Chemical Status of Different Agro-Ecological Units of Kerala: A Comprehensive Study

ABSTRACT

A study was carried out in selected panchayats/municipalities of the four *agro-ecological units* (AEUs), AEU 8 (Southern laterites), AEU 9 (South central laterites), AEU 10 (North central laterites), and AEU 11 (Northern laterites) of Kerala to assess the electrochemical properties such as pH and *electrical conductivity* (EC) and chemical properties like available *nitrogen* (N), *phosphorus* (P), and *potassium* (K) by following one-way ANOVA. The main objective of the study was to document the soil fertility status of the study area. The perusal of the data revealed that most of the collected soils were strongly acidic and moderately acidic in nature, with the lowest mean value of 5.42 pH being noticed in south central laterites (AEU 9), whereas the highest mean value of 6.21 recorded in northern laterites (AEU 11). The mean values of EC of the four AEUs varied from 0.03 to 0.10 dS m^{-1} and were found to be within the critical limit. Regarding N, the mean values varied from 219.97 to 259.88 kg ha^{-1}. The available P was high in 96% of the soil samples tested. It was noticed that 83% of samples were under the medium category for available K. Liming the soil to correct its acidity could enhance microbial activity, which in turn could improve the utilisation of N fertilisers that are applied. Furthermore, balanced fertilisation will boost soil health, increase nutrient use efficiency, and enhance the productivity of the study area.

Keywords: Agro-ecological units, Available nutrients (nitrogen, phosphorus, and potassium), Electrical conductivity, Soil pH

1. INTRODUCTION

Soil is a vital, dynamic natural entity that sustains life for all living organisms on Earth [1], and it is also a chief non-renewable natural resource that must be maintained in a healthy and productive state in a sustainable manner due to its significant role in increasing agricultural productivity. The interplay between the organic and mineral constituents within soil promotes plant growth [2]. Its physical, chemical, and biological attributes empower the provision of nutrients in the proper quantity and maintain the equilibrium necessary for plant growth [3]. In addition to its abilities in promoting plant growth, high-quality soil possesses the capacity to mitigate air and water pollution, prevent soil erosion, and deter land degradation. Maintaining or improving the levels of soil fertility, preventing soil deterioration, and enhancing food quality and safety are all possible with effective soil management [4]. At the same time, inadequate soil management practices on cultivated lands have resulted in a greater rate of soil erosion, reduced crop production and productivity, and deteriorated soil quality [5]. Therefore, assessing soil fertility might be the most fundamental tool for determining suitable nutrient management practices [6]. Soil testing is the approach most commonly performed worldwide to determine soil fertility, yet there are other approaches as well [7]. In order to maximise crop yields and ensure sufficient fertility in soils for a prolonged period of time, fertiliser recommendations rely on the results of soil tests, which evaluate the current status of fertility and offer knowledge about the availability of nutrients in soils. The electrochemical properties such as soil pH (important in agriculture since the reactions and availability of plant nutrients depend on the soil pH) and EC (quantitative measure of soluble salts in soils and/or groundwater), along with the chemical properties (available N, P, and K), give information regarding the ability of soil to provide mineral nutrients and also play vital roles in determining the quality and productivity of soil.

Kerala state lies between 8° 18' and 12° 48' N latitude and 74° 52' and 77° 22' E longitude. It covers an area of 38,864 km^2. The state has a series of hills and valleys intersected by various rivers. Based on climatic variability, landforms, and soils, Kerala has been divided into 23 AEUs, each of which corresponds to a particular soil and climatic conditions.

In this context, the present study was aimed at assessing selected electrochemical and chemical properties of soils in southern laterites (AEU 8), south central laterites (AEU 9), north central laterites (AEU 10), and northern laterites (AEU 11) of Kerala with the objective of documenting the soil fertility status of the study area and furnishing management strategies and future lines of work.

2. MATERIAL AND METHODS

This study focused on soil samples collected from AEU 8 (Southern laterites), AEU 9 (South central laterites), AEU 10 (North central laterites), and AEU 11 (Northern laterites). After conducting a preliminary survey, a total of 100 georeferenced representative soil samples (0-15 cm depth) of 25 from each of the four AEUs were collected during March-April, 2019, before premonsoon showers. Which included Athiyanoor, Balaramapuram, Kalliyoor, Kottukal, and Venganoor panchayats/municipalities of Thiruvananthapuram district for AEU 8, Kottarakkara, Kulakkada, Mylom, Neduvathoor, and Pavithreswaram panchayats/municipalities of Kollam district for AEU 9, Chalakudy, Kadukutty, Kodakara, Koratty, and Meloor panchayats/municipalities of Thrissur district for AEU 10, and Chathamangalam, Koduvally, Mukkam, Omassery, and Peruvayal panchayats/municipalities of Kozhikode district for AEU 11. The collected soil samples were analysed for electrochemical properties like pH and EC, and chemical properties like available N, P, and K. Electrochemical properties (pH and EC) were analysed in the 1:2.5 soil:water suspension using pH meter and EC meter, respectively [8]. Alkaline permanganometry was adopted for available N [9]. Bray extraction accompanied by spectrometry was employed for available P [10]. Neutral normal ammonium acetate extraction accompanied by flame photometry was used for available K [8]. The statistical design followed was one-way ANOVA using the open software GRAPES [11]. The details of the study area are depicted in Fig. 1.

3. RESULTS AND DISCUSSION

3.1 Electrochemical properties (Soil pH and EC)

The results of soil pH and EC of different panchayats/municipalities in southern laterites (AEU 8), south central laterites (AEU 9), north central laterites (AEU 10), and northern laterites (AEU 11) are presented in Table 1a. It is evident from the data that the mean values of soil pH of different panchayats/municipalities in southern laterites (AEU 8), south central laterites (AEU 9), and north central laterites (AEU 10) showed a significant difference except for northern laterites (AEU 11). The perusal of the data revealed that there was no significant difference among the panchayats/municipalities in southern laterites (AEU 8), south central laterites (AEU 9), north central laterites (AEU 10), and northern laterites (AEU 11) with regard to EC.

In southern laterites (AEU 8), the mean values of pH ranged from 4.97 to 5.97. The lowest mean pH value of 4.97 was observed in Kalliyoor panchayat, whereas the highest value was recorded by the panchayat of Kottukal (5.97), which was found to be on par with Athiyanoor panchayat (5.74). In south central laterites (AEU 9), the mean values of pH ranged from 5.22 to 5.73. The lowest mean value of pH of 5.22 was noticed in the Neduvathoor panchayat, whereas the highest value was noticed in the Kulakkada panchayat (5.73). The mean pH values in north central laterites (AEU 10) varied from 5.20 to 5.76. The lowest mean pH value of 5.20 was observed in Kodakara panchayat, whereas the highest mean pH value (5.76) was noticed in Kadukutty panchayat, which was comparable to the panchayats Koratty and Meloor (5.72).

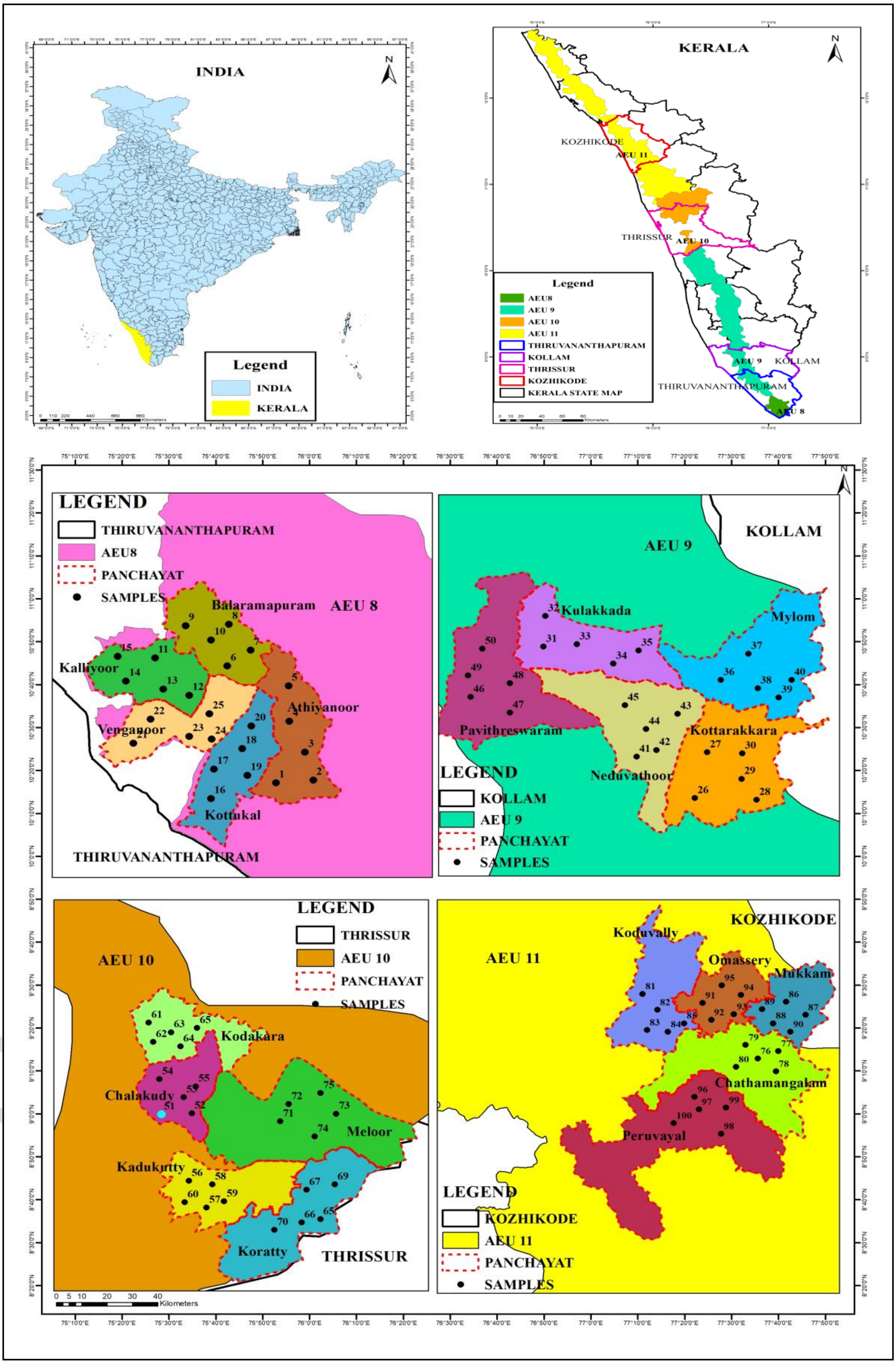

Fig. 1. Location map of soil samples in AEUs 8, 9, 10, and 11 of Kerala

Table 1a. Soil pH and EC of different Panchayats/Municipalities of AEUs 8, 9, 10, and 11

Panchayat/Municipality	pH	EC (dS m^{-1})
Southern laterites (AEU 8)		
Athiyanoor	5.74 ^{ab}	0.10
Balaramapuram	5.32 ^{c}	0.11
Kalliyoor	4.97 ^{d}	0.12
Kottukal	5.97 ^{a}	0.08
Venganoor	5.67 ^{b}	0.11
SEd (±)	0.128	0.025
SEm (±)	0.090	0.018
CD (0.05)	0.266	NS
South central laterites (AEU 9)		
Kottarakkara	5.37 ^{c}	0.04
Kulakkada	5.73 ^{a}	0.03
Mylom	5.24 ^{c}	0.03
Neduvathoor	5.22 ^{c}	0.03
Pavithreswaram	5.56 ^{b}	0.05
SEd (±)	0.081	0.006
SEm (±)	0.057	0.004
CD (0.05)	0.168	NS
North central laterites (AEU 10)		
Chalakudy	5.33 ^{b}	0.03
Kadukutty	5.76 ^{a}	0.04
Kodakara	5.20 ^{b}	0.03
Koratty	5.72 ^{a}	0.03
Meloor	5.72 ^{a}	0.04
SEd (±)	0.114	0.009
SEm (±)	0.080	0.007
CD (0.05)	0.237	NS
Northern laterites (AEU 11)		
Chathamangalam	6.33	0.08
Koduvally	6.29	0.05
Mukkam	6.23	0.04
Omassery	5.86	0.14
Peruvayal	6.32	0.03
SEd (±)	0.293	0.051
SEm (±)	0.207	0.036
CD (0.05)	NS	NS

Table 1b. Soil pH and EC of different AEUs 8, 9, 10, and 11

AEU	pH		EC (dS m^{-1})	
	Mean±SD	Range	Mean±SD	Range
Southern laterites (AEU 8)	5.53±0.40 [b]	4.85-6.42	0.10±0.04 [a]	0.02-0.18
South central laterites (AEU 9)	5.42±0.23 [b]	5.13-5.85	0.04±0.01 [c]	0.02-0.05
North central laterites (AEU 10)	5.54±0.29 [b]	5.03-5.89	0.03±0.01 [c]	0.02-0.07
Northern laterites (AEU 11)	6.21±0.46 [a]	5.34-6.93	0.07±0.08 [b]	0.01-0.41
SEd (±)	0.101		0.013	
SEm (±)	0.071		0.009	
CD (0.05)	0.201		0.027	

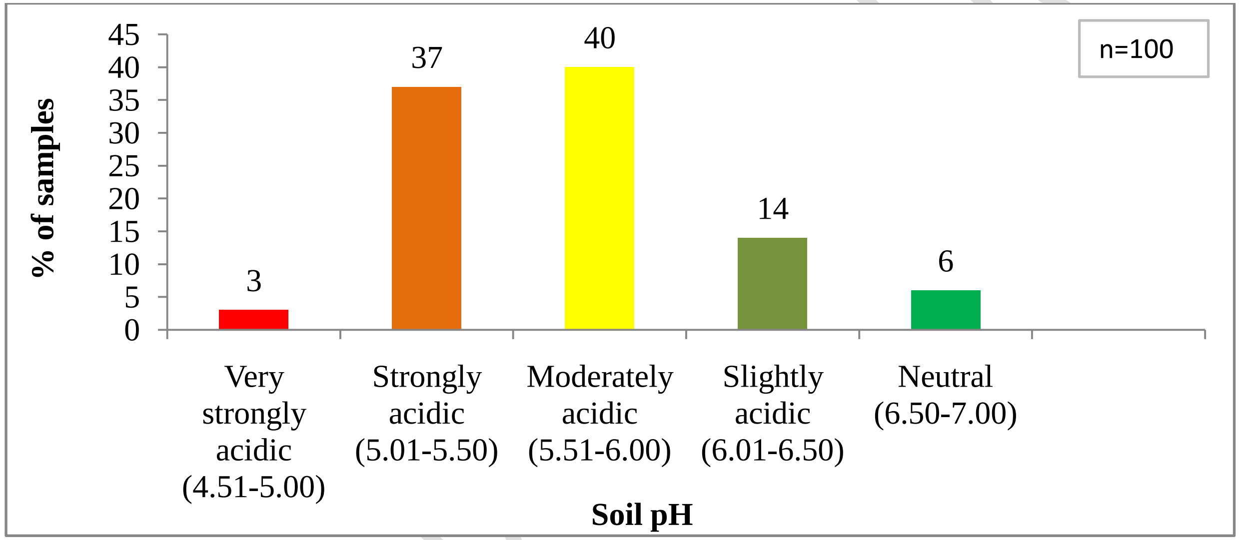

Fig. 2. Frequency distribution of pH in the soils of AEUs 8, 9, 10, and 11

The mean values of pH of four AEUs, viz., southern laterites (AEU 8), south central laterites (AEU 9), north central laterites (AEU 10), and northern laterites (AEU 11), are displayed in Table 1b. As per Table 1b, among the four AEUs, there was a significant difference with respect to pH, which varied from 5.42 to 6.21. The lowest mean value of 5.42 pH was noticed in south central laterites (AEU 9), whereas the highest mean value of 6.21 was recorded in northern laterites (AEU 11). Frequency distribution analysis of the data revealed that about 3% of the collected soil samples were noticed to be very strongly acidic, 37% were strongly acidic, 40% were moderately acidic, 14% were slightly acidic, and 6% were neutral in pH (Fig. 2). The soils of Kerala were mostly laterites and basically acidic in reaction [12]. Leaching of basic cations like calcium and magnesium from the soil might be the reason for increased acidity. The most effective technique for reducing soil acidity is liming [13]. The pH of the soil, the type of lime, the farming technique, and the amount of rainfall will determine how much lime is required [14], and lime with a higher percentage of smaller particulates will react more quickly to neutralise acidity in the soil [15]. But few of the collected soils fell under the neutral pH range. This might be because of the buildup of some basic cations at the surface. The presence of organic deposits at the surface might have prevented the production of organic acids, which led to an increase in pH [16].

The mean values of EC of four AEUs, viz., southern laterites (AEU 8), south central laterites (AEU 9), north central laterites (AEU 10), and northern laterites (AEU 11), are presented in Table 1b. Among the four AEUs, there was a significant difference with respect to EC, which varied from 0.03 to 0.10 dS m^{-1} (Table 1b). The lowest mean value of 0.03 dS m^{-1} was observed in north central laterites (AEU 10), while the highest mean value of 0.10 dS m^{-1} was noticed in southern laterites (AEU 8), and they were found to be within the critical limit. The obtained EC values might have been due to the variation in soluble salts and the variation in mineral composition [17]. However, the low EC values in the present study might be due to the leaching of soluble salts [18, 19].

3.2 Chemical properties (available N, P, and K)

Various parameters, like available N, P, and K, were analysed for the soil samples of the study area, and the results are furnished in Tables 2a and 2b.

3.2.1 Available N

Soil available N in southern laterites (AEU 8) and north central laterites (AEU 10) showed a significant difference at the panchayat/municipality level, but there was no significant difference noticed in south central laterites (AEU 9) and northern laterites (AEU 11), as furnished in Table 2a. The mean value of available N in southern laterites (AEU 8) ranged from 202.53 to 294.22 kg ha^{-1}. The lowest mean value of 202.53 kg ha^{-1} was noticed in the panchayat Kottukal, while the highest mean value of 294.22 kg ha^{-1} was recorded in the panchayat Kalliyoor. In north central laterites (AEU 10), the mean value of available N ranged between 198.97 and 275.87 kg ha^{-1}. The lowest mean value of 198.97 kg ha^{-1} was noticed in the panchayat Kadukutty, whereas the highest mean value of 275.87 kg ha^{-1} was observed in the panchayat Koratty, making it comparable to the panchayat Kodakara (260.21 kg ha^{-1}).

Overall, among the four AEUs, there was a significant difference for available N (Table 2b). The mean values of available N varied from 219.97 to 259.88 kg ha^{-1}. The lowest mean value of 219.97 kg ha^{-1} was recorded in south central laterites (AEU 9), whereas the highest mean value of 259.88 kg ha^{-1} was noticed in northern laterites (AEU 11). Frequency distribution analysis of the data from the study area revealed that 84% of samples indicated low levels of available N, while 16% of samples were found to be in medium status (Fig. 3). These results are consistent with those of other authors [20]. This might be because of its unstable nature, particularly its inorganic forms, which undergo numerous transformations, some of which occur quickly, including plant uptake, microbial immobilisation, leaching, volatilization, nitrification, and denitrification [21].

3.2.2 Available P

Agro-ecological units, southern laterites (AEU 8), south central laterites (AEU 9), north central laterites (AEU 10), and northern laterites (AEU 11) had reported a significant difference at the panchayat/municipality level for soil available P (Table 2a). In southern laterites (AEU 8), the mean value of available P ranged from 50.35 to 124.81 kg ha^{-1}. The lowest mean value of 50.35 kg ha^{-1} was observed in panchayat Balaramapuram, whereas the highest mean value of 124.81 kg ha^{-1} was recorded by panchayat Kalliyoor. The soils of various panchayats/municipalities of south central laterites (AEU 9) had mean values of available P ranged from 23.11 to 64.62 kg ha^{-1}, and the lowest mean value of 23.11 kg ha^{-1} was observed in panchayat Kulakkada, whereas the highest mean value of 64.62 kg ha^{-1} was recorded by panchayat Kottarakkara. In north central laterites (AEU 10), the mean value of available P ranged from 48.90 to 83.99 kg ha^{-1}. The lowest mean value of 48.90 kg ha^{-1} was recorded by the panchayat Kadukutty, while the highest mean value of 83.99 kg ha^{-1} was recorded by the panchayat Koratty, which was found to be on par with the panchayats Meloor (72.86 kg ha^{-1}) and Kodakara (64.81 kg ha^{-1}). In northern laterites (AEU 11), the mean values of available P ranged from 39.86 to 99.21 kg ha^{-1}. The lowest mean value of 39.86 kg ha^{-1} was recorded by the panchayat Koduvally, while the highest mean value of 99.21 kg ha^{-1} was recorded by the panchayat Omassery, and it was on par with the panchayat Chathamangalam (96.92 kg ha^{-1}).

Among the four AEUs, there was a significant difference for available P (Table 2b). The mean values of available P varied from 38.66 to 92.74 kg ha^{-1}. The lowest mean value of 38.66 kg ha^{-1} was noticed in south central laterites (AEU 9), whereas the highest mean value of 92.74 kg ha^{-1} was observed in southern laterites (AEU 8). From the data analysed, it was noticed that the available P is high in 96% of the soil samples tested (Fig. 3), which might be due to local differences in soil genesis and previous P-fertilisation in the area because heavy inputs of phosphatic fertilisers might also cause the building up of very high levels of P in soils. Moreover, orthophosphate ions readily form complexes with Al^{3+} and Fe^{2+}, which are widely available in soils that are acidic. In addition, soils containing an abundant amount of manganese (Mn), iron (Fe), and aluminium (Al) might retain P and render it inaccessible for plant consumption [22, 23]. As a result, nearly 80% of applied P becomes unavailable to plants [24], as observed in south central laterites (AEU 9).

3.2.3 Available K

There was a significant difference in soil available K at the panchayat/municipality level in southern laterites (AEU 8), south central laterites (AEU 9), and north central laterites (AEU 10), except in northern laterites (AEU 11), as presented in Table 2a. In southern laterites (AEU 8), the mean value of available K ranged from 111.12 to 167.06 kg ha^{-1}. The lowest mean value of 111.12 kg ha^{-1} was observed in panchayat Kottukal, whereas the highest mean value of 167.06 kg ha^{-1} was recorded by panchayat Kalliyoor, which was found to be on par with the panchayats Athiyanoor (153.82 kg ha^{-1}) and Venganoor (146.10 kg ha^{-1}). In south central laterites (AEU 9), the mean value of available K ranged from 103.24 to 248.89 kg ha^{-1}. The lowest mean value of 103.24 kg ha^{-1} was observed in panchayat Mylom, whereas the highest mean value of 248.89 kg ha^{-1} was recorded by panchayat Pavithreswaram. In north central laterites (AEU 10), the mean value of available K ranged

Table 2a. Available N, P, and K in the soils of different Panchayats/Municipalities of AEUs 8, 9, 10, and 11

Panchayat/Municipality	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Southern laterites (AEU 8)			
Athiyanoor	221.75 ^{bc}	82.16 ^{c}	153.82 ^{a}
Balaramapuram	209.31^{bc}	50.35 ^{d}	121.90 ^{b}
Kalliyoor	294.22 ^{a}	124.81 ^{a}	167.06 ^{a}
Kottukal	202.53 ^{c}	98.61 ^{b}	111.12 ^{b}
Venganoor	235.69 ^{b}	107.78 ^{b}	146.10 ^{a}
SEd (±)	12.747	6.859	10.572
SEm (±)	9.013	4.850	7.475
CD (0.05)	26.589	14.307	22.052
South central laterites (AEU 9)			
Kottarakkara	239.44	64.62 ^{a}	136.79 ^{b}
Kulakkada	210.97	23.11 ^{d}	132.90 ^{b}
Mylom	209.29	29.85 ^{cd}	103.24 ^{c}
Neduvathoor	216.11	35.62 ^{bc}	103.51 ^{c}
Pavithreswaram	224.03	40.12 ^{b}	248.89 ^{a}
SEd (±)	15.005	3.501	7.207
SEm (±)	10.61	2.475	5.096
CD (0.05)	NS	7.302	15.034
North central laterites (AEU 10)			
Chalakudy	229.65 ^{b}	50.87 ^{b}	121.99 ^{b}
Kadukutty	198.97 ^{c}	48.90 ^{b}	136.63 ^{ab}
Kodakara	260.21 ^{a}	64.81 ^{ab}	141.17 ^{a}
Koratty	275.87 ^{a}	83.99 ^{a}	139.98 ^{a}
Meloor	231.09 ^{b}	72.86 ^{a}	150.99 ^{a}
SEd (±)	12.323	9.393	7.481
SEm (±)	8.714	6.642	5.290
CD (0.05)	25.706	19.593	15.604
Northern laterites (AEU 11)			
Chathamangalam	248.09	96.92 ^{a}	151.47
Koduvally	267.12	39.86 ^{d}	160.97
Mukkam	292.01	56.89 ^{c}	157.02
Omassery	235.97	99.21 ^{a}	180.45
Peruvayal	256.19	79.24 ^{b}	168.07
SEd (±)	25.652	8.064	21.145
SEm (±)	18.139	5.702	14.951
CD (0.05)	NS	16.820	NS

Table 2b. Available N, P, and K in the soils of different AEUs 8, 9, 10, and 11

AEU	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Southern laterites (AEU 8)	232.70±38.18 ^{b}	176.42-326.14	92.74±27.65 ^{a}	44.51-129.54	140.00±25.98	107.20-193.20
South central laterites (AEU 9)	219.97±24.40 ^{b}	156.13-263.42	38.66±15.32 ^{c}	21.91-74.19	145.07±55.89	98.37-274.96
North central laterites (AEU 10)	239.16±32.53 ^{b}	170.84-288.16	64.28±19.16 ^{b}	30.91-95.05	138.15±14.44	117.59-165.85
Northern laterites (AEU 11)	259.88±41.81 ^{a}	202.11-327.55	74.42±26.20 ^{b}	30.00-108.54	163.60±32.18	116.58-241.85
SEd (±)	9.858		6.407		10.042	
SEm (±)	6.971		4.531		7.101	
CD (0.05)	19.568		12.718		NS	

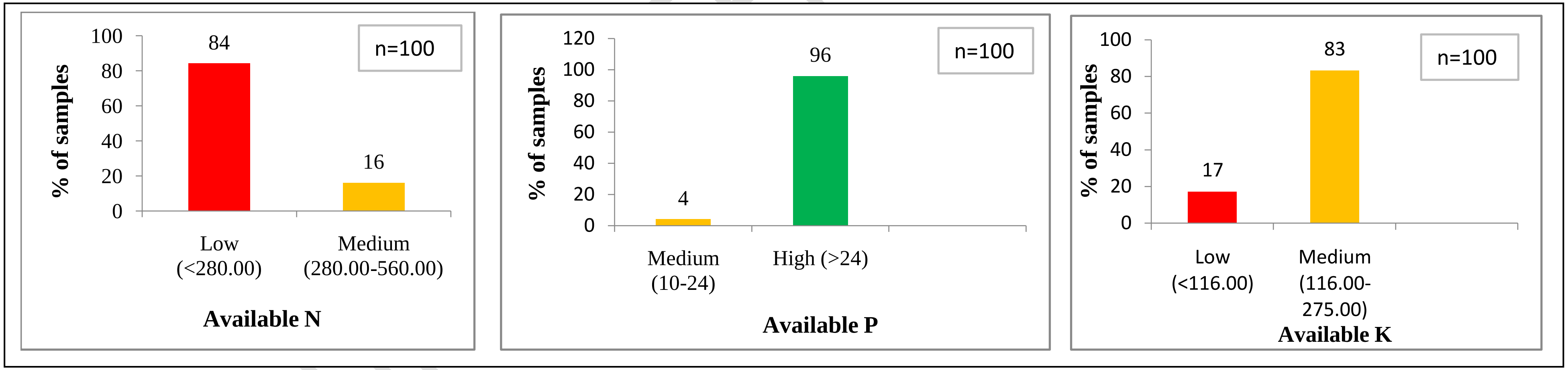

Fig. 3. Frequency distribution of available N, P, and K in the soils of AEUs 8, 9, 10, and 11

from 121.99 to 150.99 kg ha^{-1}. The lowest mean value of 121.99 kg ha^{-1} was noted in panchayat Chalakudy. The highest mean value of 150.99 kg ha^{-1} was recorded by the panchayat Meloor, which was found to be on par with the panchayats Kodakara (141.17 kg ha^{-1}), Koratty (139.98 kg ha^{-1}) and Kadukutty (136.63 kg ha^{-1}).

There was no significant difference regarding the mean values of available K (Table 2b) among the four AEUs. However, from the soil samples analysed, it was noticed that nearly 17% of samples fall under the low category, and the remaining 83% of samples fall under the medium category (Fig. 3). Laterite soils in tropical regions primarily consist of low-activity clays like kaolinite, as well as iron and aluminium oxides and hydroxides. Surprisingly, these tropical soils are able to retain K effectively, even in the absence of a significant quantity of high-activity clays, preventing K leaching [25]. Hence, it can be assumed that the low-activity clay minerals in these soils efficiently held onto exchangeable K, likely contributing to the increased availability of K.

4. CONCLUSION

The overall study indicated that the majority of the collected soils were strongly acidic and moderately acidic in nature, with low levels of available N, high levels of available P, and a medium range of available K content. Acidity was noticed to be a major problem in the study area. Liming the soil to correct its acidity could enhance microbial activity, which in turn could improve the utilisation of N fertilisers that are applied. Moreover, balanced fertilisation will improve the productivity of the study area and enhance nutrient use efficiency, as well as soil health. By safeguarding soil health, we can promote sustainable agriculture, secure food security, and protect the long-term well-being of our ecosystems.

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