International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2021; 9(2): 53-58

Received: 14-01-2021
Accepted: 19-02-2021

Shafna SH
Department of Soil Science and Agricultural Chemistry, Kerala Agricultural University, College of Agriculture, Vellayani, Kerala, India

Gladis R
Department of Soil Science and Agricultural Chemistry, Kerala Agricultural University, College of Agriculture, Vellayani, Kerala, India

Manorama Thampatti KC
Department of Soil Science and Agricultural Chemistry, Kerala Agricultural University, College of Agriculture, Vellayani, Kerala, India

Biju Joseph
Department of Soil Science and Agricultural Chemistry, Kerala Agricultural University, College of Agriculture, Vellayani, Kerala, India

Sheeja K Raj
Department of Agronomy, Kerala Agricultural University, College of Agriculture, Vellayani, Kerala, India

Corresponding Author:
Shafna SH
Department of Soil Science and Agricultural Chemistry, Kerala Agricultural University, College of Agriculture, Vellayani, Kerala, India

Impact of flood on soil quality of South Central laterites (AEU 9) of Kerala and mapping using GIS techniques

Shafna SH, Gladis R, Manorama Thampatti KC, Biju Joseph and Sheeja K Raj

Abstract
A study was conducted to determine the soil quality and changes in the fertility status of soils after 2018 flood in Agro-ecological unit (AEU) 9 in Pathanamthitta district of Kerala and GIS maps were generated. A survey was conducted in the study area and seventy five geo referenced soil samples were collected from flood affected panchayaths. The samples were analysed for pH, organic carbon, N, P, K, Ca, Mg, S and micronutrients and GIS based thematic maps were prepared. The results of the study revealed that pH of soil falls into very strongly acidic, strongly acidic and moderately acidic categories after flood. Organic carbon and available K were increased and available P slightly decreased after the floods and widespread deficiency of available nitrogen were observed. Calcium and magnesium status also low in post flood soils. Among the micronutrients boron was highly deficient. The results outline the need for regular liming to control soil acidity and to alleviate Ca deficiency. The soils should be supplemented with Mg and B in addition to recommended dose of N, P and K fertilizers. Soil quality index of the post-flood soils of AEU 9 was calculated from eight parameters of minimum data set *viz*., organic carbon, bulk density, available K, available B, available S, sand percent and manganese. Majority of the soils had high soil quality index of more than 70.

Keywords: Post flood soils, soil quality, GIS, AEU (Agro ecological unit), soil quality index)

Introduction

Kerala is a state of rain and rivers. The state has mainly two rainy seasons, the south west monsoon that arrives at the end of May or early June and north east monsoon that arrives at mid of October. However the south west monsoon of 2018 had a different impact as the monsoon resulted in a disastrous flood. The peak spell of rain that created the extreme flood in Kerala occurred between 8th to 17th August 2018. The devastating flood heavily impacted the agricultural sector in the south central laterite area. The high intensity rainfall eroded the surface and subsurface soils from hilly terrain and rivers transported this sediment into faraway places and deposited in the plains and valleys. This severe erosion and deposition changes the physical, chemical and biological characteristics of the soil. In addition to this leaching of nutrients, surface crusting, surface cracking of soils and destruction of fauna such as earthworms have occurred due to the flood. The devastating impact of flooding on soils and deterioration in soil quality has necessitated the needs for urgent attention to restore and sustain soil productivity. Hence the present study was conducted to assess and map the fertility status of the flood affected soils of AEU 9 in Pathanamthitta district of Kerala.

Materials and Methods

The AEU 9 (south central laterites) in Pathanamthitta includes Mallappally, Koipram, Elanthoor, Parakkode, and Panthalam blocks and Adoor municipality. The south central laterites agroecological unit represent the midland laterite terrain with typical laterite soil and short dry periods. The climate is tropical humid monsoon type having mean annual temperature 26.5^{0}C and rainfall 2810 mm. These soils are strongly acidic, gravelly, contains lateritic clay and underlined by plinthite.

Major crops includes rubber, coconut, banana, tapioca, paddy and vegetables such as amaranth, brinjal, bhindi, cowpea, cucumber, bottlegourd, snakegourd, ashgourd, chilli and tomato. Parts of Manimala, Pamba and Achankovil rivers passes through AEU 9. The flood affected panchayaths of AEU 9 are Kaviyur, Thumbamon, Kulanada, Thottapuzhassery, Kallupara, Mezhuvely, Panthalam, Kozhanchery, Aranmula, and Mallapally.

Representative geo referenced surface soil samples (0-20 cm) were collected from seventy five sites from flood affected area of AEU 9. The soil samples were shade dried, powdered with wooden pestle and mortar, sieved through a 2mm sieve and stored prior to analysis. With the help of GPS, geographical coordinates of each sample site was recorded.

Soil samples were analyzed for soil texture by Bouyoucos hydrometer method (Bouyoucos (1936) [2], pH (soil - water ratio of 1:2.5) using pH meter (Jackson, 1973) [7], organic carbonby wet oxidation method (Walkley and Black, 1934) [25], available nitrogen byalkaline permanganate method (Subbaiah and Asija, 1956) [22], available Phosphorus by colorimetric method (Watanabe and Olsen,1965) [26], available potassium by neutral normal ammonium acetate extraction followed by flame photometry method(Jackson, 1973) [7], Available calcium and magnesium by Versanate titration method (Hesse, 1971) [6], Available Boron by Azomethane H reagent method (Gupta, 1972) [5], Available sulphur by $CaCl_2$ extraction and estimation using spectrophotometer (Massoumi and Cornfield, 1963) [15]and micronutrients (Fe, Mn, Zn, Cu) by extracting with 0.1 N HCl and using atomic absorption spectroscopy (Sims and Johnson, 1991) [21].

In order to assess the quality of soil, soil quality index were calculatedas per the procedure given by Larsen and Pierce (1994) [12].The attributes selected for MDS were assigned appropriate weight based on existing soil conditions, cropping system and agroclimatic conditions. Each attributes were classified into 4 classes, class l, class ll, class lll, classl V. Scores of 4, 3, 2 and 1 were assigned to class l, class ll, class lll, class lV respectively (Kundu *et al*., 2012) [11] with slight modifications based on soil fertility ratings for Kerala soils.

SQI was represented by equation,

$$SQI = \sum W_i \times S_i$$

Where W_i is the weight of indicators and S_i is the score assigned to the indicator classes.

Relative soil quality index (RSQI) was the measurement of changes in soil quality. It was calculated using equation given by Karlen and Slott (1994) [9]. The sampling location were rated based on RSQI value (Kundu *et al*., 2012) [11].

$$RSQI = (SQI/SQI_m) \times 100$$

Where, SQI was the calculated SQI and SQI_m was the theoretical maximum.

GIS based thematic maps were prepared using ArcGIS 10.5.1 software following Inverse Distance Weighting method (IDW).

Results and Discussion

Soil texture

The proportion of sand, silt and clay indicates the texture of soil. Sand, silt and clay content exhibited wide variations in the soils of AEU 9. Loam was the predominant textural class observed in 62.7 percent of soils in AEU 9 of Pathanamthitta district, followed by clay loam (21.3%), sandy loam (13.3%) and sandy clay loam (2.7%).Sandy loam texture was observed in Kalloopara where high amount sand and silt were deposited. Clay loam texture was exhibited by Kulanada and Panthalam where deposition of sand and clay occurred. All other panchayats showed loam texture. In post-flood soils a slight shift from sandy clay to loam texture was noticed in majority of surface soil which can be attributed to the sediment deposition of sand and silt due to flood.

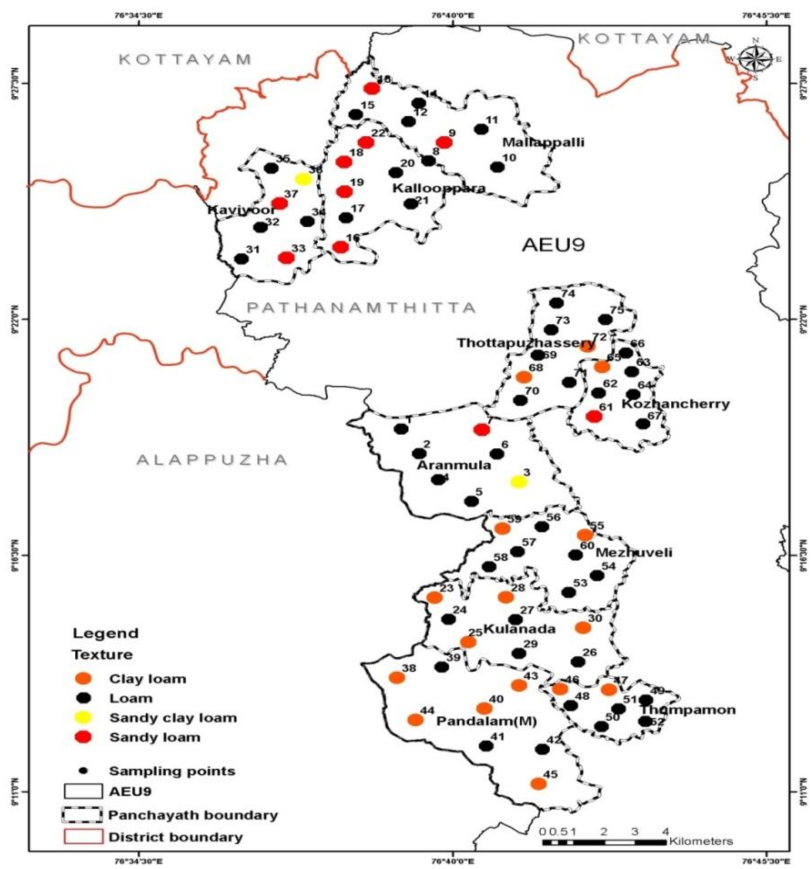

Fig 1: Spatial distribution of textural classes in the post-flood soils of AEU 9

Soil pH: The pH of soil varied between 4.60 and 5.60 with a mean of 5.16. Majority of soils (90.6%) were in the range of very strongly acidic to strongly acidic category (Fig 2).

Leaching of basic cations from the soil might have led to increased acidity. Soil acidity was observed to be lower in areas with sediment deposits where concentration of basic cation like Ca was observed to be higher. Acidity falls into very strongly acidic, strongly acidic and moderately acidic categories after flood. Extremely acidic and slightly acidic categories vanished after flood (KSPB, 2013) [10]. Leaching of basic cations from the soil might have led to increased acidity and also the soil acidity lowered in regions where sediment deposits with high basic cations occurred. Similar results were reported by Akpovete *et al.*, (2014) [1].

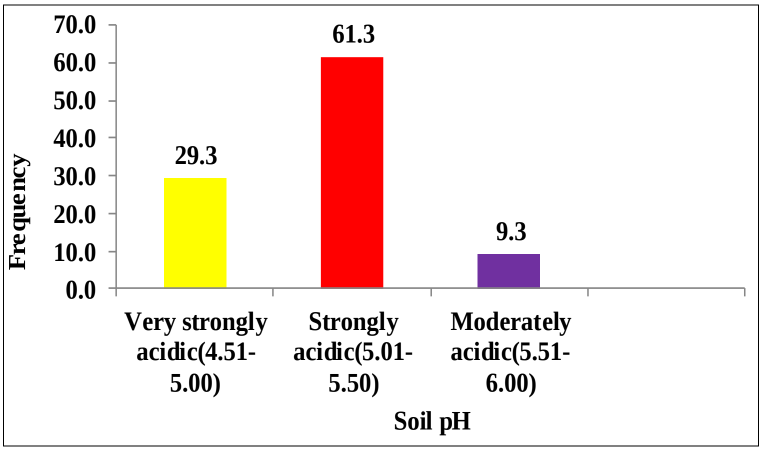

Fig 2: Frequency distribution of soil pH in post flood soils of AEU 9

Organic carbon

Organic carbon content varied from 0.40 to 3.50% with a mean value of 1.63%. Majority (57.3%) of the post flood soils are having medium organic carbon status followed by 38.7% soils with high status (Fig 3). Most of the sample (96%) falls under medium and high status after flood. Percent of sample low in organic carbon status decreased after flood compared to pre flood soil (KSPB, 2013) [10]. Organic carbon was high in Kaviyur (2.53%) followed by Aranmula (2.43%). This can be due to the deposition of sediments rich in organic matter under the inflow of flood water and is in compliance with the findings of Kalshetty *et al.* (2012) [8].

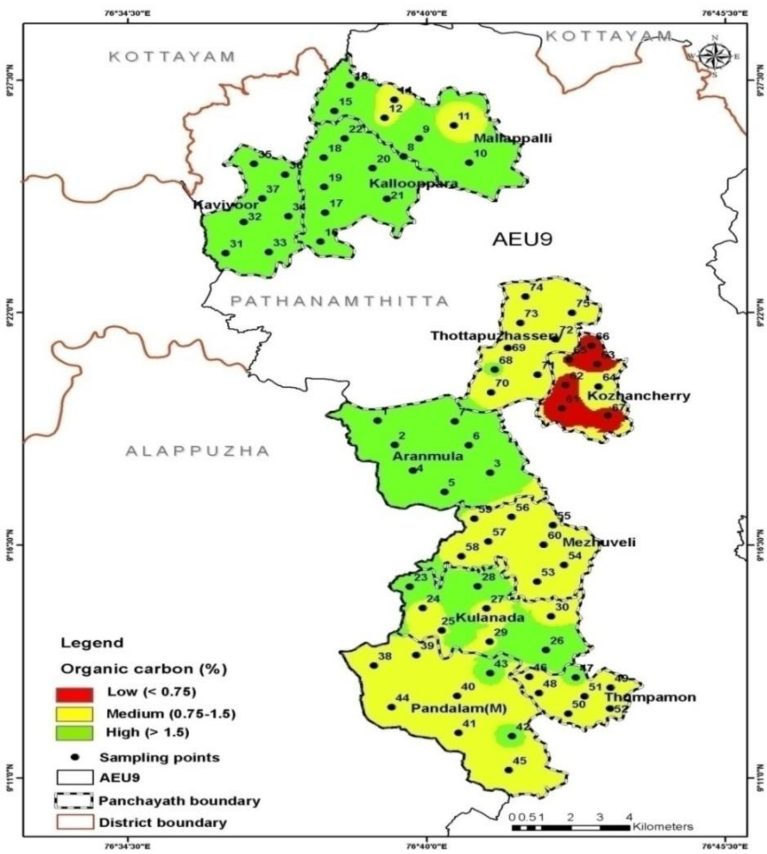

Fig 3: Spatial distribution of organic carbon in the post flood soils of AEU 9

Primary and Secondary Nutrients

Available nitrogen: The available nitrogen content of soil varied between 201 to 464 kg ha^{-1} with a mean of 289 kg ha^{-1}. Available nitrogen was medium in 54.7% samples and low in 46.7% of the post flood soils. The reason for low available nitrogen observed in some panchayats eventhough they showed medium to high organic carbon status may be attributed to low mineralization of organic matter as the soils are highly acidic. These results are in confirmation with those of Usha and Jose (1983) [23] in laterite soils. The low availability of nitrogen in soil might also be due to leaching of nitrate nitrogen present in soil in the study area which received high amount of rain fall and also under the anaerobic conditions nitrogen loss would have occurred due to nitrate reduction and denitrification (Unger *et al.*, 2009) [24]. Slow decomposition rate of organic matter also added to the decreased nitrogen availability. Increasing soil acidity obstructs mineralization of organic matter and decreased the availability of nitrogen in soil under submerged condition (Liji, 1987) [14].

Available phosphorous: The available phosphorous content of soil varied from 8.10 and 104 $kgha^{-1}$ with a mean of 31.9 kg ha^{-1} and was found to be medium in37.3% of the soils, high in 58.7% and low in 4% soils. Soils with medium status of available phosphorous increased in post-flood (37.3) compared to pre-flood (17%) whereas high phosphorous soils decreased from 65% to 58.7% (KSPB, 2013) [10]. The phosphorus availability in these soils have reduced after flood which can be attributed to change in soil pH. The phosphorus availability is highly dependent on soil pH and P availability will be maximum at a pH of 6.5. It is evident from the data of pre flood soil. Most of the sample falls under very strongly acidic to strongly acidic category after flood and there is no slightly acidic category after flood. Organic matter deposition in the soils may have also contributed to phosphate sorption and reduction in phosphorous availability. This agree with the findings of Sah and Mikkelsen (1989) [20] who reported that flood induced P deficiency in soil is caused by high P sorptivity.. Available phosphorous was low in some locations of Thottapuzhassery and it was high in Mallapally, Mezhuvely, Kulanada, Aranmula and Kozhenchery.

Available potassium: The available K content in soil ranged between 78.7 and 493 kg ha^{-1} with a mean of 246kg ha^{-1}. Majority (50.7%) of the soils were medium in available K, 44.0% were high and 6.7% low. Available K status in soil increased in post-flood soils compared to pre-flood soils. About 96.7% samples became medium and high in K status earlier it was 92%. Samples low in potassium status were reduced compare to pre flood soil. Similar findings were reported by Kalshetty *et al.* (2012) [8].
Low activity clays such as kaolinite and iron and aluminium oxides and hydroxides are predominant in laterite soils. These tropical soils can store K even without a large content of high activity clays and avoid leaching losses (Rosolem and Steiner, 2017) [19]. Which have contributed to increased availability of potassium. High organic carbon content and low pH may also have added to the increase in potassium status. These agree with the findings of Nair *et al*. (2013) [17].

Available calcium: Available calcium ranged between 151 and 521 mg kg^{-1} in the post-flood area with a mean of 326 mg kg^{-1}. Available Ca was deficient in 36% of post-flood soils and adequate in 65.3% but in pre flood soils 30% were deficient and 70% adequate in calcium. Decrease in calcium content after flood was due to the leaching of basic cations in flood water. These findings were in accordance with those reported by Leno *et al.* (2013) [13] and Mengel *et al.* (2011) [16]. The entire areas in Aranmula, Kalloopara, Mallapally and Kaviyur were found to be deficient in calcium and other areas were adequate in Ca. The present study showed significant positive correlation of Ca with clay content.

Available magnesium: Available Mg varied between 30.4 and 210 mg kg^{-1} and the mean value was 106 mg kg^{-1}. There was a decline in available magnesium in soil due to the flood. Available magnesium was found to be deficient in 68% of the post flood soils. Percent of sample deficient in Mg reduced (68%) compared to pre-flood soils (74%). This reduction in Mg deficiency is due to the deposition of sediments and organic matter. Most of the samples are deficient in Mg in both pre and post flood conditions. Magnesium being a weak competitor of exchange sites with aluminium and calcium, appears to accumulate in soil solution and is subject to leaching loss in acid soils (Edmeades *et al.*,1985) [3] which might be the reason for lower magnesium levels in soils despite the high calcium content observed in the same areas. Similar findings were also reported by Natarajan *et al*. (2013) [18].

Available sulphur: Available sulphur content in soil varied between 0.5 and 87.5 mg kg^{-1} with mean value of 21.4 mg kg^{-1} and was found to be adequate in 91.7% soils. The higher levels of available sulphur might be due to the accumulation of organic matter and sediments in these soils. Available S was significantly and positively correlated with silt content. Similar results were reported by Kalshetty *et al.* (2012) [8]. The combined effects of decreased adsorption, increased mineralisation and accumulation of sulphur bearing minerals from sediments would have increased in available sulphur levels in soil.

Table 1: Available primary and secondary nutrients in the post-flood soils of AEU 9

Panchayat/Municipality	N_2 (Kg ha^{-1})	P (Kg ha^{-1})	K (Kg ha^{-1})	Ca (mg Kg^{-1})	Mg (mg Kg^{-1})	S (mg Kg^{-1})
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Aranmula	291±22.2	26.4±4.80	254±74.5	258±39.3	110±21.2	7.06±0.75
Mallapalli	245±15.34	57.8±24.4	313±19.4	289±32.6	94.5±11.6	7.10±3.79
Kalloopara	358±50.1	15.0±3.32	154±30.3	220±28.4	55.0±18.8	7.90±2.11
Kulanada	300±13.0	44.5±4.89	356±78.9	370.±29.4	107±15.1	3.71±2.30
Kaviyur	292±30.3	21.1±7.45	105±19.0	213±46.0	69.4±9.33	14.0±4.76
Panthalam	310±19.8	22.6±8.12	194±20.2	416±22.7	142±25.6	37.9±22.2
Thumbamon	298±54.7	25.5±11.0	162±25.8	449±89.0	137±33.6	30.9±11.4
Mezhuveli	258±49.6	51.4±9.42	327±59.9	368±61.8	91.4±33.4	12.3±7.38
Kozhanchery	263±30.8	35.9±11.6	318±43.4	326±50.6	108±14.5	51.2±24.0
Thottapuzhassery	279±21.2	14.3±6.40	246±30.3	327±38.1	141-44.1	42.8±20.0
AEU 9	289±43.3	31.9±18.0	246±92.2	326±86.5	106±36.6	21.4±20.7

Micronutrients

Available iron: Available iron content was adequate in all the soil samples. The sufficiency of available iron in the post flood soil might be due to the reason that insoluble form of Fe is reduced to more soluble form (Fe^{2+}) under submerged condition (Fageria *et al.*, 2011) [4]. Presence of iron rich parent material and leaching of basic materials from the surface layers of the soils may also leads to the high available iron.

Available manganese: Available manganese content was adequate in 100% of samples. Manganese content remained high in the study area in both pre and post flood period. The sufficiency of available Mn in the post flood soil might be due to the reason that insoluble form of Mn is reduced to more soluble form (Mn^{2+}) under submerged condition (Fageria *et al.*, 2011) [4].

Available zinc: Available zinc content was adequate in 66.7% and deficient in 33.3% of samples. Deficiency of Zn increased after flood (33.3%) compare to pre flood condition (10%) (KSPB, 2013) [10]. This deficiency may be due to leaching losses occurred during flood. Similar reduction in availability of Zn reported by Fageria *et al.* (2011) [4] in submerged soils.

Available copper: Available copper content was adequate in all the samples, which was deficient in 13% samples of pre flood soil. This may be due to accumulation of organic matters and sediments after flood.

Available boron: Available boron in soil ranged between 0.01 mg kg^{-1} and 0.45 mg kg^{-1} with mean of 0.13 mg kg^{-1}. Available B became deficient in all the soils of AEU 9 after the flood earlier deficiency was 59% (KSPB, 2013) [10]. This can be attributed to the higher mobility of boron in soils and also leaching losses which led to B deficiency in these soils. High intensity rainfall will lead to loss of soluble forms of boron by leaching (Mengel *et al.*, 2011) [16].

Table 2: Available Fe, Mn, Zn, Cu and B in the post-flood soils of AEU 9

Panchayat/Municipality	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg Kg^{-1})
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Aranmula	78.0±30.1	26.1±3.14	2.69±0.57	3.90±0.98	0.23±0.12
Mallapalli	96.7±97.3	52.9±33.8	0.46±0.21	4.29±0.84	0.05±0.03
Kalloopara	76.8±2.41	23.8±7.29	1.08±0.16	4.83±0.32	0.08±0.02
Kulanada	31.4±1.80	84.1±17.1	1.17±0.33	5.68±1.37	0.13±0.08
Kaviyur	140±21.3	49.3±22.0	1.09±0.26	5.28±0.44	0.16±0.05
Panthalam	124±6.56	95.0±13.3	1.31±0.16	4.31±0.24	0.14±0.07
Thumbamon	92.3±35.4	119±10.4	1.34±0.11	4.44±0.31	0.18±0.14
Mezhuveli	68.0±19.0	22.5±11.7	0.77±0.13	1.71±0.70	0.17±0.13
Kozhanchery	125±13.7	95.2±16.9	1.68±0.40	4.72±1.12	0.12±0.09
Thottapuzhassery	151±6.06	110±9.96	3.24±0.62	5.91±0.62	0.05±0.02
AEU 9	108±66.2	85.6±74.7	1.48±0.87	5.19±2.81	0.13±0.10

Soil Quality Index: Soil quality index of the post-flood soils of AEU 9 of Pathanamthitta was calculated from eight parameters of minimum data set *viz*., organic carbon%, bulk density, available K, available B, available S, sand percent and manganese. Relative soil quality index of the soil ranged between 62 and 96%. Majority of the soils (86.7%) had high soil quality while 13.3 percent of soils had medium soil quality. Soil quality was observed to be maximum in Aranmula and Mezhuveli where organic carbon, available potassium, boron, organic carbon and available sulphur were found to be high and sediment depositions were observed. The contribution of organic carbon and available nutrient status to soil quality is substantial as the important indicators of soil quality index.

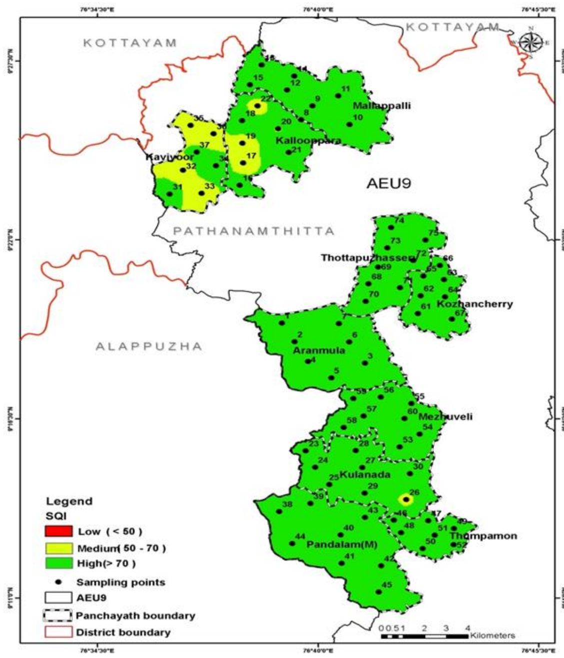

Fig 4: Spatial distribution of SQI in the post-flood soils of AEU 9

Conclusion

The results of the study revealed that the nutrient status were slightly altered in the soils of AEU 9 in Pathanamthitta district after the 2018 flood. Soil acidity increased in some areas due to the leaching of basic cations and erosion by flowing flood water. Organic carbon and available K were increased and available P slightly decreased after the floods and widespread deficiency of available nitrogen were observed. Deficiency of calcium and magnesium increases after flood. The entire study area showed deficiency of boron. The results outline the need for regular liming to control soil acidity and to alleviate Ca deficiency. The soils should be supplemented with Mg and B in addition to recommended dose of N, P and K fertilizers. The soil quality analysis revealed that majority of soils had high soil quality index.

References

1. Akpoveta VO, Osakwe SA, Ize-Iyamu OK, Medjor WO, Egharevba F. Post flooding effect on soil quality in Nigeria: the Asaba, Onitsha experience. Open J Soil Sci 2014;12:13-19.
2. Bouyoucos GJ. Directions for Making Mechanical Analysis of Soils by Hydrometer Method. Soil Sci 1936;4:225-228.
3. Edmeades DC, Wheeler DM, Crouchley G. Effect of liming on soil magnesium on some soils in New Zealand. Commun. Soil Sci. Plant. Anal 1985;16(7):727-739.
4. Fageria NK, Carvalho GD, Santos AB, Ferreira E. Chemistry of Lowland Rice Soils and Nutrient Availability. Commun. Soil Sci. Anal 2011;42(16):1913-1933.
5. Gupta UC. Effect of boron and limestone on cereal yields and on B and N concentrations of plant tissues. Commun. Soil. Sci. plant Anal 1972;6:439-450.
6. Hesse PR. A Textbook of Soil Chemical Analysis. John Murray Publishers Ltd., London 1971,520p.
7. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Ltd., New Delhi 1973,219-221.
8. Kalshetty BM, Giraddi TP, Sheth RC, Kalashetti, MB. River Krishna Flood Effects on Soil Properties of Cultivated Areas in Bagalkot District, Karnataka State. Glob. J. Sci. Frontier Res. Chem 2012;12(6):23-28.
9. Karlen DL, Stott DE. A framework for evaluating physical and chemical indicators of soil quality. In: Doran JW, Coleman DC, Bezdicek DF, Stewart BA. (eds), Defining Soil Quality for a Sustainable Environment. SSSA Special Publication 35, Soil Science Society of America, Madison, WI, 1994,53-72p.
10. KSPB [Kerala State Planning Board]. Soil Fertility Assessment and Information Management for Enhancing Crop Productivity in Kerala. Kerala State Planning Board, Thiruvanathapuram 2013,514.
11. Kundu S, Coumar MV, Saha JK, Rajendiran S, Hati KM, Biswas AK *et al*. Assessing soil health of Vertisol of AESR 10.1 using selected physical, chemical and biological attributes of soils. J Indian Soc. Soil Sci 2012;60(4):281-287.
12. Larson WE, Pierce FJ. The dynamics of soil quality as a measure of sustainable management. Defin. Soil Qual. Sustain. Environ 1994;35:37-51
13. Leno N, Mathew R, Leenakumari S, Muralidharan P, Sajnanath K, Indira M *et al*. Soil fertility: Alappuzha district. In: Soil fertility assessment and in formation management for enhancing Crop productivity in Kerala. Kerala State Planning Board, Thiruvananthapuram, Kerala 2013,169-185.
14. Liji J. Dynamics of applied nitrogen in acidic soils of Kuttanad. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur 1987,158.
15. Massoumi A, Cornfield AH. A rapid method for determining sulphate in water extracts of soils. Analyst. 1963;88(1045):321-322.
16. Mengel R, Benbi DK, Scherer HW. Fixation and defixation of ammonium in soils: a review. Biol. Fertil. Soils 2011;47(1):1-14.
17. Nair PYR, Pillai VK. Changing ecology of Vembanad lake. Rice in Wetland Ecosystem. Kerala Agricultural University, Vellanikkara, Thrissur 1990,285.
18. Natarajan P, Varghese JJ, Oommen M, Soumiya CS, Jyothi S, Kumar KVS *et al*. Fertility of soils of Kerala. In: Soil fertility assessment and information management for enhancing crop productivity in Kerala. Kerala State Planning Board, Thiruvananthapuram, Kerala 2013,204-227.
19. Rosolem CA, Steiner F. Effects of soil texture and rates of K input on potassium balance in tropical soil. Eur. J. Soil Sci 2017;68(5):658-666.
20. Sah RN, Mikkelson DS. Phosphorus behaviour in flooded drained soils. Soil Sci. Soc. Am. J 1989;53(6):1718-1722.
21. Sims JR, Johnson GV. Micronutrient soil tests. In: Mortvedt JJ, Cox FR, Human LM, Welch RM. (eds), Micronutrient in Agriculture (2nd ed.), SSSA, Madison, USA 1991,427-476.
22. Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils. Curr. Sci 1956;25:259-260.
23. Usha PB, Jose AI. Carbon-Nitrogen relationship inlaterite soils of Kerala. Agric. Res. J Kerala 1983;21:15-22.
24. Unger IM, Motavalli PP, Muzika RM. Changes in soil chemical properties with flooding: a field laboratory approach. Agric. Ecosyst. Environ. 2009;131(1-2):105-110.
25. Walkley AJ, Black IA. Estimation of soil organic carbon by chromic acid titration method. Soil Sci 1934;31:29-38.
26. Wantanabe FS, Olsen SR. Test of an ascorbic acid method for determining Phosphorus in water and Sodium bicarbonate extracts from soil. Soil. Soc. Am. Proc 1965;29:39-45.