magnesium carbonate) and basic fertilizers. For alkaline soils, acidifying amendments like gypsum, sulphur, acid-forming fertilizers can be used to reduce pH. The incorporation of organic matter, such as compost or manure, can also enhance soil pH buffering capacity and overall soil health (Kennedy, 2022). Additionally, crops can be cultivated based on soil pH; acid-tolerant crops are suitable for acidic soils, while salinity-tolerant crops can thrive in slightly alkaline conditions.

Electrical Conductivity (EC): The analytical data regarding soil electrical conductivity is presented in Table 3. The electrical conductivity measurements for the 113 soil samples ranged from 0.08 to 0.23 dS m^{-1}, with an average value of 0.12 dS m^{-1}. The minimum electrical conductivity of 0.08 dS m^{-1} was recorded in Huchchanalli, Kengalapur and Sabbenahalli while the maximum value of 0.23 dS m^{-1} was also observed in the Ramaghatta village. Additionally, the lowest average electrical conductivity of 0.11 dS m^{-1} was noted in the soil

Table 3. Electrical Conductivity

EC (dSm^{-1})		No. of samples	Samples (%)
Class	**Range**		
Normal	<0.8	113	100
Critical for salt sensitive crops	0.8-1.6		
Critical for salt tolerant crops	1.6-2.5		
Injurious to all crops	>2.5		

Table 4. Organic Carbon

OC (%)		No. of samples	Samples (%)
Class	**Range**		
Low	<0.5	110	97.3
Medium	0.5-0.75	3	2.7
High	>0.75		

samples from Takkalupalya whereas the highest average of 0.14 dS m^{-1} was found in the samples from Bheemasandra. Similar range of electrical conductivity in Tumkur district was noticed by Basavaraja *et al*. (2016).

The soil electrical conductivity ratings, as referenced by Jackson (1967) and Richards (1954), are detailed in Table 3. Among the 113 soil samples analysed, all exhibited normal electrical conductivity levels of less than 0.8 dS m^{-1}. The results indicated that nearly all soils in the Chikkanayakanahalli block of Tumkur district, Karnataka, are characterized by low electrical conductivity. This reflects their non-saline nature, as salt concentration in the soil was not a problem.

Organic Carbon (OC): Organic matter serves as a crucial reservoir of accessible nutrients, playing a significant role in maintaining soil fertility. It enhances soil structure, facilitates the retention of mineral nutrients, and increases the capacity for water retention, infiltration, drainage, aeration, and root penetration. Furthermore, it contributes to the proliferation of soil flora and fauna (Havlin *et al*., 2010). Consequently, organic matter is a key factor in promoting soil fertility. It originates from the decomposition of plant and animal remains, and encompasses grasses, trees, bacteria, fungi, protozoa, earthworms, and animal manure. The organic carbon content in the soils of Chikkanayakanahalli block of Tumkur district varies between 0.11% and 0.54%, with an average of 0.34% as indicated in Table 4. The minimum organic carbon level of 0.11% was recorded in the soil samples from Kengalapur, Ramaghatta and Sabbenahalli. The soil sample from Kengalapur exhibited the highest organic carbon content of 0.54%. Furthermore, the highest mean organic carbon value of 0.38% was observed in the soil samples from Halli Timlapur.

The soil organic carbon ratings data, as proposed by Banger and Zende (1978), is presented in Table 4. Among the 113 soil samples analysed, a significant majority (110 samples) recorded low organic carbon levels (<0.5%), while three samples were classified as having medium organic carbon content (0.5% to 0.75%). The low levels of organic carbon in these soils result from rapid degradation of organic matter, coupled with the lack of organic manures and insufficient vegetative cover in the fields. This situation results in limited opportunities for organic carbon accumulation within the soils. Similar findings were reported by Prabhavati *et al*. (2015) concerning the soils in the Northern dry zone of Karnataka. The results indicate an urgent need to improve the organic carbon content in the soil. This can be achieved by incorporating crop residues, increasing the use of organic manures, applying biofertilizers and vermicompost, mulching with crop residues, and rotating crops with cereals and legumes or practicing mixed cropping. The addition of biochar to soil significantly increases its organic carbon levels by serving as a stable carbon sink. Biochar's high carbon content and durable structure prevent rapid decomposition by microorganisms, effectively sequestering carbon in the soil for an extended period (Jadhav *et al*. 2023).

Status of available macronutrients, *viz*. (N, P_2O_5 and K_2O), in the soil: Soil samples obtained from various villages in the Chikkanayakanahalli block of Tumkur district of Karnataka were analysed for their macronutrient content. The results, including the ranges and average values of the available macronutrients, are detailed in Table 5.

Table 5. Range and mean of macronutrients in soils from Chikkanayakanahalli block of Tumkur district

Sr. No.	Villages	Available N (Kg ha^{-1})	Available P_2O_5 (Kg ha^{-1})	Available K_2O (Kg ha^{-1})
1	Bheemasandra	109.8 - 320.0 (188.9)	18 - 68 (45.0)	106.0 – 401.0 (264.0)
2	Halli Timlapur	129.8 - 340.5 (225.2)	18 - 42 (28.7)	53.5 – 396.0 (284.0)
3	Handanakere	109.1 - 307.9 (193.6)	20 - 64 (36.5)	127.0 – 376.5 (290.3)
4	Huchchanalli	118.5 - 329.2 (179.5)	16 - 64 (34.9)	99.5- 401.0 (306.4)
5	Kengalapur	105.4 - 292.4 (158.0)	15 - 62 (34.8)	106.0 – 406.0 (307.0)
6	Puradakatte	106.6 - 294.1 (190.8)	16 - 68 (42.0)	94.5 – 395.0 (322.0)
7	Ramaghatta	114.8 - 308.6 (162.56)	12 - 68 (31.6)	202.5- 406.0 (340.3)
8	Sabbenahalli	110.4 - 141.1 (129.2)	12 - 64 (38.0)	249.0 – 407.5 (355.7)
9	Takkalupalya	104.7 - 310.1 (202.1)	16 - 68 (39.8)	161.0 – 403.0 (334.7)
Range and mean of 113 soil samples	Range	104.7 – 340.5	12 – 68	53.5 – 407.5
	Mean	176.6	36.9	314.2

Table 6. Available Nitrogen

Available Nitrogen (Kg ha^{-1})		No. of samples	Samples (%)
Class	Range		
Low	< 280	91	80.5
Medium	280-560	22	19.5
High	>560		

Available Nitrogen: The data on available nitrogen in the soil is shown in Table 6. The levels of available nitrogen ranged from 104.7 to 340.5 kg ha^{-1}, with an average of 176.6 kg ha^{-1}. The variation in nitrogen content may be associated with management practices, as well as the application of farmyard manure (FYM) and fertilizers to previous crops. The analysis of soil samples revealed that the lowest available nitrogen content was 104.7 kg ha^{-1} found in the soil samples from the villages of Takkalupalya. Conversely, the highest available nitrogen level of 340.5 kg ha^{-1} was observed in the soil sample from Halli Timlapur village. The lowest average available nitrogen, at 129.2 kg ha^{-1}, was noted in the samples from Sabbenahalli, while the highest average, at 225.2 kg ha^{-1}, was found in the samples from Halli Timlapur. Similar range of available nitrogen content in soils of Chikkanayakanahalli block of Tumkur district was observed by Basavaraja *et al*. (2016).

Out of total, 80.5 % soil samples exhibited low levels of available nitrogen in the soil whereas, only 19.5 % soil samples get in line to medium class (Table 6). A possible explanation for this deficiency could be the low organic matter content in these regions, combined with factors such as low rainfall, sparse vegetation, and high temperatures. These conditions contribute to the rapid degradation and loss of organic matter, leading to a scarcity of nitrogen. Nitrogen applied to crops can be either absorbed by the plants or lost through processes such as leaching and evaporation, which can lead to nitrogen deficiency in the soil. To improve nitrogen levels and enhance soil productivity, it is recommended to use nitrogen-fixing biofertilizers through seed treatment and to practice crop rotation with legumes such as green gram, Dolichos bean, red gram, horse gram, cowpea, and groundnut etc. Additionally, it is beneficial to cultivate crops that require low nitrogen levels. For soils classified as low-quality, it is advisable to apply 150% of the required nitrogen dosage, while for medium-quality soils, applying the standard 100% dosage is recommended.

Available phosphorous (P_2O_5): Phosphorus is an essential component of protoplasm. It does not easily move through the soil and is not washed away by rainfall or irrigation. Plants absorb phosphorus in the forms of H_2PO_4, HPO_4, or PO, depending on the soil's pH level. The data regarding available phosphorus in the soil is presented in Table 7. The concentration of available phosphorus ranged from 12 and 68 kg ha^{-1}, with an average of 36.9 kg ha^{-1}. A similar range of available phosphorous content in soils of Chikkanayakanahalli block in Tumkur district was reported by Basavaraja *et al*. (2016). The minimum level of available phosphorus was

Table 7. Available P_2O_5

Available P_2O_5 (Kg ha^{-1})		No. of samples	Samples (%)
Class	**Range**		
Low	< 22.5	27	23.9
Medium	22.5-55	71	62.8
High	>55	15	13.3

recorded 12 kg ha^{-1}, in the soil samples from Ramaghatta and Sabbenahalli. Conversely, the maximum level of 68 kg ha^{-1} was identified in the soil samples from Bheemasandra, Puradakatte, Ramaghatta and Takkalupalya. Additionally, the lowest mean value of available phosphorus, at 28.7 kg ha^{-1}, was noted in the soil samples from Halli Timlapur, while the highest mean value, at 45.0 kg ha^{-1}, was found in the samples from Bheemasandra.

The analysis of available phosphorus levels indicates a range from low to high status (Table 7). Among the 113 samples examined, 23.9 percent were classified as low, This low status might be due to a higher a higher rate of phosphorous removal compared to its replenishment, as well as the continuous cultivation of phosphorous intensive crops year after years. Among the soil samples assessed, 71 (62.8%) exhibited medium levels of available phosphorus, particularly in areas where the pH was moderately acidic. The presence of near-neutral pH significantly enhances phosphorus availability. Conversely, 15 (13.3%) of the soil samples demonstrated high levels of available phosphorus, likely resulting from varying management practices among farmers. To effectively manage soil health and crop production sustainably, it is advisable to use phosphatic fertilizers according to soil test results. In low-quality soils, an additional 50% of the recommended phosphorus dose should be applied. For medium-quality soils, the full recommended dose of phosphorus is appropriate. In contrast, for high-quality soils, it is recommended to reduce the phosphorus application by 50% as compared to the standard recommendation.

Available Potassium (K_2O): Potassium serves as a master nutrient to produce high-quality crops. It is present in the form of K and functions primarily as a catalyst. This nutrient is vital for plants as it activates numerous enzymes that play a role in various physiological processes of plants. Additionally, potassium regulates water management and enhances resistance to various pests, diseases, and environmental stresses. The analytical data concerning the available potassium levels in the soil is presented in Table 8. The available potassium content varied between 53.5 and 407.5 kg ha^{-1}, with an average of 314.2 kg ha^{-1}. The minimum level of available potassium, recorded at 53.5 kg ha^{-1}, was observed in the soil sample from Halli Timlapur. The highest available potassium concentration, measured at 407.5 kg ha^{-1}, was found in the soil samples from Sabbenahalli. Additionally, the lowest mean available potassium level of 264.0 kg ha^{-1} was identified in the soil samples from Bheemasandra, while the highest mean of 355.7 kg ha^{-1} was recorded in the soil samples from Sabbenahalli.

The data regarding the ratings for available potassium, as indicated by Patil *et al*. (2017b), is presented in Table 8. Among the analysed soil samples, 9 (8.0%) were classified as low, 41 (36.3%) as medium, and 63 (55.7%) as high in available potassium. Jagadesh (2004) also noted a similar range of available potassium in the soils of Southern Karnataka. The relatively medium to high levels of available potassium observed in certain soils may be attributed to the presence of higher quantities of potassium-bearing minerals. It has been reported that, in Karnataka, surface soils consistently exhibit higher concentrations of water-soluble and exchangeable potassium

Table 8. Available K_2O

Available K_2O (Kg ha^{-1})		No. of samples	Samples (%)
Class	**Range**		
Low	< 140	9	8.0
Medium	140-330	41	36.3
High	>330	63	55.7

Table 9. Range and mean of micronutrients in soils from Chikkanayakanahalli block of Tumkur district

Sr. No.	Villages	Fe (mg Kg^{-1})	Mn (mg Kg^{-1})	Zn (mg Kg^{-1})	Cu (mg Kg^{-1})
1	Bheemasandra	0.98 - 2.31 (1.49)	0.63 - 1.25 (1.03)	1.1 - 4.63 (2.36)	4.85 - 8.96 (7.06)
2	Halli Timlapur	1.52 - 2.81 (2.22)	1.76 - 3.94 (2.62)	2.24 - 5.7 (4.53)	5.39 - 9.77 (7.75)
3	Handanakere	1.02 - 2.27 (1.75)	1.05 - 2.97 (2.18)	0.86 - 5.5 (3.02)	1.55 - 10.31 (6.94)
4	Huchchanalli	1.15- 1.66 (1.45)	0.69 - 1.89 (1.21)	1.22 - 4.25 (2.29)	4.56 - 10.63 (7.15)
5	Kengalapur	1.08 - 2.06 (1.43)	0.25 - 2.01 (0.92)	1.14 - 5.26 (2.46)	4.85 - 11.85 (7.12)
6	Puradakatte	1.14 - 2.04 (1.39)	0.63 - 2.65 (1.54)	1.25 - 4.86 (2.62)	5.36 - 17.58 (8.33)
7	Ramaghatta	1.63 - 2.39 (2.01)	1.32 - 3.73 (2.16)	7.16 - 9.35 (7.85)	4.19 - 9.77 (6.26)
8	Sabbenahalli	0.98 - 2.63 (1.53)	0.23- 2.15 (1.32)	1.17 - 4.56 (1.87)	4.21 - 10.21 (6.66)
9	Takkalupalya	1.96 2.71 (2.20)	2.01 - 3.32 (2.73)	2.49 - 9.72 (4.64)	7.21 - 9.73 (8.63)
Range and mean of 113 soil samples	Range	0.98 – 2.81	0.23 – 3.94	0.86 – 9.72	1.55 – 17.58
	Mean	1.69	1.68	3.52	7.30

(Patil *et al*. 2011). More than 55% of soil samples showed elevated potassium levels. Therefore, excessive potassium application can result in magnesium and calcium deficiencies in various crops. To mitigate these adverse effects, it is recommended to reduce the application of potassium fertilizers by 50% in soils with high potassium content. Additionally, potassium-demanding fruit crops can be successfully grown in these soils.

Status of DTPA extractable micronutrients (Fe, Mn, Zn and Cu) in the soil: Soil samples obtained from various villages in the Chikkanayakanahalli block of Tumkur district, Karnataka were examined for DTPA-extractable micronutrients, specifically iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu). The analytical results, including the ranges and averages of the available micronutrients, are detailed in Table 9.

Available Iron (Fe): The analytical results for available iron are presented in Table 10. The concentration of available iron in the 113 analysed soil samples varied from 0.98 to 2.81 mg kg^{-1}, with an average of 1.69 mg kg^{-1}. The minimum concentration of available iron, recorded at 0.98 mg kg^{-1}, was observed in the soil sample from Bheemasandra and Sabbenahalli, while the maximum concentration of 2.81 mg kg^{-1} was found in the sample from Halli Timlapur. Additionally, the lowest mean concentration of available iron, at 1.39 mg kg^{-1}, was noted in the soil samples from Puradakatte, whereas the highest mean concentration, at 2.22 mg kg^{-1}, was identified in the samples from Halli Timlapur.

The information regarding the ratings of available iron, as indicated by Patil *et al*. (2017a), is displayed in Table 10. Among the 113 soil samples examined, 108 samples were classified as Deficient (>2.5 mg kg^{-1}) and only 5 samples were categorized within the sufficient range (2.5 to 4.5 mg kg^{-1}), in terms of available iron. However, the 95.6 percent of soil samples categorized as iron deficient could be a result of the high accumulation of phosphorus in the soil, which may stem from the prolonged application of phosphorus fertilizers for crops such as finger millets, red gram, little millets, green gram, cow pea, horse gram, dolichos bean and leafy vegetables. Phosphorus tends to bind with iron, forming iron phosphate, which diminishes the availability of iron in the soil. Iron deficiency in crops leads to inadequate chlorophyll production in the leaves. This condition usually first appears in the younger leaflets, which show a pale green colour. The veins of the leaves remain green, even as the tissue between the veins turns yellow, a phenomenon known as interveinal chlorosis. To rectify iron deficiency, apply of 0.5 to 1% solution of ferrous sulphate through foliar spray. Alternatively, applying 30 kg ha^{-1} of iron in the form of ferrous sulphate to the soil can also address the deficiency.

Available Manganese (Mn): The analytical data regarding the available manganese is presented in Table 11. The analysis of 113 soil samples revealed that the available manganese content varied from 0.23 to 3.94 mg kg^{-1}, with an average concentration of 1.68 mg kg^{-1}. The minimum level of available manganese, recorded at 0.23 mg kg^{-1}, was observed in the soil samples from Sabbenahalli. Conversely, the maximum concentration of available manganese, measured at 3.94 mg kg^{-1}, was found in the soil sample from Halli Timlapur. Additionally, the lowest mean concentration of available manganese, at 1.03 mg kg^{-1}, was identified in the soil samples from Bheemasandra, while the highest mean concentration, at 2.73 mg kg^{-1}, was noted in the soil samples from Takkalupalya.

Table 10. Available Iron

Iron (mg Kg^{-1})		No. of samples	Samples (%)
Class	**Range**		
Deficient	< 2.5	108	95.6
Sufficient	2.5-4.5	5	4.4
Excess	>4.5		

Table 11. Available Manganese (Mn)

Mn (mg Kg^{-1})		No. of samples	Samples (%)
Class	**Range**		
Deficient	< 2.0	68	60.2
Sufficient	2.0-4.0	45	39.8
Excess	>4.0		

Table 12. Available Zinc (Zn)

Zn (mg Kg^{-1})		No. of samples	Samples (%)
Class	**Range**		
Deficient	< 0.6		
Sufficient	0.6-1.5	20	17.7
Excess	>1.5	93	82.3

The information regarding the ratings of available manganese, as indicated by Patil *et al*. (2017a), is detailed in Table 11. Among the 113 soil samples examined, 68 were classified as deficient (<2.0 mg kg^{-1}) and 45 as sufficient (2.5-4.0 mg kg^{-1}). Manganese is characterized by its low mobility within the plant, leading to the initial manifestation of deficiency symptoms in the younger leaves. A manganese deficiency is identified by interveinal chlorosis, which presents as yellowing between the leaf veins, while the veins themselves retain a dark green colour. It is recommended to apply the organic fertilizers such as Farmyard Manure (FYM), compost, along with the application of 25 kg of $MnSO_4$ ha^{-1} as a basal treatment or a 0.5% $MnSO_4$ spray, can effectively address manganese deficiency in a timely manner.

Available Zinc (Zn): The analytical data regarding the available zinc content is presented in Table 12. The analysis of 113 soil samples revealed that the available zinc levels varied from 0.86 to 9.72 mg kg^{-1} of soil, with an average concentration of 3.52 mg kg^{-1}. The minimum available zinc concentration of 0.86 mg kg^{-1} was recorded in the soil sample from Handanakere, while the maximum concentration of 9.72 mg kg^{-1} was observed in the soil sample from Takkalupalya. Additionally, the lowest mean available zinc concentration of 1.87 mg kg^{-1} was identified in the soil samples from Sabbenahalli, whereas the highest mean concentration of 7.85 mg kg^{-1} was found in the soil samples from Ramaghatta.

The data regarding the ratings of available zinc, as indicated by Patil *et al*. (2017a), is displayed in Table 12. Among the 113 soil samples examined, 20 samples (17.7%) were classified as sufficient (0.6 to 1.5 mg kg^{-1}), while 93 samples were categorized as having excess levels (>1.5 mg kg^{-1}) of available zinc. The predominance of soil samples in the excess category may be attributed to the presence of zinc as a contaminant in phosphatic fertilizers. To prevent the potential toxicity associated with zinc, it is advisable to avoid the application of zinc containing straight or complex fertilizers every year.

Available Copper (Cu): The analytical data regarding the available copper content is presented in Table 13. The analysis of 113 soil samples revealed that the available copper levels ranged from 1.55 to 17.58 mg kg^{-1} of soil, with an average concentration of 7.30 mg kg^{-1}. The minimum available copper concentration of 1.55 mg kg^{-1} was recorded in the soil sample from Handanakere, while the maximum concentration of 17.58 mg kg^{-1} was observed in the soil sample from Puradakatte. Additionally, the lowest mean available copper concentration of 6.26 mg kg^{-1} was identified in the soil samples from Ramaghatta, whereas the highest mean concentration of 8.63 mg kg^{-1} was found in the soil samples from Takkalupalya.

The information regarding the ratings of available copper, as indicated by Patil *et al*. (2017a), is detailed in Table 13. Only 13.3 % soil samples (15 samples) are categorized as sufficient range (>0.2 to 5.0 mg kg^{-1}) and remaining 86.7 % soil samples (98 samples) observed as excess (>5.0) copper content in soil. More than 86 % soil samples categorize as excess class might be due to, the presence of copper as an ingredient in fungicides, along with their regular application to either soil or crops, may have contributed to elevated levels of copper in the soils (Patil *et al*., 2017a). Copper toxicity initially occurs in the roots before progressing to the aerial parts of the

Table 13. Available Copper (Cu)

Cu (mg Kg^{-1})		No. of samples	Samples (%)
Class	**Range**		
Deficient	< 0.2		
Sufficient	0.2-5.0	15	13.3
Excess	>5.0	98	86.7

plant, thereby disrupting various physiological functions. Elevated levels of copper in the soil can hinder and damage root development, leading to diminished absorption of nutrients and water. Copper toxicity results in the breakdown of root cuticles, a decrease in the proliferation of root hairs, a darker pigmentation, stunted growth, and significant alterations in root structure. Copper toxicity can be prevented by avoiding the fertilizers and pesticides that contain copper. The use of sticky traps, light traps, pheromone traps and organic pesticides like Neem oil, Dashparni ark, Agniastra etc. should be encouraged alongside non-copper-based pesticides to facilitate integrated pest management.

4. CONCLUSION

The current study observed that the soils in the Chikkanayakanahalli block of Tumkur district in Karnataka exhibit pH levels ranging from moderately acidic to slightly alkaline. These soils are characterized by normal electrical conductivity and generally low organic carbon content, with a few exceptions. The assessment of available macronutrients indicated a low to medium in nitrogen, whereas phosphorus and potassium levels varying from low to high. Additionally, the evaluation of available micronutrients revealed that all soil samples were either deficient to sufficient in iron and manganese, whereas indicating sufficient to excessive levels of copper and zinc. The findings of this research emphasize the urgent need for intensive soil nutrient management due to the overexploitation of soil resources. Declining levels of critical parameters, such soil organic carbon, significantly affect soil health and agricultural sustainability, posing serious challenges in the near future. The analysis conducted in one block may serve as a representative example for the entire state, suggesting that similar conditions are likely to exist elsewhere. This situation calls for prompt action to ensure the sustainable management of soil resources.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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