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Chemical Characterization of Soils from *Kole* Land Ecosystem of Thrissur District, Kerala, 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

Chemical characteristics of acid sulphate soils (*Kole*) of Thrissur district were done after the flood in 2018, in order to access the fertility and productivity of the soil. A total of 25 random samples were collected from different locations of AEU 6 in Thrissur district and its chemical characterization and mapping were done. Soils of *Kole* lands of Thrissur district were ultra to moderately acid in reaction (3.31 to 6.42) with an average pH of 4.98 and with medium to high organic carbon content (1.17 to 4.41 %) and 92 per cent of soil samples were high in available nitrogen which was resulted due to the presence of more organic matter and clay. Forty percent of soils were low in available phosphorus content. Almost 80 per cent of soil samples showed sufficiency in potassium content. Among the secondary nutrients, calcium and sulphur were sufficient while 52 per cent of soil

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samples showed deficiency in available magnesium. Among the micro nutrient content in collected soil samples, available Fe, Mn and Zn were high and no Zn deficiency was noticed. Cation exchange capacity ranged from 7.57 to 22.01 cmol (+) kg^{-1} with a mean content of 13.92 cmol (+) kg^{-1}. The present study on mapping and primary characterisation form the base for further detailed study of *Kole* land ecosystem of Thrissur district in post flood scenerio.

Keywords: Cation exchange capacity; iron; kole; pH; phosphorus; wetland.

1. INTRODUCTION

A wetland is a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem. Wetlands are typically shallow, so sunlight can penetrate the surface to facilitate subterranean photosynthesis, making these ecosystems, one of the most biologically productive areas on the planet. Primarily, the factor that distinguishes wetlands from other land forms or water bodies is the characteristic vegetation, adapted to its unique soil conditions ie. Hydric soil. Wetlands are crucial for delivering diverse ecological services around the world due to their regulating activities in the aquatic sequence, high efficiency, and biodiversity [1,2]. Considering the functional values of wetland which include groundwater replenishment, water purification, flood control biodiversity reservoir, recreation tourism and climate change mitigation it is often described as the kidneys of the landscape [3].

The National Wetland Inventory and Assessment compiled by the Indian Space Research Organisation (ISRO), estimates India's wetlands to span around 1, 52,600 square kilometres, which is 4.63 % of the total geographical area of the country. A little over two-fifths are inland natural wetlands and about a quarter are coastal wetlands. One of the important wetland systems of Kerala is the *Kole* land system known as the granary of Thrissur and Malappuram district situated between 10° 20' to 10° 40' N latitude and 75° 58' to 76° 11' E longitude and lying 0.5 to 1m below mean sea level. The *Kole* lands, a part of Vembanad *Kole*, is one of the major wetland systems in South-west coast of India, extending from the northern bank of Chalakudy river in the south to the southern bank of Bharatapuzha river in the north and mainly divided as Thrissur *Kole* and Ponnani *Kole*.

Since 2002, these wetlands are assigned as Ramsar site because it is renowned for its live clam resources and sub-fossil deposits, paradise of migratory and resident birds, habitat for variety of finfish, shellfish and act as a transitional ecotone between sea and land. The convention on wetlands (Ramsar convention) is the only international legal treaty primarily focussed on wetlands. It works globally to promote their conservation and wise use [4]. Under the classification of National Bureau of Soil Survey and Land Use Planning [5], *Kole* lands come under agro-ecological unit 6 (AEU 6) with an area of 13,632 ha. The word, *Kole* in malayalam indicates bumper yield or high returns from crops.

Irene [6] in her study found that the water logged soils are subjected to flooded or anaerobic condition for a long period of time. These soils have distinctive gley horizons due to redox reactions. Rice is the major crop which is grown under this unique wetland system. The soil is mostly ultra acidic in reaction often underlain by potential acid sulphate sediments. These acid sulphate soils are characterised by low pH, aluminium (Al) and iron (Fe) toxicity and are typically deficient in phosphate (PO_4). This toxicity also results in the unavailability of phosphorus due to its fixation by these elements. Soils are mostly clayey in texture with a redox potential of 0.20 to -0.40 V.

In 2018, Kerala state received very high rainfall during the monsoon season which resulted in widespread flood and landslide events. The western Ghats were affected with landslides and the top soil in the hilly areas had been removed in the flash flood and were deposited in the low laying tracts which resulted in the alteration of physical, chemical and biological properties of soil of Kerala and this necessitated a site specific investigation of the flood affected areas in the state in order to put forward post flood management strategies. In this regard a study was conducted to give special emphasis to spatial distribution and chemical characterisation of soils from *Kole* land ecosystem of Thrissur district, in Kerala.

2. MATERIALS AND METHODS

The present study was carried out at the Radiotracer laboratory, College of Agriculture, KAU during 2019-2020. Representative samples

(25 Nos.) from *Kole* land coming under the order Entisols & Inceptisols (AEU-6) were collected during Novermber 2019 and location map of 25 geo referenced samples in AEU 6 was done with the help of GIS software (Fig. 1). Soil sampling was done using core sampler from 0-20 cm depth without disturbing the reduced condition as far as possible. The collected samples were immediately sealed and labelled the covers with the location details and additional information so as to maintain the redox condition without any disturbance. Geographical co-ordinates of sampling sites were recorded using GPS. Samples varying in chemical characteristics were collected by means of random sampling method. Details of sampling locations are presented in the location map (Fig. 1).

2.1 Characterization of Soil Samples

Soil samples collected from different paddy fields of *Kole* lands were analysed for soil reaction, electrical conductivity, organic carbon, available N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and cation exchange capacity. Soil reaction was determined in a 1:2.5 soil water suspension potentiometrically using a pH meter [7,8]. Electrical conductivity was estimated in the supernatant liquid of the soil water suspension (1:2.5) used for pH estimation with the help of a conductivity meter [7]. Wet digestion method was used for the determination of organic carbon content of the soil and expressed as per cent organic carbon after doing correction for incomplete oxidation. Available nitrogen was determined by alkaline potassium permanganate ($KMnO_4$) method by Subbiah [9]. The soil was mixed with $KMnO_4$ solution and distilled using Kjeldahl distillation unit to liberate ammonia which was condensed and absorbed in known volume of boric acid (H_3BO_3) with mixed indicator to form ammonium borate. This ammonia was determined volumetrically by titration with standard acid (0.02 N H_2SO_4). Available phosphorus was extracted using Bray No.1 extractant which was widely used as an index of available P in acid soil. The P content in the extract was determined colorimetrically as phospho-molybdate blue colour complex with ascorbic acid as a reducing agent [10]. The intensity of blue colour was measured using a spectrophotometer. Available potassium, calcium and magnesium in the soil samples were extracted using neutral normal ammonium acetate [7]. Potassium content in the extract was estimated by flame photometry. Calcium and magnesium content was estimated in Atomic Absorption Spectrophotometer (Model: Perkin Elmer-PinAAcle 500). Available sulphur was extracted by using 0.15% $CaCl_2$ and estimated by turbidimetry [11] using a spectrophotometer (Model: Systronics169). Available micronutrients were analysed using 0.1M HCl extractant and concentration of micronutrients (Fe, Mn, Zn and Cu) were measured using AAS. Barium chloride extractable cations were determined by following the procedure of [12]. The cations present in the exchangeable sites in the soil were replaced by barium. Forty millilitres of 0.1M $BaCl_2$ was added to 4 g of soil in a centrifuge tube. After a shaking period of 2 hrs, it was filtered through Whatman No.42 filter paper for the determination of CEC. Estimation of cations in the extract (Ca, Mg, Al, Fe, Mn, Cu, Zn, Na and K) was done using ICP-OES (Model: Perkin Elmer-Optima 8000). Since the lowland soils are high in water soluble cations, deduction of water soluble fraction from barium chloride extractable cations was carried out to avoid over estimation. Deionised water (25 mL) was added to 5g soil in a centrifuge tube. The supernatant was decanted after centrifugation at 4000 rpm for 30 minutes. Using 25 mL deionized water, the residue was washed, shaken, centrifuged and filtered. Estimation of cations was done using ICP-OES (Model: Perkin Elmer-Optima 8000). CEC was expressed as cmol(+) kg^{-1} [13].

2.2 Data Analysis

Data obtained from the laboratory was subjected to descriptive statistics using Microsoft- excel. The mean was used as primary estimates of central tendency, and standard deviation, minimum and maximum values were used to describe the degree of variability in soil chemical properties (SAS Institute Inc., 2002). Data was also analyzed using Pearson correlation using KAU GRAPE software to depict the relationship between the determined parameters and scatter diagram was plotted using Microsoft-excel. All the results were again verified using OPSTAT package.

3. RESULTS AND DISCUSSION

The soils were ultra-acidic (3.31) to slightly acidic (6.42) in reaction with an average value of 4.98. The lowest pH was reported in Tharishukarimbhana (3.31) of Puzhakkal block where as highest pH in Thiruthinthazham padav (6.42) of Puzhakkal block (Table 2). The details of soil reaction in the collected soil samples is given in Table 1. According to Johnkutty [14],

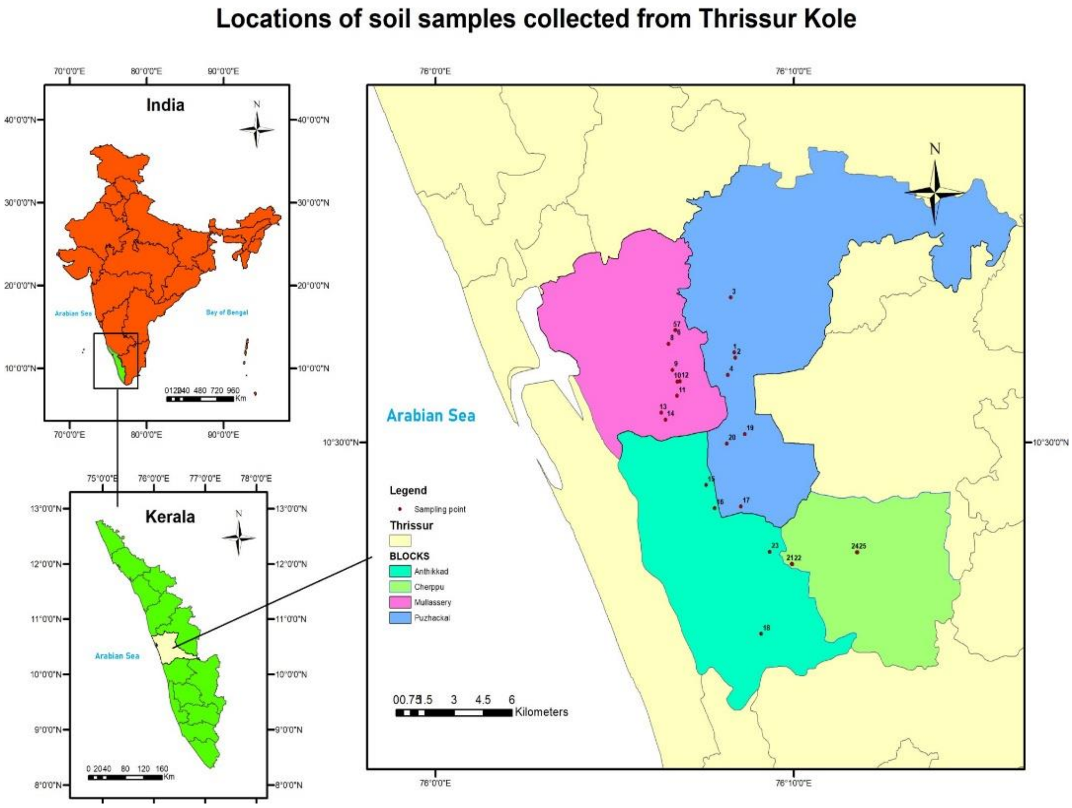

Fig. 1. Location map of soil samples collected from *Kole* lands of Thrissur district

soils in *Kole* areas were generally acidic with pH varying from 2.6 to 6.3. The extreme acidity of these soils is due to the presence of organic peat layer in subsurface.

Electrical conductivity which represents the salt content of the soil varied from 0.07 to 0.58 dS m^{-1} with an average value of 0.24 dS m^{-1}. The lowest EC value of 0.07 was observed in Ombhathumuri padav of Puzhakkal block and highest EC value of 0.58 was recorded in Rajmut of Andhikkad block (Table 2). All the soil samples collected from *Kole* lands had an electrical conductivity less than 1 dS m^{-1} [6]. The lesser EC might be due to loss of soluble salts during flooding, variation in mineralogy of soil and high soil moisture content [15]. In the correlation matrix presented below (Table 3) a strong positive correlation was noticed between EC and available sulphur (0.7***) and this may be due to the presence of more soluble sulphate. Organic carbon content of *Kole* land soil ranged from 1.17 to 4.41 % with a mean value of 2.58%. The lowest and highest value for organic carbon content was reported by Ponnamudha padav and Vadakekonchira of Mullessery block respectively (Table 2). Most of the samples were high in organic carbon content (> 1.5%). Irene [6] reported that lack of major electron acceptor: free oxygen enhance or increases the organic matter status in submerged soil. Due to the slow, inefficient and incomplete decomposition, there is net accumulation of organic matter under flooding. Chibba [16] found that in acid soils of high rainfall areas of Punjab, organic carbon content was high (0.5 to 1.4 per cent). Sarangi [17] concluded that in acid sulphate soils in the Ganges Delta contains comparatively higher organic carbon (OC) in the Ap and BA horizons (0–70 cm) because of depositions of organic matter. Kavitha [18] claimed that the high organic carbon content of *Kole* land soils was due to high deposition of silt material washed down by rivers from the mountains. Available nitrogen ranged from 487.06 kg ha^{-1} to 4171 kg ha^{-1} with an average content of 1700.71 kg ha^{-1}. Almost 92 per cent of soil samples were high in available nitrogen (> 560 kg/ha) and two locations, Ponnamudha of Mullessery block and Chaladipazham *Kole* of Andhikkad block came under medium range (280-560 kg ha^{-1}). These locations were also found to be low in organic matter content compared to other locations, even though *Kole* land represent high organic matter content. High content of available nitrogen is due to the presence of more amount of organic matter [19]. In the correlation matrix (Table 3) there is a strong positive correlation between the available nitrogen and organic matter content (0.663**). Soil samples collected from *Kole* land showed variation in the content of available P which ranged from 1.05 to 130.20 kg ha^{-1} with a mean value of 27.17 kg ha^{-1}.

The lowest and highest value for available phosphorus was recorded in Madhukkara thaek and Vadakkaekonchira of Mullessery block panchayath (Table 2). About 40 per cent of the samples collected from *Kole* region of Thrissur came under low range (<10 kg ha^{-1}) and 32 per cent were medium in phosphorus content (10-24 kg ha^{-1}) where as 28 percent showed high P content (>24 kg ha^{-1}). Low availability of P is due to fixation of phosphorus under acidic soil reaction. Sanchez [20] observed that the P fixed was held with five times more bonding energy in acid soils compared to calcareous soils. Acid soils which fix large quantities of P are invariably medium- to fine- textured soils high in oxides and hydroxides of Fe and Al.

Table 1. Soil reaction of collected soil samples

Sl. No.	Soil acidity	pH range	Per cent
1	Ultra acidic	<3.5	8
2	Extremely acidic	3.5 to 4.5	20
3	Very strongly acidic	4.5 to 5	20
4	Strongly acidic	5.1 to 5.5	16
5	Moderately acidic	5.6 to 6	32
6	Slightly acidic	6.1 to 6.5	4

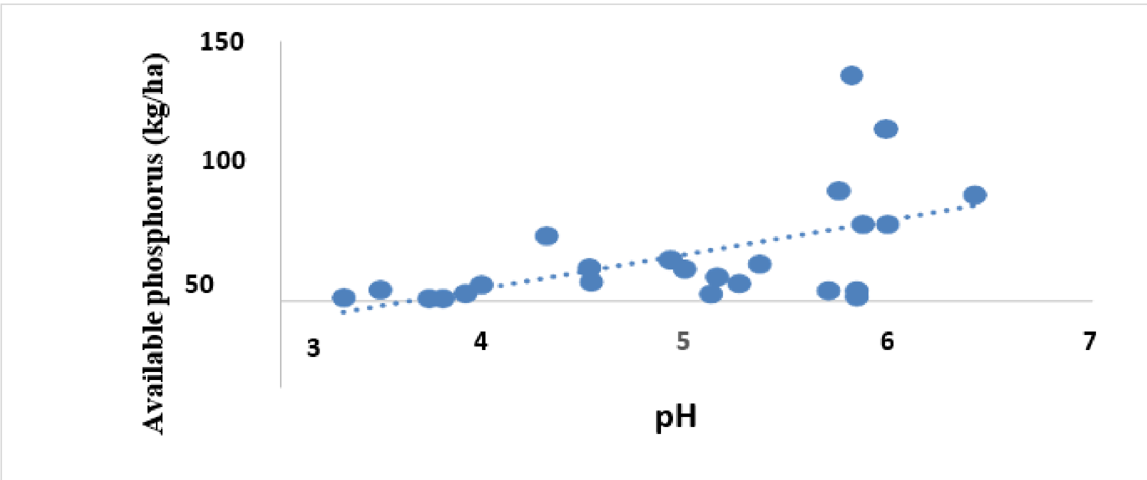

Fig. 2. Relationship between soil pH and available P (kg ha^{-1})

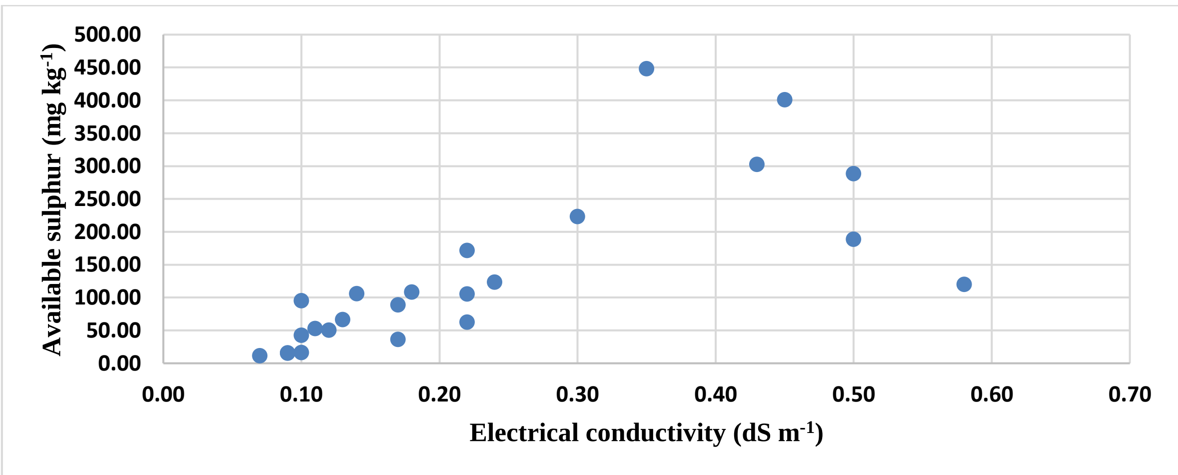

Fig. 3. Relationship between soil EC and available S (kg ha^{-1})

Penn [21] agreed with these results and stated that low pH contribute to P fixation. The deficiency of P might be due to fixation of phosphorus or loss of available P by washing out during flood. Amrutha [22] reported low content of available phosphorus in acid rice soils of Kerala. Koshy [23] observed that more phosphorus is fixed per gram of clay than per gram of silt. They suggested that in acid soils fixation is primarily due to the formation of insoluble phosphates of iron and aluminium. Occurance of high P is in accordance with the findings of [24] and [25] found that flooding increased the phosphorus availability due to release of phosphorus bound to iron during reduction of Fe (III) to Fe (II). The phosphorus was found high before flood [26]. But after the flood, the status of phosphorus changed to medium to high. The increase in pH of acid soils and the decrease in pH of calcareous and sodic soils enhance the availability of P. High availability of phosphorus in some locations of *Kole* land is due to remobilization of phosphorus in sediments mainly caused by P release from reductant-soluble elements, like Fe, and mineralization of P containing organic compounds [27]. In the correlation matrix (Table 3), pH of the soils was found to have a strong positive correlation with available phosphorus (0.551**) (Fig. 2). Available potassium ranged from 87.76 to 271.70 kg ha^{-1} with an average of 185.40 kg ha^{-1}. The lowest available potassium was observed in Ombhahumuri padav of Puzhakkal block and the highest available potassium was recorded in Madhukkara vadak of Mullessery (Table 2). Almost 80 per cent of soils collected from *Kole* land of Thrissur showed high potassium content (>280 kg ha^{-1}) and this may be due to the incorporation of paddy stubbles in the soil after paddy cultivation or due to variation in mineral composition [28]. Afari-Sefa [29] reported that this might be due to variation in mineral compostion, high cation exchange capacity and clayey texture of soil. In the correlation matrix (Table 3) available potassium is found to have positive correlation with cation exchange capacity (0.42*), available Ca (0.46*) and available Mg (0.588**). Where as 20 per cent of soil samples showed low values in potassium content (<120 kg/ha). Potassium deficiency in *Kole* was reported by [14]. Ubuoh [30] found that flood affected farm fields of Abakaliki, Nigeria, showed a decline in availability of potassium content. Available calcium content varied from 112.89 to 1313.74 mg kg^{-1} with a mean value of 586.50 mg kg^{-1}. 76 per cent of the samples collected from *Kole* land was sufficient in calcium content (> 300 mg kg^{-1}) especially from Mullessery and Andhikkad block and 24 per cent showed deficiency of available calcium (<300 mg kg^{-1}). Lowest amount of calcium may be due to the removal of calcium by means of leaching which is caused by high rainfall or low pH in these locations where Ca is too soluble to be retained in the soil and the highest values indicate the presence of calcium bearing minerals (lime deposits) in acid sulphate soil as these locations are situated near to Enamavu Kettu or bund which prevent fresh water of Enamakkal lake from mixing with salty sea water. Calcium also showed a strong positive correlation with available magnesium (0.942***) and cation exchange capacity (0.728**) (Table 3). Venugopal [31] found that calcium is the predominant exchangeable base in the surface layer of *Kole* soils (2.09 cmol kg^{-1}) and this was due to relatively higher amounts of humus and clay. Soil samples from the *Kole* land showed 50 per cent deficiency of available magnesium content. It ranged from 66.21 to 240.36 mg kg^{-1} with a mean value of 135.74 mg kg^{-1}. The lowest available magnesium was recorded in Ponnaudha padav of Mullessery block and the highest value in Pallippuram padav of Andhikkad block (Table 2). Among the collected samples, 48 per cent comes under sufficiency range (>120 mg kg^{-1}) and 52 percent comes under deficiency range (<120 mg kg^{-1}). The deficiency of magnesium might be due to low soil reaction. Sureshkumar [32] reported that magnesium solubility was higher when pH of soil fell below 7.5. They found that magnesium depletion was a common phenomenon in acidic soils due to higher instability of magnesium minerals in acidic condition. Since magnesium is deficient in soil, application of magnesium fertilizers are recommended after every cropping season. In the correlation matrix (Table 3) available magnesium showed a strong positive correlation with cation exchange capacity (0.771**). Available sulphur varied from 11.73 to 448.44 mg kg^{-1} with a mean content of 131.10 mg kg^{-1}. Highest available sulphur was observed in Pavuttai padav of Mullessery block and the lowest value in Ombhathumuri padav of Puzhakkal block (Table 2). Almost all the samples showed high amount of available sulphur, this is in accordance with the findings of [33]. The influence of sea water intrusion may be the reason for very high available sulphur content in low land soils of Pokkali, *Kole* and Kuttanad. Strong correlation between sulphur and EC formed the base for these findings (Fig. 3).

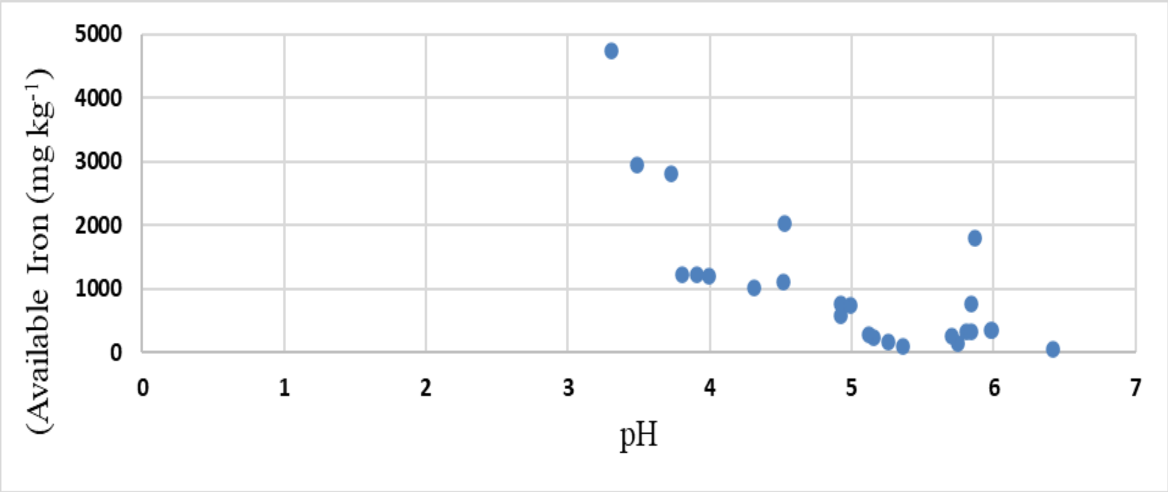

Fig. 4. Relationship between soil pH and available Fe (mg kg^{-1})

3.1 Available Micronutrients

Available iron content ranged from 100.25 to 1775.72 mg kg^{-1} with an average of 681.12 mg kg^{-1}. The highest available iron was reported in Jubilethurav padav of Andhikkad block and the lowest iron content in Erumakuzhi padav of Cherpu block (Table 2). Most of the sampling locations fell under sufficiency range in the iron content (>5mg kg^{-1}). Amrutha [22] also reported the occurence of high iron content in acid sulphate wetland which is caused by the reduction of Fe (III) to Fe(II) due to flooding. This will increase the solubility of Fe (II) and may reach to a toxic level. Patnaik [34] reported that *Kole* land was generally acidic with low base saturation, high P fixing capacity, and high Fe and Al toxicity which may cause serious problems in crop production. In the correlation matrix available (Table 3) iron showed a strong negative correlation with pH (-0.615**) (Fig. 4).

Available manganese content ranged from 6.61 to 91.5 mg kg^{-1} with a mean content of 21.12 mg kg^{-1}. The highest value of 91.5 mg kg^{-1} was recorded in Ombhathumuri padav of Puzhakkal block and the lowest value in Jubilethurav padav of Andhikkad block (Table 2). Soil samples of *Kole* land showed sufficiency in available Mn content (>1 mg kg^{-1}). This may be due to release of available Mn during flood. Amarawansha [35] claimed that available manganese content increased due to flood. During flooding Mn^{4+} reduced to Mn^{2+} and this led to increased solubilisation of manganese in soil. Available copper content ranged from 0.73 to 9.96 mg kg^{-1} with an average of 6.58 mg kg^{-1}. The highest copper content was observed in Vadakkaekonchira of Mullassery block and the lowest value in Thiruthinthazham padav of Puzhakkal block panchayath (Table 2). Almost 96 per cent of the collected samples came under sufficiency range (>1 mg kg^{-1}). Safnathmol [15] reported that the increased availability of copper might be due to the effect of flooding. During flooding, reduction of hydrous oxides of Fe and Mn and the production of organic complexing agents would have increased the solubility of copper. Available Zn content ranged from 2.4 to 9.72 mg kg^{-1} with a mean of 4.85 mg kg^{-1}. The highest Zn content was reported in Kodayatti padav of Andhikkad block panchayath and the lowest value in Erumakuzhi padav of Cherpu block (table 1). There is no Zn deficiency in Thrissur *Kole* lands (<1 mg kg^{-1}). Safnathmol [15] noted that the sufficiency in zinc availability might be due to low pH and high organic matter content in soil. Praseedom [36] observed a variation from 0.3 to 7.77 ppm Zn in surface layers of Kerala soils and suggested that Kerala soils may be considered to be satisfactory with respect to Zn levels.

3.2 Cation Exchanage Capacity

Cation exchange capacity ranged from 7.57 to 22.01 cmol (+) kg^{-1} with a mean content of 13.92 cmol (+) kg^{-1}. Highest and the lowest value of cation exchange capacity was reported in Manalurthazham and Chaladipazhankole of Andhikkad block (Table 2). Shao [27] reported that the soils of the *Kole* area had a cation exchange capacity ranging from 4.86 to 9.84 cmol (+) kg^{-1}. The clay content, CEC and organic matter were higher for the surface layer soils.

Table 2. Chemical characteristics of soil samples collected from Thrissur *Kole* lands

	pH	EC	OC (%)	Av.N (kg/ha)	Av.P (kg/ha)	Av.K (kg/ha)	Av.Ca (kg/ha)	Av.Mg (kg/ha)	Av.S (kg/ha)	Av.Fe (mg/kg)	Av.Mn (mg/kg)	Av.Cu (mg/kg)	Av.Zn (mg/kg)	Moisture (%)	CEC cmol (+) kg-1
1	4.52	0.07	1.86	1111.66	18.84	87.76	668.83	102.88	11.73	487.43	91.5	8.11	5.34	37.94	12.07
2	5.99	0.1	2.41	1088.94	43.82	147.2	234.67	93.69	95.29	269.77	9.28	5.56	3.94	38.2	11.31
3	3.31	0.43	3.97	4171.61	1.63	117.77	352.34	95.19	302.73	1147.38	8.06	3.41	3.49	46.4	11.19
4	6.42	0.1	3.08	1622.78	60.99	213.32	655.8	145.35	42.61	1593	59.43	0.73	9.63	62.28	19.11
5	5.36	0.3	1.68	1198.14	21.03	195.77	587.28	117.93	223.18	241.92	16.8	6.57	2.71	40.42	11.63
6	4.92	0.35	2.74	2671.45	23.38	226.32	682.62	142.35	448.44	800.93	27.9	7.82	5.86	47.63	12.74
7	3.8	0.18	2.62	1583.6	1.14	226.68	412.54	116.3	108.37	1208.41	18.06	6.93	3.69	44.04	13.75
8	5.15	0.17	2.49	2476.87	13.65	271.7	489.61	135.04	89.19	273.97	12.03	9.12	5.45	50.34	14.35
9	5.26	0.11	1.48	1862.7	9.79	263.07	787.5	189.98	52.83	289.27	9.86	9.15	4.52	47.42	14.02
10	5.12	0.22	1.71	1202.79	3.75	208.19	857.32	180.63	62.64	350.71	16.39	6.55	3.54	22.5	11.44
11	4.92	0.14	1.17	500.72	23.53	92.5	112.89	66.21	106.22	747.55	7.62	4.43	3.93	26.17	9.44
12	3.73	0.44	3.41	1752.46	1.05	247.41	998.23	204.44	132.35	1230.71	27.76	8.85	5.89	47.83	15.81
13	5.81	0.24	4.41	3403.71	130.2	215.64	490.78	143.04	123.46	258.22	17.78	9.96	5.09	60.68	17.24
14	4.99	0.12	3.58	2058.33	17.98	223.23	557.88	113.66	50.65	683.04	15.14	9.08	5.96	49.26	14.3
15	5.87	0.45	2.52	1639.06	43.92	153.64	734.45	179.32	401.07	331.74	24.02	7.08	5.5	48.86	22.01
16	3.49	0.58	2.58	3336.28	6.12	226.8	282.4	115.98	120.36	1227.75	12.7	4.7	3.14	31.09	10.87
17	4.53	0.22	3.16	2276.73	10.78	237.5	1127.69	188.62	105.73	583.25	30.63	8.66	9.72	45.35	18.76
18	5.75	0.09	1.99	1033.17	63.22	206.38	679	142.85	15.87	360.6	10.85	5.01	3.49	38.82	14.15
19	5.98	0.1	1.87	1170.37	99.29	160.45	220.67	88.65	16.65	538.89	26.02	6.66	7.92	46.88	11.03
20	5.84	0.5	1.29	487.06	5.62	119.47	240.9	87.03	188.96	140.97	23.35	3.66	2.85	27.06	7.57
21	5.84	0.13	3.63	2063.4	2.17	233.27	1313.74	240.36	66.56	250.92	21.82	9.3	6.38	55.71	20.29
22	3.91	0.5	2.59	950.14	4.01	161.43	1308.35	222.2	288.69	1158.7	8.99	6.68	3.22	45.13	19.62
23	4.31	0.09	2.56	1304.03	37.28	120.05	385.94	112.45	15.55	976.97	18.24	7.06	3.35	42.44	12.57
24	3.99	0.22	2.82	957.84	8.99	133.54	360.72	92.49	171.87	1775.72	6.61	6.72	4.37	42.13	10.35
25	5.7	0.17	2.88	594.14	5.55	146.11	120.6	77.08	36.66	100.25	7.24	2.88	2.4	49.01	12.55

Table 3. Correlation (r) of important chemical parameters of soil samples

	pH	EC	Av N	Av P	Av K	Av Ca	Av Mg	Av S	OC	Av Fe	Av Mn	Av Cu	Av Zn	Moisture	CEC
pH	1														
EC	-0.426*	1													
Av N	-0.329	0.306	1												
Av P	**0.551****	-0.257	0.082	1											
Av K	0.051	0	**0.417***	-0.052	1										
Av Ca	-0.077	0.117	0.101	-0.261	**0.46***	1									
Av Mg	-0.01	0.181	0.18	-0.182	**0.588****	**0.942*****	1								
Av S	-0.21	**0.7*****	0.284	-0.155	-0.075	0.146	0.151	1							
OC	-0.19	0.111	**0.663*****	0.126	0.283	0.237	0.259	0.129	1						
Av Fe	**-0.615****	0.213	0.16	-0.182	-0.05	0.011	-0.033	0.137	0.279	1					
Av Mn	0.121	-0.208	-0.068	0.117	-0.142	0.202	0.041	-0.169	-0.041	0.071	1				
Av Cu	-0.125	-0.129	0.24	0.008	0.45*	0.47*	0.476*	-0.003	0.217	-0.25	0.006	1			
Av Zn	0.265	-0.284	0.199	0.271	0.349	0.36	0.313	-0.128	0.31	0.16	0.497*	0.196	1		
Moisture	0.236	-0.195	0.395	0.331	0.398*	0.283	0.33	0.041	0.703***	0.107	0.153	0.236	0.536**	1	
CEC	0.179	0.029	0.21	0.111	**0.42***	**0.728*****	**0.771*****	0.158	**0.496***	0.021	0.17	0.308	0.511**	0.678***	1

***Correlation is significant at the 0.01 level (2-tailed)*
**Correlation is significant at the 0.05 level (2-tailed)*

4. CONCLUSION

All the soil samples collected from the *Kole* land showed acidic soil reaction. Addition of lime can be recommended to ameliorate soil acidity. Electrical conductivity in AEU 6 was below the toxicity level. The organic carbon had been shifted towards medium to high from low to medium level after the flood. Available nitrogen content was high in most of the soil samples whereas available phosphorus was deficient in 40 per cent of soil and medium in 32 per cent of soils. Strong correlation between pH and phosphorus reaffirm the fixation of phosphorus by iron and aluminium oxides. Available potassium was sufficient in 80 per cent of soil samples. Among the secondary nutrients, available calcium and sulphur was sufficient in 74 per cent of soils. Deficiency of available magnesium was severe in *Kole* lands. Among micro nutrients, available Fe, Mn and Zn was high in AEU 6. There is no Zn deficiency in Thrissur *Kole* lands. Cation exchange capacity ranged from 7.57 to 22.01 cmol (+) kg^{-1} with a mean content of 13.92 cmol (+) kg^{-1}. Due to flooding, lowering of EC, accumulation of organic matter, medium to high in available phosphorus content, decline in availability of potassium and increase in content of Fe, Mn and Cu occurred. Phosphorus deficient regions due to fixation by Fe and Al necessitate the importance of addition of phosphatic fertilizers. Magnesium fertilisers are also recommended in acid sulphate regions of *Kole* land. These findings formed the basis for efficient nutrient management in acid sulphate soils in *Kole* regions of Thrissur during the post flood scenario as well as further research works especially for the dynamics of phosphorus in submerged soils.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Dr. Amrutha K K, Dr. Beeena V I, Dr. Geetha P, 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 manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Janse JH, Van Dam AA, Hes EM, de Klein JJ, Finlayson CM, Janssen AB, van Wijk D, Mooij WM, Verhoeven JT. Towards a global model for wetland ecosystem services. Current Opinion in Environmental Sustainability. 2019;36:11–19.
2. Bai J, Ouyang H, Deng W, Zhu Y, Zhang X, Wang Q. Spatial distribution characteristics of organic matter and total nitrogen of marsh soils in river marginal wetlands. Geoderma. 2005, Jan 1;124(1-2):181-92.
3. Patel K, Chaurasia M, Nagar S. Wetland conservation and restoration. Wetlands Conservation: Current Challenges and Future Strategies. 2021;272-283.
4. Neha T. Economic valuation of ecosystem services: A case study of *Kole* wetlands, Ramsar site. Ph.D (Ag) thesis, Department of wildlife sciences, College of Forestry, Vellanikkara. 2021;83.
5. NBSS & LUP [National Bureau of Soil Survey and Land Use Planning]. Soil Resource Mapping; 2012.

   Available: https://www.nbsslup.in/new-delhi.html [20 July 2020].
6. Irene EJ. Wet analysis for nutrient prescription in paddy soil. M. Sc. (Ag) thesis, Kerala Agricultural University, Thrissur. 2014;254.
7. Jackson ML. Soil Chemical Analysis. Prentice Hall, Englewood Cliffs, NJ. 1958;341.
8. Walkley A, Black TA. An examination of the Degt. Jarett method for determination of soil organic matter and a proposed modification of cromic acid titration method. Soil Science. 1934;37:29-38.
9. Subbiah BV, Asija GL. A rapid procedure for the determination of available nitrogen in soil. Current Science. 1956; 25:259-260.
10. Bray RH, Kurtz LT. Determining total, organic and available forms of phosphate in soils. Soil Science. 1945;59:39-45.
11. Massoumi J, Cornfield AH. A rapid method for determination sulphate in water extracts of soils. Analyst. 1963;88:321-322.
12. Sims JR, Johnson GV. Micronutrient soil tests. In: Mortvedt JJ, Cox FR, Shuman LM, Welch RM (eds), Micronutrient in

Agriculture (2nd Ed.). Soil Science Society of America, Madison, USA. 1991;427-476.

13. Hendershot WH, Duquette M. A simple barium chloride method for determining cation exchange capacity and exchangeable cations. Soil Science Society of America Journal. 1986;50:605-608.
14. Johnkutty I, Venugopal VK. *Kole* Lands of Kerala. Kerala Agricultural University, Vellanikkara, Thrissur.1993;77.
15. Safnathmol P. Assessment of soil quality in the post flood scenario of AEU 6 in Thrissur and Malappuram districts of Kerala and mapping using GIS techniques. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur. 2020;112.
16. Chibba IM, Sekhon GS. Effect of pH and organic carbon on availability of nutrients in acid soils. Journal of the Indian Society of Soil Science.1985;33:409-411.
17. Sarangi SK, Mainuddin M, Maji B. Problems, management, and prospects of acid sulphate soils in the Ganges Delta. Soil Systems. 2022;6(4):95.
18. Kavitha C, Sujatha MP. Evaluation of soil fertility status in various agroecosystems of Thrissur district, Kerala, India. International Journal of Agriculture and Crop Sciences. 2015;8:328-338.
19. Amritha K, Durga Devi KM. Effect of pre and post emergence herbicides on microbial biomass carbon and dehydrogenase activity in soils. Journal of Tropical Agriculture. 2017;55(1):114-118.
20. Sanchez PA, Uehara G. Management considerations for acid soils with high phosphorus fixation capacity. In: Khasawneh, FE. Sample, EC. Kamprath, EJ. (eds.), The Role Phosphorus in Agriculture, ASA-CSSA-SSSA, Madison. 1980;514.
21. Penn CJ, Camberato JJ. A critical review on chemical processes that control how soil pH affects phosphorus availability to plants. Agriculture. 2019;9:1- 18.
22. Amrutha KK, Beena VI, Geetha P. Nutrient status of acid sulphate soils of upper kuttanad of Kerala, India. International Journal of Environment and Climate Change. 2023;13(9):1834-1842.
23. Koshy MM, Brito- Mutunayagam ARA. Fixation and availability of phosphorus in soils of Kerala. Agricultural Research Journal of Kerala. 1965;69-78.
24. Gallardo A. Spatial variability of soil properties in a floodplain forest in Northwest Spain. Ecosystems. 2023; 6:564-576.
25. Amery F, Smolders E. Unlocking fixed soil phosphorus upon waterlogging can be promoted by increasing soil cation exchange capacity. European Journal of Soil Science. 2012;5(1):1-8.
26. GoK [Government of Kerala]. Kerala Soil Health Information System; 2013.
    Available:https://www.keralasoilfertility.net/en/agroecology.jsp. [12 June 2020]
27. Shao X, Liang X, Wu M, Gu B, Li W, Sheng X, Wang S. Influences of sediment properties and macrophytes on phosphorous speciation in the intertidal marsh. Environmental Science and Pollution Research. 2014;21:10432-41.
28. Bhindu PS. Chemistry and transformations of calcium and magnesium in tropical acid soils of Kerala, Ph.D.(Ag) thesis, Kerala Agricultural University. 2017; 283.
29. Afari-Sefa V, Kwakye PK, Anti DK, Imoro AZ. Potassium availability in soils-forms and spatial distribution. Soil Science. 2004;37:29-38.
30. Ubuoh EA, Uka A, Egbe C. Effects of flooding on soil quality in Abakaliki agro-ecological zone of south-eastern state, Nigeria*.* International Journal of Environmental Chemistry and Ecotoxicology Research. 2016;3(1):20-32.
31. Venugopal VK, Koshy MM. Exchaneable cations of some important soil profiles of Kerala. Agricultural Research Journal of Kerala. 1976;14:37-42.
32. Sureshkumar P, Sandeep S. Secondary nutrients in soils and their management.In: Rattan RK, Katyal JC, Dwivedi BS, Sarkar AK, Bhattacharyya T, Tarafdar JC, Kukal SS. (eds), Soil Science: an Introduction. Indian Society of Soil Science, New Delhi. 2015;601-623.
33. Reshma MR. Anionic equilibria in major soil types of kerala. Ph.D (Ag) thesis, Kerala Agricultural University, Thrissur. 2020;300.
34. Patnaik S. Natural sources of nutrients in rice soils. Soils and Rice. 1978;501-519.
35. Amarawansha EA, Kumaragamage D, Flaten D, Zvomuya F, Tenuta M. Phosphorus mobilization from manure-amended and unamended alkaline

soils to overlying water during simulated flooding. Journal of Environmental Quality. 2015;44(4):1252-1262.

36. Praseedom RK, Koshy MM. The Zn status of Kerala soils. Agricultural Research. Journal of Kerala. 1975;13:1-4.

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