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Evaluation of fertility status of soils under traditional paddy land cover in Udupi district of coastal Karnataka

T Kantharaj, KV Sudhir Kamath, Lakshmana and SM Jayaprakash

Abstract
A survey was conducted to evaluate the fertility status of soils under traditional paddy land cover in Udupi district, Coastal Karnataka during 2019-20. In this study an assessment of physico-chemical properties *viz*., soil acidity classification, electrical conductivity, soil organic carbon content, available N, P_2O_5, K_2O, S and micronutrient status were carried out in 741 soil samples collected from paddy growing fields in Udupi, Kundapura and Karkala taluks. The results on soil acidity indicated 73.01 percent soils were neutral pH with average of 6.51, 17.68 percent under medium acidic (5.87 average pH), 6.88 percent under strongly acidic (5.37 average pH), 2.29 percent under very strongly acidic (4.77) and only 0.13 percent under extremely acidic (4.38 average pH) in entire Udupi district. The soils of Kundapura had highest mean value of 13.4 g kg^{-1} organic carbon content than Karkala (12.7 g kg^{-1}) and Udupi soils (11.4 g kg^{-1}). Very low status of available nitrogen in soil was distributed with average of 92.1 kg ha^{-1} and soils contained narrow range of 8.5 to 217.9 kg N ha^{-1} in entire Udupi district. Udupi soils had 72.9 percent, Kundapura soils had 48.6 percent and Karkala soils had 22.0 percent distribution under high status of available phosphorus within the range of 0.3-343.5 kg ha^{-1}. The available potassium ranged from 14.9 to 983.3 kg ha^{-1} with average value of 190.6 kg ha^{-1} which revealed that 77.4 percent soils were distributed under low status in Kundapura followed by Udupi (77.1%) and Karkala (57.1%) soils. The available nitrogen content was very low fertility rate (NI=1.0) in the entire district. The available phosphorus content was high (2.63 NI) in Udupi soils than Kundapura (2.28) and Karkala (1.74) soils were classified under medium NI. The nutrient indices of Udupi soils (1.75) remained medium fertility rate with respect to available potassium status wherein, Karkala and Kundapura soils were low (> 1.60 NI).

Keywords: Paddy land cover, acid soils, primary nutrients, fertility status, nutrient index, etc.

Introduction
Karnataka state represents a wide variety of geological, climatic, diversified and physiographic features which have influenced soil formation and thus given rise to various types of soils. Accordingly, the different soils have distinct morphological and physico-chemical properties that have a bearing on plant growth and have influenced the cropping pattern, giving a unique status to the state. A scientific knowledge of soils is a pre-requisite to understand the local ecology and useful in planning for cropping systems. In India, rice continues to play a vital role in the national food and lively hood security of the system covering an area 43.19 million ha with a production of 110.15 million tons (Anonymous, 2017). However, the productivity is 2.55 t ha^{-1} of milled rice which is very less compared to global productivity. In Karnataka, rice is grown on an area of 12.38 lakhs ha with production and productivity of 38.18 lakhs tons and 3084 kg ha^{-1} respectively (Harish Shenoy, 2020) [5]. In Coastal region, paddy varieties with coarse grain and red kernels are generally preferred for parboiling rice as their main staple food.

Coastal Karnataka is characterized by warm humid tropical climate has assured rainfall. It received actual rainfall ranges from 4,334.0 to 5,018.2 mm against the normal rain fall of 3,729 to 3,735.6 mm during 2019 and 2020, respectively (Annual report of zone-10, 2019 and 2020). The rice soils are mostly growing in alluvial and laterites with poor fertility and are generally deficient in lime content due to ample of heavy rainfall results leaching of soluble salts. Coastal alluvium soils occur on gently sloping to nearly level plains as a narrow strip along the western coast line of Karnataka. Laterite soils mainly occur on gently undulating, rolling, plain to hilly topography of peninsular gneiss, occupying areas as a long strip along with western coast in the coastal high rainfall region comprising 13 taluks distributed in entire district of Udupi, Mangalore and parts of Uttara Kannada district. These soils are well drained to excessively drain with moderate to moderately rapid permeability. Due to favourable physical condition of these soils, sustained and better yields can be obtained on many of these soils by adopting recommended package of practices and proper soil and agricultural management systems.

The area under paddy cultivation in Udupi district has come down to 36,000 hectares in 2019-20. The major constraints in the region are scarcity of labours, leaching of nutrients, infrastructures, soil acidity, crop damage by wild animals, erratic rainfall, pest-disease complex and seasonal floods. Apart from all these, knowledge about regional soil fertility status is the important key factor for enhancement of crop productivity without any hamper to farming communities with respect to proper nutritional prospects of human. Thus, an effort has been made to identify fertility status through determining the physico-chemical properties of surface soils under traditional paddy growing areas in Udupi district of Coastal Karnataka. The study would concentrate on pros and cons of lateritic-alluvium soils whether suits for paddy cultivation and/or to know requirement of proper nutritional management in a sustainable rice production which help us to nurture growing population in the modern *era*.

Materials and methods

Estimation of physico-chemical properties of surface soils (0-20 cm) under traditional paddy growing land covers in Udupi district to identify fertility status. It was studied by collection of 741 samples from entire Udupi district which comprises paddy growers of Udupi, Kundapura and Karkala taluks in Coastal Karnataka. The gravelly laterite soil are well distributed in upland, maidan midland region characterized by acidic in reaction, low in CEC, base saturation and water holding capacity. Whereas, lowland regions are formed by deposition of Coastal alluvial soils with effluents of washed down materials from the Western Ghats and by the action of the Arabian Sea. These soils are also acidic in reaction, low in CEC, base saturation and water holding capacity and deficient in the major nutrients.

The collected soil samples were dried under shade and processed to pass through 2 mm sieve. The laboratory analysis of soil samples was conducted at the Zonal Agricultural and Horticultural Research Station, Brahmavar and Soil Testing Laboratory, Adi Udupi, Karnataka during 2019-20. The following standard procedures were adopted for analysis of the nutrients in the laboratory for soil reaction by Potentiometric method (Jackson, 1973) [6], electrical conductivity (dS m^{-1}) by Conductivity Bridge (Jackson, 1973) [6], soil organic carbon (g kg^{-1}) by wet oxidation method (Walkley and Black, 1934) [24], available nitrogen estimation by modified alkaline permanganate method (Subbaiah and Asija, 1956) [2], available phosphorus by Spectro photometry using Bray's No.1 extractant (0.03N NH_4F + 0.025N HCl) (Jackson, 1973) [6], available potassium by Flame photometry using neutral normal ammonium acetate at 1: 5 soil to extract ant (Jackson, 1973) [6] and available sulphur by Turbidometry using 0.15 percent calcium chloride (Black, 1965) [1]. Available micronutrients such as zinc, boron, iron, manganese and copper were estimated by Atomic Absorption Spectrometer (AAS) using DTPA extract ant at 7.3 (Lindsay and Norvell, 1978) [8].

Nutrient indices were computed by adopting soil fertility ratings as described by Ramamurthy and Bajaj (1969) [14].

$$\text{Nutrient Index Value} = \frac{(\%\ \text{samples testing low} \times 1 + \%\ \text{samples testing medium} \times 2 + \%\ \text{samples testing high} \times 3)}{100}$$

The data on different nutrients are presented as a mean of locations under each taluk. Correlations and regressions were also worked out as given by Sundarraj *et al.* (1972) [21].

Results and Discussion

Soil reaction (pH)

Table 1 and 2 furnished the data on descriptive classification and their distribution of soil pH in the study area. It was ranged from extremely acidic to neutral pH (4.38 -7.31) in Udupi taluk. More than fifty percent soil groups were distributed in the neutral range with average value of 6.56 and below 25 percent of soils were medium acidic with average of 5.83 pH. Nearly 6.0 and 16.0 percent of soil samples were grouped under very strongly to strongly acidic with the average pH values of 4.77 and 5.37 in Udupi taluk, respectively. In Kundapura taluk, the soils were classified under strongly acidic (5.48) to neutral pH (7.34). More than 95.0 percent soil samples were classified in the neutral range with an average of 6.50 and below 0.5 to 5.0 percent of soils were strongly acidic to medium acidic with average of 5.48 and 5.93 pH, respectively. Whereas, 73.36 percent soils were classified under neutral range of 6.47 pH and 2.34 to 24.30 percent soils were strongly acidic to medium acidic with the average values of 5.34 and 5.90 pH in Karkala taluk, respectively. Looking into entire Udupi district, 73.01 percent soils were neutral pH with average of 6.51, 17.68 percent under medium acidic (5.87 average pH), 6.88 percent under strongly acidic (5.37 average pH), 2.29 percent under very strongly acidic (4.77) and only 0.13 percent distributed under extremely acidic of 4.38 pH.

The rice growing region in the district is mainly characterized by yellow sandy loam to alluvial soil with high iron and aluminium contents. The district has received heavy annual rainfall as high as 4,334 mm of actual against 3,729 mm of normal rainfall during 2019, which was more than 16 percent surplus amount of rain water sufficient for leaching and washing out of salts and nutrients from soil surface. Due to loss of basic cations in surface soils under humid tropical climate, gradually aluminium hydroxides ($AlOH_3$) build-up leading to formation of acid soil. Soil acidity influences many chemical and biological reactions that impair plant nutrient availability and the toxicity of some elements (Harish Shenoy, 2020) [5]. Crop productivity on such soils is mostly constrained by aluminium (Al) and iron (Fe) toxicity, phosphorus (P) deficiency, low base saturation, impaired biological activity and other acidity-induced soil fertility and plant nutritional problems. The levels of soil acidity along with its associated impacts on soil fertility and crop productivity are expected to further intensify in a changing climate (Sanjay Swami and Shubham Singh, 2019) [22]. Soil acidity management and crop productivity improvement on such soils is therefore important for enhancing rice productivity.

Coastal soils of paddy land cover in Udupi are formed under warm, humid tropical conditions have Fe^{2+} and $A1^{3+}$ as the dominant cation and hence, their pH is very low (4.38-7.34).

These Fe^{2+} and $A1^{3+}$ ions are able to produce higher concentration of H^+ ions as a result of dissociation of water molecule on soil clay complex. The increased concentrations of H^+ ions are responsible for soil acidity in an alarming rate. The high iron and aluminium ions convert the soluble phosphates into their insoluble precipitates. The soil acidity can be managed by applying liming material based on the lime requirement of the soil (Malhotra, *et al*., 2017) [10]. Thus, the farmers are applying lime for reclamation of acid soils every year to neutralize the excess H^+ ions in the soil solution.

Electrical conductivity

Udupi soils found to possess relatively higher EC (0.02-1.34 dSm^{-1}) and that of lowest (0.05-1.17 dSm^{-1}) in Kundapura soils with a mean values of 0.89 and 0.53 dSm^{-1}, respectively (Table 2). Karkala soils found to intermediate in EC (0.06-1.16 dSm^{-1}) with a mean value of 0.59 dSm^{-1}. As these soils are derivatives of granite and granitic gneiss usually lack basic minerals due to sufficient rainfall with proper distribution and found to possess acidic pH and low electrical conductivity (Vishwanath Shetty *et al*., 2008) [23]. In low laying areas where the soils are frequently inundated by brackish water and submergence of excess drained water from the higher altitude for a certain period of the year results soil salinity problems. These findings are in accordance with the results of Malhotra *et al*. (2017) [10].

Soil organic carbon

Among the three taluks, the soils of Kundapura had the highest organic carbon content (1.1-28.9 g kg^{-1}) followed by Karkala (1.1-29.4 g kg^{-1}) and Udupi (1.7-27.6 g kg^{-1}) taluks with mean values of 13.4, 12.7 and 11.4 g kg^{-1}, respectively (Table 2). Soil organic matter generally, increases with biomass production where organic materials incorporated into soil builds higher contents of SOC under warm, humid tropical climate which enhanced the rate of microbial decomposition of added organic residues. Harish Shenoy (2019) [4] also obtained similar observations. The higher content of SOC can be attributed to luxuriant vegetative growth and consequent addition of cheaply available organic manures to soil every year. The soil physical properties in upland and midland areas were vulnerable to microbial degradation as fast as possible which reduced the SOC, washed out through the rain water. Whereas, low lying areas have alluvial plain soils become poor soil physical conditions which were worst for bio-degradation of organic matter thereby accumulated in large amount (Siddaram patil *et al*., 2017) [19].

Nutrient status of soil

Available nitrogen

The data on available macro nutrient status is presented in Table 2. The available nitrogen content in soils are greatly influenced by the organic carbon content of soils, but strong soil acidity encountered the rate of decomposition by arresting microbial activities. Udupi district contains narrow range of available nitrogen (Table 2) was ranged from 8.5 to 217.9 kg ha^{-1} with an average of 92.1 kg ha^{-1} which showed 100 percent soils were distributed under very low status. Among the taluks, lowest mean value of available nitrogen was depicted in Udupi (84.4 kg ha^{-1}) followed by Karkala (93.9 kg ha^{-1}) and Kundapura (99.5 kg ha^{-1}) soils. Even with high organic carbon status of the soils under study, low nitrogen status of the soil may be due to the low mineralization of organic matter as the soils are acidic. It is a fact that the area received very high rainfall (3500 mm) which results in loss of N due to leaching and de nitrification in the soils. Therefore, the soils could retain only a limited quantity of mineralized N. These results are commensurate with the findings of Sidharampatil *et al*. (2017); Sannappa and Manjunath (2013) [19, 17].

Available phosphorus

The phosphorus content of soils in study area ranged between 0.3-343.5 kg ha^{-1} (Table 2). Generally, Coastal acid soils have been classified under *Enti sols*, *Alfisols*, *Oxisols* and *Ultisols* orders usually revealed phosphorus build-up due to free Fe and Al ions on exchange complex. Udupi soils had highest range of available phosphorus content with a mean value of 131.2 kg ha^{-1} followed by Kundapara (62.4 kg ha^{-1}) and Karkala soils (37.3 kg ha^{-1}). The Karkala soils had 48.1 percent under low status, 29.9 percent in medium and 22.0 percent in high range. Reverse was true in case of Kundapura soils (20.6, 30.9 & 48.6% soils were distributed in low, medium & high, respectively). Whereas, Udupi soils had72.9 percent distribution under high status of available phosphorus, 9.9 and 17.3 percent under low to medium range, respectively (Table 3).

The low status of available P_2O_5 was attributed to its higher removal than replenishment and fixation of P as Fe-P and Al-P as they are generally laterite soils which are rich in hydrated as well as amorphous oxides of Fe and Al (Sidharam patil *et al*., 2017) [19]. Similarly, low status of available P_2O_5 in Western Ghats was recorded by Sathisha and Badrinath (1994) [18]. Available P_2O_5 content was medium at some sites in the study area where pH was moderately acidic. The near neutral pH has a significant role in enhancing the P availability. Available P increases with pH and decreases with organic carbon. The increase in available phosphorus due to increase in pH may be due to lowering of activities of Fe and Al^{3+} which increases the solubility of Strengite and Variscite and increases electro-negativity of colloidal complex with a consequent decrease in sorption of P (Dhanya *et al.*, 2009) [3]. Whereas, high in available P_2O_5 might be due to the different management practices followed among the farmers in Udupi soils.

Available potassium

The available potassium content in Udupi district ranged from 14.9 to 983.3 kg ha^{-1} with an average value of 190.6 kg ha^{-1}. Among the taluks, Udupi soils had highest mean value of 236.6 kg ha^{-1} as compared to Karkala (176.8 kg ha^{-1}) and Kundapura (149.1 kg ha^{-1}) soils represented in Table 2. These soils are dominated by kaolinite clay minerals, which have no inter lattice binding sites for K and hence cannot hold any non-exchangeable K (Patil *et al.* 1976) [25]. The influence of clay minerals in K supply to the nutrient pool was also indicated by Ramanathan and Krishnamoorthy (1912) [27]. But it is high in alluvial soils and those formed under warm, humid tropical climatic conditions such as Alfisols and Ultisols. The quantity-intensity relationship and the potential buffering capacity of soil potassium regulate the potassium availability to coconut (Malhotra *et al*., 2017) [10]. Potassium adsorption is comparatively more and uniform in laterite soils than in red sandy loam, river alluvium and coastal sands cultivated to coconut (Harish Shenoy, 2020) [5]. There was a sharp increase in the prices of P and K fertilizers following withdrawal of subsidy, which was led to their decreased consumption by the farmers. The low purchasing power of the farming community and the issue of soil health have again difficult task for uplift of soil fertility.

The available potassium revealed 77.4 percent soils were distributed under low status in Kundapura followed by Udupi (77.1%) and Karkala (57.1%) soils (Table 3). Coarse textured and gravelly soils with deeper solum are particularly low in available potassium, possibly due to faster and deeper leaching and physico-chemical properties (Srinivasan *et al*., 2013) [26]. The results are in line with Sanappa and Manjunath (2013) [17] who recorded low available K statusin lateritic soils of coastal plain and Western Ghats of Karnataka.

Available sulphur

The available sulphur content ranged between 0.32 to 169.5 mg kg^{-1} with a mean value of 8.9 mg kg^{-1} in Udupi district (Table 4). Among the taluks, Udupi soils had highest mean value of 12.8 mg kg^{-1} as compared to Kundapura (7.7 mg kg^{-1}) and Karkala (5.1 mg kg^{-1}) soils. It represented 83.6 percent soils distributed under deficient in Karkala taluk followed by Kundapura (77.8%) and Udupi (52.8%) soils (Table 4). Whereas, sufficiency of sulphur was higher in Udupi soils (47.2 mg kg^{-1}) compared to Kundapura (20.2 mg kg^{-1}) and Karkala (16.4 mg kg^{-1}). Deficiency of sulphur is due to low pH and low content of sulphur bearing minerals (Sidharam patil *et al.*, 2017) [19]. Moreover, coarse texture soil, inherent low organic matter content and soil conditions that favour sulphur leaching losses are also reason for low available sulphur in soil (Patra *et al*., 2012) [12].

Available micronutrient status in soil (Zn, B, Fe, Mn and Cu)

The data on available micronutrient status in soils under paddy land cover in the study area are depicted in Table 4. The available zinc status in the study area was varied from 0.07 to 11.48 mg kg^{-1} with a mean value of 1.48 mg kg^{-1} and 74.8 percent sufficiency level. Udupi taluk has higher mean value of 2.8 mg kg^{-1} and 85.6 percent of sufficiency of zinc as compared to Kundapura (1.1 mg kg^{-1} and 75.7%) and Karkala taluks (0.82 mg kg^{-1} and 59.4%). Overall district contained very few numbers of soils were deficient (25.2%) in zinc content as compared to Udupi (14.4%), Kundapura (24.3%) and Karkala (40.6%) taluks (Table 4). The continuous addition of chemical fertilizers might have increased the adequate levels of zinc in these soils. The present results are in line with those of Sidharam patil *et al*. (2017) [19], Kavitha and Sujatha (2015) [7] who found adequate Zn content in soils of Western Ghats and Coastal Karnataka, Kerala respectively.

The hot water extractable boron content in the study area was very low variability (0.015-1.21 mg kg^{-1}) and mean value of 0.15 mg kg^{-1} with a 97.3 percent deficiency level (Table 4). Most of the soils were very poor in boron status; Udupi taluk has lower mean value of 0.13 mg kg^{-1} and 97.9 percent deficiency compared to Kundapura (0.18 mg kg^{-1} and 96.3%) and Karkala (0.13 mg kg^{-1} and 97.7%) taluk. The lower variability of sufficiency level was found in Udupi (2.1%), Karkala (2.3%) and Kundapura (3.7%). Deficiency of boron is wide spread in most of the acid laterite, red alluvial and coastal sandy soils (Malhotra *et al*., 2017) [10]. The high precipitation of 3,735 mm may be the major cause of prolonged B leaching from soils (Chandrakala *et al*., 2018) [2]. The rice growing areas have been observed under cultivation for a long period with continuous boron uptake by crops (Sidharam patil *et al*., 2017) [19]. However, B fertilizer is not applied to replenish the soils and nutrient mining is offered as one possible reason for B deficiency. In general, management of B in the soil is difficult because of its high mobility and fixations at high pH (Saleem *et al*., 2010) [16].

The available iron was sufficient in the entire study area and it ranged from 0.18 to 64.10 mg kg^{-1} with a mean value of 28.10 mg kg^{-1} and the standard deviation of 14.33 (Table 2). Among the taluks, Udupi has higher level of sufficiency (99.6%) with a mean value of 31.78 mg kg^{-1} followed by Kundapura (98.8%; 29.46 mg kg^{-1}) and Karkala (97.2%; 21.68 mg kg^{-1}) taluks. This is due to high organic carbon prevailing in study area might have influenced the suitability and availability of iron by chelating action which might have protected the iron from oxidation and precipitation, which consequently increased the availability of iron as stated by Sidharam patil *et al*. (2017) [19]. The availability of iron and manganese are generally high in acid laterite and red soils due to Laterization along with de-silication process under tropical humid climate. Therefore, acidic soil reaction showed inherent capacity to supply sufficient amount of available iron. Similar results were also reported by Malhotra *et al*. (2017) [1] and Mahajan *et al.* (2015) [9] in Coastal acid saline soils of Goa.

Similarly, the available copper and manganese content were varies from 0.008 to 63.34 mg kg^{-1} and 0.06 to 51.00 mg kg^{-1} along with mean values of 2.24 and 5.45 mg kg^{-1}, its sufficiency level was 94.2 and 60.5 percent, respectively in the entire district of the paddy land cover. Among the taluks, Kundapura soils has highest percent distribution of sufficiency range with respect to copper (96.7%) and manganese (73.7%) followed by Udupi (93.7 & 71.8%) and Karkala (92.1 & 30.4%), respectively.

As most of soils in paddy land cover are acidic, with decrease in soil pH the adsorption of Cu to the permanent charges will decrease, which is the common phenomena making it higher available to crop. Moreover, Cu being ingredient in fungicide and their frequent application either to soil or crops might have increased their level in the soils (Sidharampatil *et al*., 2017; Prathibha and Kuligod, 2020) [19, 13].

Similar to Fe, the higher content of available Mn in paddy soils is attributed to its chelation by organic compounds released during the decomposition of organic matter and crop residues, as the study area covers most of the plantation crop with tropical ecological region. These observations are in accordance with the findings of (Sidharam patil *et al*., 2017; Prathibha and Kuligod, 2020) [19, 13].

Nutrient index and fertility rating of soil

The available nitrogen content was noticed very low fertility rate in the entire district, its computed nutrient index (NI) value was low (1.0) due to all soils in the study area reported lowest range available N (Table 2 & 3). In case of available phosphorus content was resulted high nutrient index value of 2.63 in Udupi soils which depicts high fertility rating as compared by Kundapura (2.28 NI) and Karkala (1.74 NI) soils were classified under medium fertility ratings. The nutrient indices of Udupi soils (1.75) remained medium fertility rate with respect to available potassium status whereas, Karkala and Kundapura soils were low (> 1.60 NI) in fertility rating (Table 5). The variations among nutrient indices are clearly observed on nutrient management practices impacted on soil fertility status and help us to take-off appropriate measures for development of sustainable soil health. These observations are similar to the findings of arecanut garden soils of Karnataka (Vishwanath Shetty *et al*.,

2008) [23]. Sidharampatil *et al*. (2017) [19] reported that all the major nutrients *viz*., N, P and K were found low in fertility status with nutrient index value of 0.71, 1.37 and 1.09, respectively. But, according to Ravikumar and Somashekar (2014) [15], the NPK status of Karnataka was L-L-H.

Correlation between soil physicochemical properties

The correlations between soil physicochemical properties are depicted in Table 6. The electrical conductivity has significantly highest positive correlation with available P_2O_5 (0.624), K_2O (0.611), Zn (0.690), Mn (0.516) and S (0.449). Similarly, soil organic carbon has significantly highest positive correlation with available N (0.998) and Fe (0.592), while, between available N and Fe was 0.464. In case of available P_2O_5 and Zn showed significantly higher positive correlation (0.561). Whereas, Mn had strong positive correlation with available K_2O (0.545) and Zn (0.505) at 1 percent level significant. These results are corroborating the findings of Vishwanath Shetty *et al*. (2008) [23].

Table 1: Descriptive classification of soil reaction (pH) and their distribution of acid soil under paddy land cover in Udupi district of Coastal Karnataka

Sl. No.	Name of the taluk	Total No. of soil samples	Extremely acidic	Very Strongly acidic	Strongly acidic	Medium acidic	Neutral pH
			(< 4.5)	(4.5–5.0)	(5.1–5.5)	(5.6–6.0)	(6.1–8.5)
1	Udupi	284	01 (0.35%)	17 (5.99%)	45 (15.85%)	69 (24.3%)	152 (53.52%)
		Average values	4.38	4.77	5.37	5.83	6.56
2	Kundapura	243	-	-	01 (0.41%)	10 (4.12%)	232 (95.47%)
		Average values	-	-	5.48	5.93	6.50
3	Karkala	214	-	-	05 (2.34%)	52 (24.30%)	157 (73.36%)
		Average values	-	-	5.34	5.9	6.47
4	Overall Udupi district	741	01 (0.13%)	17 (2.29%)	51 (6.88%)	131 (17.68%)	541 (73.01%)
		Average values	4.38	4.77	5.37	5.87	6.51

Table 2: Descriptive statistics of paddy soil samples analysed for different physico-chemical properties in Udupi district of Coastal Karnataka

Name of the taluk	Particulars/ Soil properties	Soil reaction	Electrical Conductivity	Organic carbon	Avail. N	Avail. P_2O_5	Avail. K_2O
		(pH)	(dS m^{-1})	(g kg^{-1})	---------------(kg ha^{-1}) ------------		
1. Udupi	Range	4.38-7.31	0.02-1.34	1.7-27.6	12.8-204.6	0.3-343.5	26.6-983.3
	Mean value	6.08	0.89	11.4	84.4	131.2	236.6
2. Kundapura	Range	5.48-7.34	0.05-1.17	1.1-28.9	8.5-214.4	1.4-213.8	32.6-881.3
	Mean value	6.47	0.53	13.4	99.5	62.4	149.1
3. Karkala	Range	5.24-7.15	0.06-1.16	1.1-29.4	8.5-217.9	0.7-291.9	14.9-763.7
	Mean value	6.30	0.59	12.7	92.1	37.3	176.8
Overall Udupi district	Range	4.38-7.34	0.02-1.34	1.1-29.4	8.5-217.9	0.3-343.5	14.9-983.3
	Mean value	6.27	0.68	12.4	92.1	81.5	190.6
	Std. Deviation	0.50	0.29	0.51	37.6	79.8	179.6

Table 3: Classification and distribution of fertility status of major nutrients (kg ha^{-1}) under the paddy land soils in Udupi district of Coastal Karnataka

Name of the taluk	Particulars/ Soil properties	Avail. N	Avail. P_2O_5			Avail. K_2O		
		Low	Low	Medium	High	Low	Medium	High
1. Udupi	284	284	28	49	207	138	79	67
	Percent distribution	100	9.9	17.3	72.9	48.6	27.8	23.6
	Mean value	84.4	10.6	39.2	169.3	77.1	236.6	565.1
2. Kundapura	243	243	50	75	118	170	42	31
	Percent distribution	100	20.6	30.9	48.6	70.0	17.3	12.8
	Mean value	99.5	13.0	42.5	95.9	77.4	211.6	457.8
3. Karkala	214	214	103	64	47	115	68	31
	Percent distribution	100	48.1	29.9	22.0	53.7	31.8	14.5
	Mean value	93.9	10.1	36.0	98.6	79.1	207.8	471.1
Overall Udupi district	741	741	372	188	181	423	189	129
	Percent distribution	100	50.2	25.4	24.4	57.1	25.5	17.4
	Mean value	92.1	11.0	39.4	137.1	77.8	220.7	516.7

Table 4: Descriptive statistics of available soil micro-nutrients and their distribution under paddy land cover in Udupi district of Coastal Karnataka.

Name of the taluk	Particulars/ Soil properties	Sulphur	Zinc	Boron	Iron	Manganese	Copper
		--------------- (mg kg^{-1}) --------------					
1. Udupi	Range	0.32-113.4	0.15-11.48	0.015-1.21	2.39-59.96	0.21-43.38	0.08-8.70
	Mean value	12.8	2.8	0.13	31.78	7.79	1.43
	Deficient soils (%)	52.8	14.4	97.9	0.4	28.2	6.3
	Sufficient soil (%)	47.2	85.6	2.1	99.6	71.8	93.7
2. Kundapura	Range	0.32-169.5	0.09-9.97	0.015-0.86	1.71-64.10	0.21-51.00	0.008-63.34
	Mean value	7.7	1.11	0.18	29.46	5.30	3.32
	Deficient soils (%)	79.8	24.3	96.3	1.2	26.3	3.3

	Sufficient soil (%)	20.2	75.7	3.7	98.8	73.7	96.7
3. Karkala	Range	0.32-27.9	0.07-6.18	0.015-1.21	0.18-58.96	0.06-32.88	0.04-43.00
	Mean value	5.1	0.82	0.13	21.68	2.52	2.08
	Deficient soils (%)	83.6	40.6	97.7	2.8	69.6	7.9
	Sufficient soil (%)	16.4	59.4	2.3	97.2	30.4	92.1
Overall Udupi district	Range	0.32-169.5	0.07-11.48	0.015-1.21	0.18-64.10	0.06-51.00	0.008-63.34
	Mean value	8.9	1.48	0.15	28.10	5.45	2.24
	Std. deviation	12.78	1.53	0.15	14.33	7.71	4.40
	Deficient soils (%)	70.6	25.2	97.3	1.3	39.5	5.8
	Sufficient soil (%)	29.4	74.8	2.7	98.7	60.5	94.2

Table 5: Nutrient index values of macro-nutrients under paddy land soils in Udupi district of Coastal Karnataka

Sl. No.	Name of the taluk	Total No. of soil samples	Avail. N		Avail. P_2O_5		Avail. K_2O	
			Nutrient Index value	Fertility ratings	Nutrient Index value	Fertility ratings	Nutrient Index value	Fertility ratings
1.	Udupi	284	1.0	Low	2.63	High	1.75	Medium
2.	Kundapura	243	1.0	Low	2.28	Medium	1.43	Low
3.	Karkala	214	1.0	Low	1.74	Medium	1.61	Low
4.	Overall Udupi district	741	1.0	Low	1.74	Medium	1.60	Low

Table 6: Correlation coefficients (r) between physico-chemical properties of soils under paddy land cover in Udupi district of Coastal Karnataka

Soil properties	Soil pH	Electrical conductivity	Organic carbon	Avail. N	Avail. P_2O_5	Avail. K_2O	Avail. S	Zinc	Boron	Iron	Manganese
Electrical conductivity	0.105**										
Organic carbon	0.076*	0.106**									
Avail. N	0.076*	0.106**	0.998**								
Avail. P_2O_5	0.058^{NS}	0.624**	0.112**	0.108**							
Avail. K_2O	0.133**	0.611**	-0.023^{NS}	-0.021^{NS}	0.346**						
Avail. S	0.097**	0.449**	0.066^{NS}	0.059^{NS}	0.279**	0.154**					
Zinc	0.106**	0.690**	0.154**	0.145**	0.561**	0.410**	0.297**				
Boron	-0.061^{NS}	0.061^{NS}	0.151**	0.135**	0.103**	-0.016^{NS}	0.027^{NS}	0.134**			
Iron	$-.050^{NS}$	0.222**	0.592**	0.464**	0.410**	-0.090*	0.228**	0.358**	0.116**		
Manganese	0.185**	0.516**	0.056^{NS}	0.049^{NS}	0.220**	0.545**	0.154**	0.505**	0.045^{NS}	0.115**	
Copper	0.054^{NS}	0.015^{NS}	0.192**	0.180**	0.027^{NS}	0.061^{NS}	0.012^{NS}	0.180**	0.147**	0.187**	0.088*

Note: ** - Correlation is significant at 1%
* - Correlation is significant at 5%

Conclusion

The paddy cultivation practice has been exhausted in coastal Karnataka due to rice crop suffers with toxicity of Fe and Al ions owed to extreme to strongly acidity in soil solum. The main reason for the development of soil acidity was high rainfall under warm-humid tropical climate which led to acid bearing parent materials, leaching of soil clay complex from surface layers, loss of plant nutrient and moisture holding capacity. In acid, red laterite and lateritic soils have been identified with major nutrient deficiency symptoms, because, lack of response to the balanced fertilizers application. In these soils the plant nutrients applied through fertilizers are also lost rapidly and investment on fertilizers becomes risky. Further, low water retention capacity due to high permeability brings in moisture stress condition quickly after the cessation of rains.

Application of appropriate liming materials for increasing soil pH to ensure spectacular increase in sustainable rice production, high nutrient supply and reducing leaching loses. The use of bio-fertilizers as sources of plant nutrients for rice production along with the bulky organic manures like FYM, quick growing leguminous crops grown in the cropping sequence properly inoculated with Rhizobia grown in the sequence of blue green algae and Azolla. The available N, specially has high mobility in both soil and plant systems might be guide us to tackle reasons for low productivity of rice through nano-science, sensor based fertilizer application. Ultimately, the rice yield potential can be enhanced by strengthening nutrient use efficiencies by use of nano-fertilizer techniques in combination with integrated nutrient management practices are an eco-friendly, pollution free management techniques under traditional paddy growing areas.

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