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Soil fertility assessment and GIS mapping of flood affected Agro ecological unit in Kerala

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Abstract
A study was undertaken to evaluate the soil quality and changes in the fertility status of post flood soils of Agro-ecological unit (AEU) 9 in Alappuzha district of Kerala. Representative geo referenced surface soil samples (0-20 cm) were collected and analyzed for pH, organic carbon, N, P, and K. Soil nutrient index were worked out and GIS based thematic maps were prepared. The results of the study revealed strongly acidic to extremely acidic soils in the flood affected areas of AEU 9. Organic carbon content, available phosphorous and potassium were increased while widespread deficiency of available nitrogen were observed. Nutrient index in terms of organic carbon, nitrogen and phosphorous were medium, low and medium respectively. Nutrient index for potassium was medium to high. The results outline the need for regular liming to control soil acidity and soils should be supplemented with nitrogen and phosphorus to improve soil quality.

Keywords: Post flood soils, soil quality, GIS maps, nutrient index

Introduction
Kerala experienced a disastrous flood resulted out of unprecedented continuous heavy rainfall during August 2018. The state received 2346.6 mm of rainfall during this period as against the average rainfall of 1649.5 mm which was 41% more than normal. The damage caused to the ecosystem includes river bank collapse, erosion of fertile top soil, deposition of sand, silt, clay and gravel in lowlands and agricultural lands, pollution due to waste deposition, changes in water quality, soil piping, loss of lives and vegetation. Severe soil erosion and deposition of sediments due to high intensity rainfall affects the soil quality and brought about changes in physical, chemical and biological properties.
The devastating flood caused severe damage to the soil environment and agriculture. Flooded soil experienced post flood syndrome due to water stagnation, soil erosion, nutrient depletion, deposition of sand, silt and clay etc. which needs 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 9in Alappuzha district of Kerala.

Materials and Methods
The AEU 9 in Alappuzha district of Kerala lies between 9°23'38.28" and 9°33'63.71" N latitude, 76°57’88.39’’ and 76°65'02.00" E longitude, spread over the eastern part of Chengannur block which includes Mulakkuzha, Ala, Cheriyanad and Venmony Panchayaths and Chengannur municipality which were severely affected by flood havoc and submergence that occurred during August 2018.
The AEU 9 (South central laterites) represents midland laterite terrain with typical laterite soils and short dry period. The climate is tropical humid monsoon type with mean annual temperature 26.5ºC and rainfall 2827 mm. The soils are strongly acid, lateritic clay, gravelly and often underlined by plinthite. Major crops include coconut, banana, tapioca, betelvine, rubber, pepper, arecanut, paddy and vegetables.
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 pH (soil - water ratio of 1:2.5) using pH meter (Jackson, 1973) [7], organic carbon by wet oxidation method (Walkley and Black, 1934) [21], available nitrogen by alkaline permanganate method (Subbaiah and Asija,1956) [18], available Phosphorus by colorimetric method (Watanabe and Olsen, 1965) [22], available potassium by neutral normal ammonium acetate extraction followed by flame photometry method(Jackson, 1973) [7].
In order to evaluate the soil fertility status, nutrient indices were calculated for soil organic carbon, available nitrogen, phosphorous and potassium in soils using the equation given by Parker *et al.*, (1951) [15].

$$NI = 1x\ N_l + 2\ x\ N_m + 3x\ N_h/N_t$$

Where,
N_l, N_m, N_h were number of samples in low, medium and high category respectively. The soils were rated based on the nutrient index value as suggested by Ramamurthy and Bajaj (1969) [16]. GIS based thematic maps were prepared using ArcGIS 10.5.1 software following Inverse Distance Weighting method (IDW).

Results and Discussion
Soil Properties
Soil pH: The pH of soil varied from 4.10 to 6.90 with a mean value of 5.02 (Table 1). Majority of soils (90.3%) were in the extremely acidic to strongly acidic category (Fig 1). Increased acidity after the flood is attributed to the leaching of basic cations from the soil in flowing flood water. Soil acidity was observed to be lower in areas where sediment deposits occurred having higher concentrations of basic cations like K and Ca. An increase in percent of soils with extreme acid pH in post flood soils (20%) compared to pre-flood indicating leaching of basic cation from soils (KSPB, 2013) [9]. This is also evident from the deficient levels of calcium (63.9%) and magnesium (100%) observed in these soils. Similar results were reported by Akpovete *et al.*, (2014) [1].

Table 1: Soil pH and organic carbon content in post flood soils of AEU 9

Panchayat/ Muncipality	Soil pH		Organic Carbon (%)	
	Range	Mean	Range	Mean ±SD
Chengannur	4.51-6.90	5.42 ± 0.83	1.61-3.92	2.41 ± 0.62
Mulakuzha	4.22-5.60	4.93 ± 0.52	1.12-2.42	1.61 ± 0.42
Cheriyanad	4.10-6.10	4.84 ± 0.58	0.51-2.62	0.95 ± 0.47
Venmony	4.41-6.62	5.22 ± 0.73	0.52-1.23	0.82 ± 0.18
Ala	4.32-5.65	5.13 ± 0.42	0.51-1.33	0.81 ± 0.32
AEU 9	4.10-6.90	5.02 ± 0.61	0.51-2.62	1.42 ± 0.73

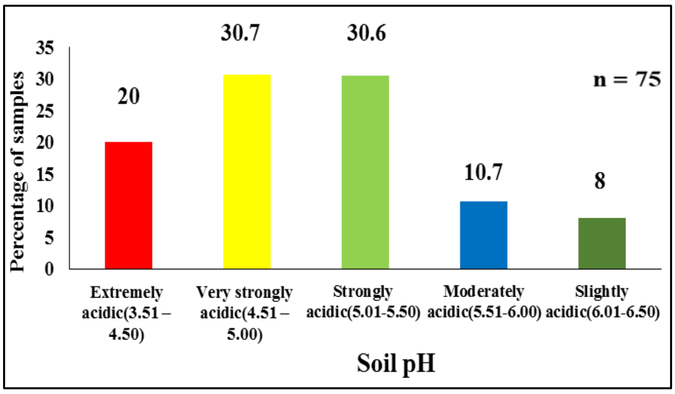

Fig 1: Frequency distribution of soil pH in post flood soils of AEU 9

Organic carbon: Organic carbon content ranged between 0.51 and 2.62% with a mean value of 1.42% (Table 1). Majority (61.3%) of soils having medium organic carbon status followed by high status in 38.7% soils (Fig 2). An increase in organic carbon status was observed in high category from 18% in pre-flood to 38.7% in post flood soils. Similarly percent of soils with medium organic carbon status increased from 47% in pre-flood to 61.3% in post-flood soils (KSPB, 2013) [9]. Organic carbon was high for most of the area in Chengannur and Mulakuzha and medium in other panchayats. This can be attributed 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.* (2015). Spatial variability of organic carbon in the post-flood area of AEU 9 is given in Fig 3.

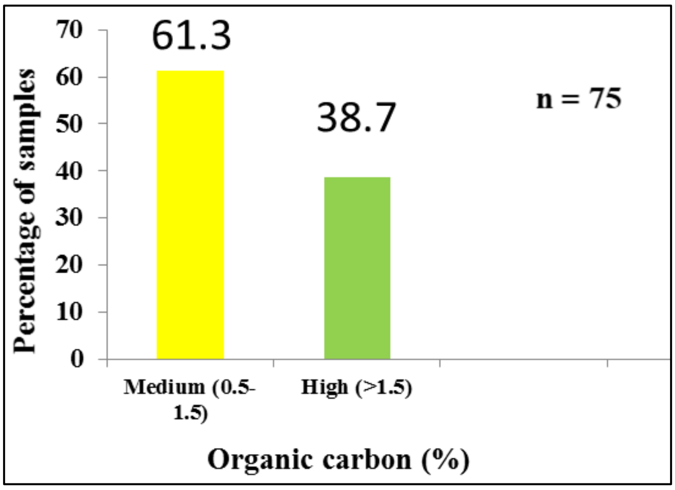

Fig 2: Frequency distribution of organic carbon in the post flood soils of AEU 9.

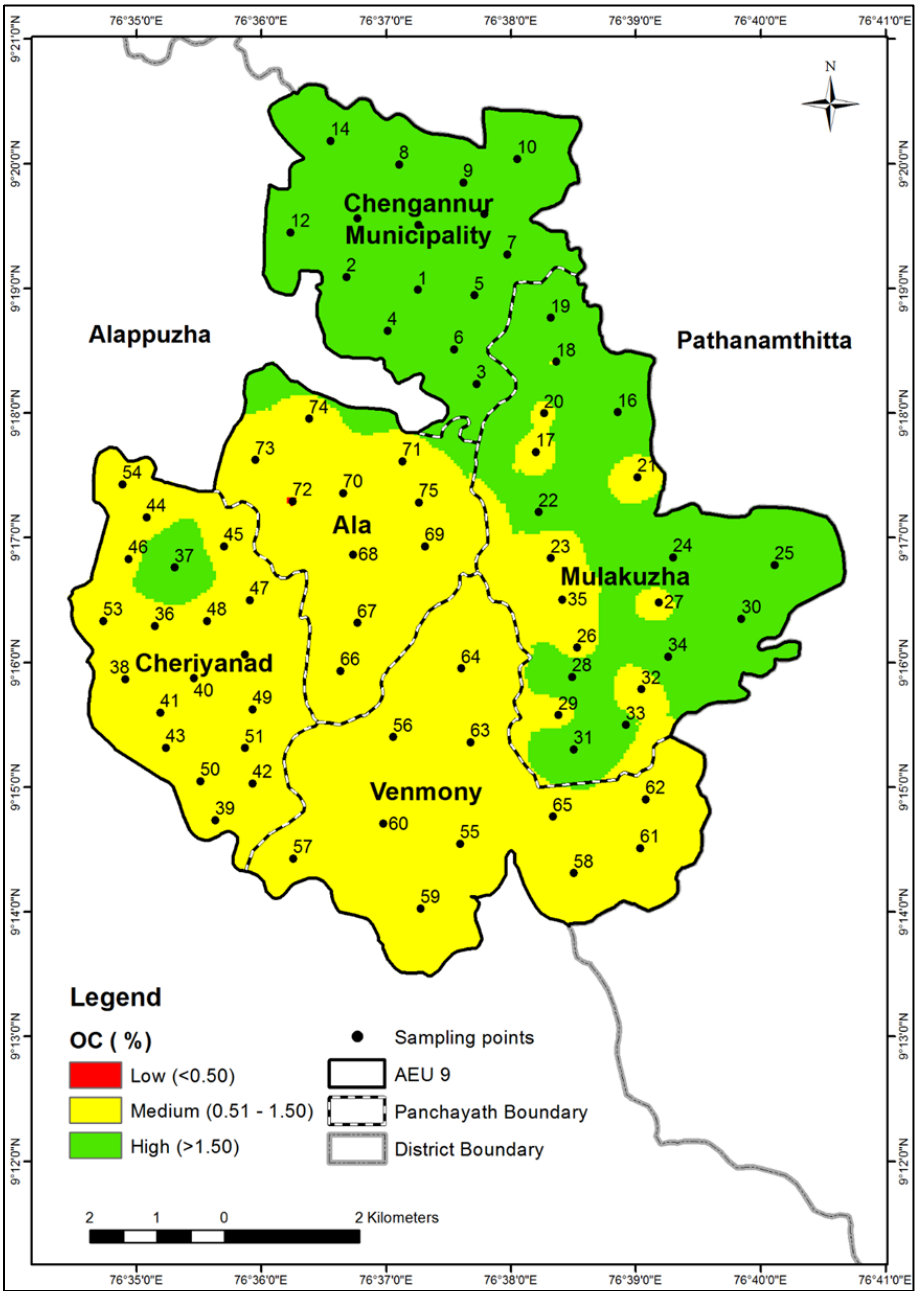

Fig 3: Spatial distribution of organic carbon in the post flood soils of AEU 9

Available nitrogen: The available nitrogen content of soil varied between 100 and 627 kg ha^{-1} with a mean value of 197 kg ha^{-1} (Table2). Available nitrogen was low in majority (89.3%) of the post flood soils and only 10.7% in the medium range (Fig.4). The thematic map of available nitrogen is depicted in Fig.5. Available nitrogen was found to be medium in some areas of Mulakuzha, Ala and Cheriyanad panchayats and low in other areas. Even with medium to high organic carbon status of the soils under study, low nitrogen status of soil may be attributed to low mineralization of organic matter as the soils are highly acidic. The low availability of nitrogen in soil might be due to leaching of nitrate nitrogen present in soil in the study area received high amount of rainfall and also under anaerobic condition nitrogen loss occurred due to nitrate reduction and denitrification (Unger *et al.*, 2009) [19]. 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, 1989) [10].

Table 2: Available N,P and K content in post flood soils of AEU 9

Panchayat/ Muncipality	Available nitrogen (kg ha^{-1})		Available phosphorus (kg ha^{-1})		Available potassium (kg ha^{-1})	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ±SD
Chengannur	100-263	156 ± 44.4	9.32-44.6	16.2 ± 9.22	100 – 246	177 ± 40.6
Mulakuzha	100-627	233 ± 116	8.32-47.8	19.2 ± 11.9	112 – 492	299 ± 115
Cheriyanad	112-526	183 ± 89.7	9.21-29.8	13.1 ± 6.31	123 – 460	280 ± 105
Venmony	138-238	189 ± 31.9	9.13-14.7	10.2 ± 1.72	112 – 380	219 ± 82
Ala	163-363	219 ± 69.3	9.02-28.0	12.3 ± 5.85	123 – 436	254 ± 101
AEU 9	100-627	197 ± 85.8	8.32-47.8	14.8 ± 8.78	100 – 492	252 ± 103

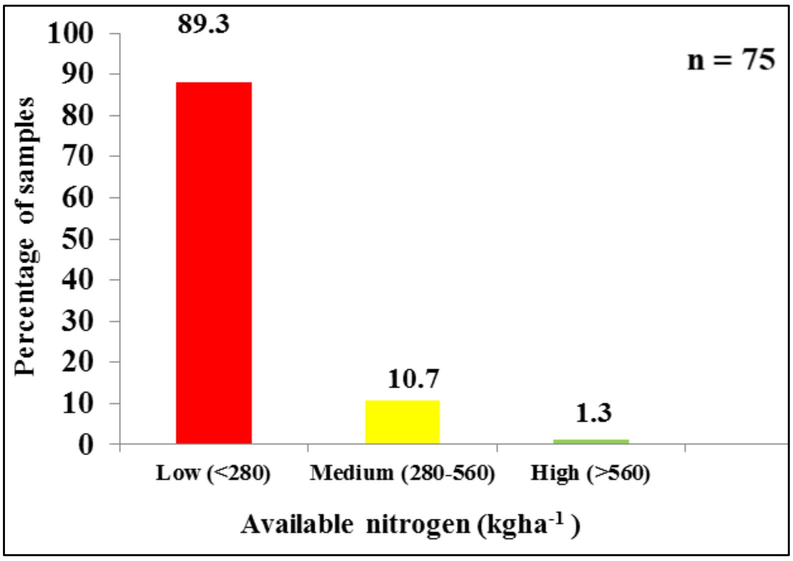

Fig 4: Frequency distribution of available nitrogen in the post flood soils of AEU 9

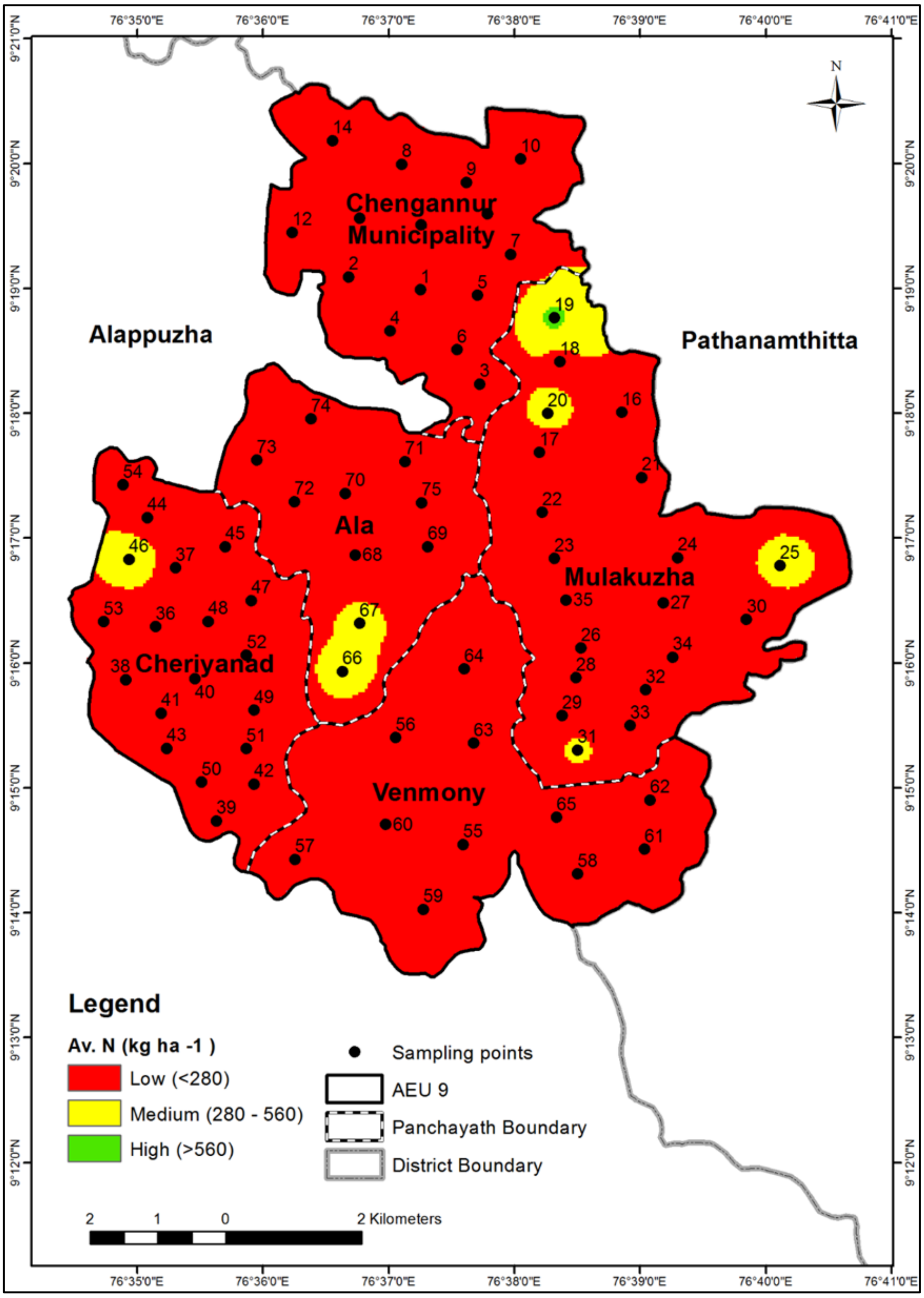

Fig 5: Spatial distribution of available nitrogen in the post flood soils of AEU 9

Available phosphorous: The available phosphorous content of soil varied from 8.32 to 47.8 kg ha-1 (Table2) and was found to be medium in 60% of the soils, high in 26.7% and low in 13.3% soils (Fig 6). Soils with medium status of available phosphorous increased in post-flood (60%) compared to pre-flood (15%) whereas high phosphorous soils decreased from 68% to 26.7% (KSPB, 2013) [9].The phosphorus availability in these soils have reduced after flood which may 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 increase in soil acidity after the flood in 20% soils. Clay and organic matter deposition in the soils may also contribute to phosphate sorption and reducing availability. This agree with the findings of Sah and Mikkelsen (1989) [17] who reported flood induced P deficiency in soil is caused by high P sorptivity. Similar findings were observed by Beegum (2016) [2] who reported a similar decreasing trend in phoshorous status of Kuttanad soils due to clay accumulation. Spatial distribution of available phosphorous presented in Fig.7 revealed that available phosphorous was low in some areas of Ala and Venmony whereas high in Chengannur and Mulakuzha.

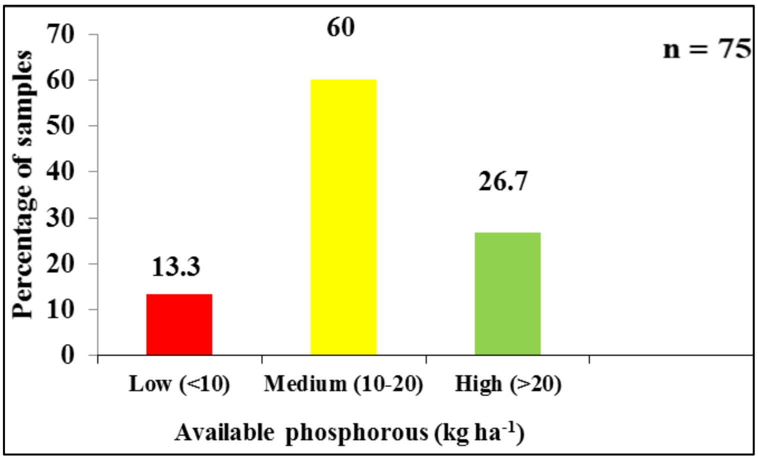

Fig 6: Frequency distribution of available phosphorous in post flood soils of AEU 9.

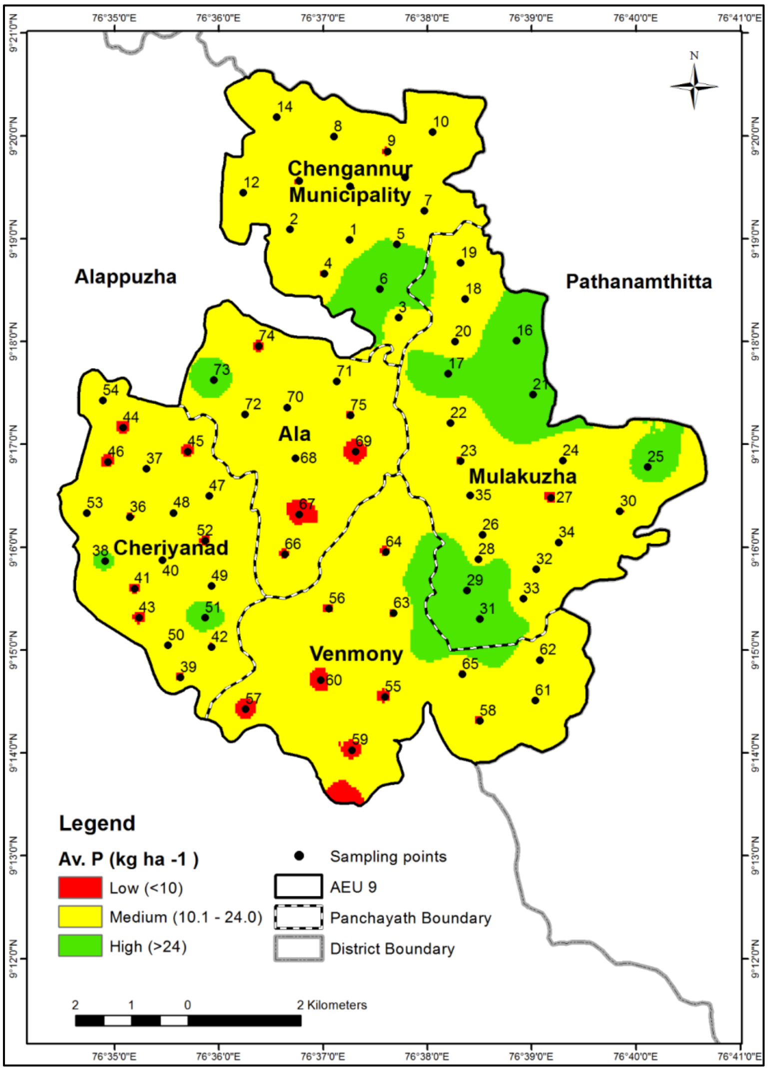

Fig 7: Spatial distribution of available phosphorous in the post flood soils of AEU 9

Available potassium: The available K content in soil ranged between 100 and 492 kg ha-1 (Table2). Majority (53.1%) of the soils were medium in available K, 44.6% high and 2.3% low (Fig 8). Available K status in soil increased in post-flood soils compared to pre-flood soils (KSPB,2013)[9]. Similar findings were reported by Kalshetty*et al.* (2012)[8]. Clay deposition after the flood might have contributed to this variation in the potassium status. Low activity clays such as kaolinite and iron and aluminium oxides and hydroxides are predominant in laterite soils. Hence it may be inferred that the low activity clay minerals in these soils were efficient in holding the exchangeable potassium to a considerable extent which might have contributed to increased availability of potassium. High organic carbon content and low pH may also have added to the increase in potassium status. This agree with the findings of Nair (1990)[13]. The thematic map of available K depicted in Fig.9 showed that majority of area in Cheriyanad, Ala and Mulakuzha were high in available potassium whereas Cheriyanad and Venmony were medium in available K. Despite heavy rainfall and consequent leaching, the high available K in some of these areas could be attributed to accumulation of K bearing sediments at the sampling points after the flood.

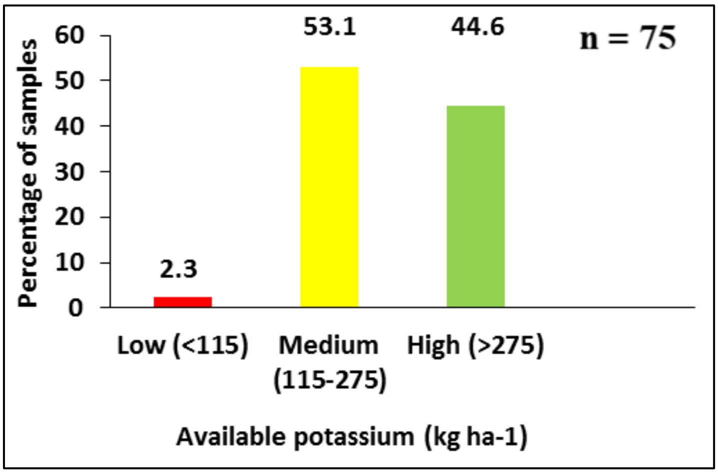

Fig 8: Frequency distribution of available potassium in post flood soils of AEU 9.

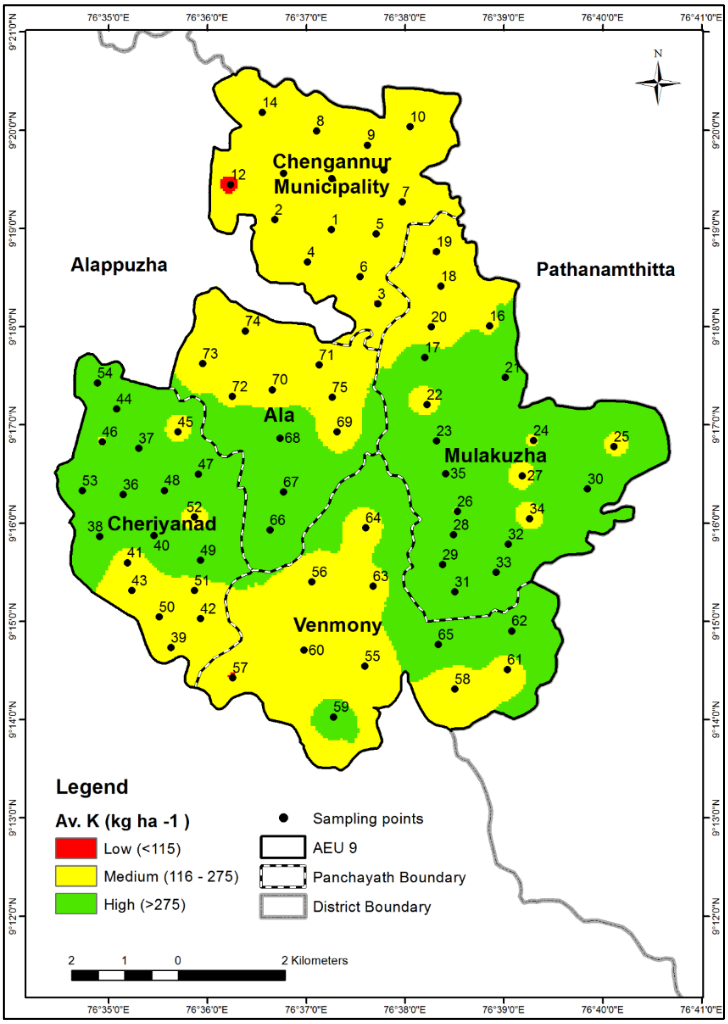

Fig 9: Spatial distribution of available potassium in post flood soils of AEU 9

Nutrient index

Nutrient Index was worked out for organic carbon, available nitrogen, phosphorous and potassium contents in soil and presented in Table.3. Soil nutrient index in terms of organic carbon was found to be medium in all the five panchayaths. Fertility status of the soil in terms of nutrient index of nitrogen was rated low in all panchayaths. This is attributed to the losses of nitrogen that has occurred and also low mineralization of organic matter in highly acidic soil which requires replenishment for sustaining soil productivity (Liji,1989) [10]. The nutrient index of phosphorous was medium in all panchayaths with the exception of Venmony which recorded only a low status. This is attributed to low pH, phosphate sorption and also fixation of soluble inorganic P in the soils (Sah and Mikkelsen (1989) [17]. A high nutrient index of potassium was observed in Mulakuzha and Venmony panchayaths whereas medium in other panchayaths which may due to the accumulation of sediments and also potassium bearing capacity of soil as reported by Kalshetty *et al.* (2012) [8].

Table 3: Nutrient index in post flood soils of AEU 9

Panchayat/ Municipality	Nutrient Index (NI)							
	Organic		Available		Available P		Available	
	NI	Rating	NI	Rating	NI	Rating	NI	Rating
Chengannur	2.1	Medium	1.0	Low	1.6	Medium	1.9	Medium
Mulakuzha	2.0	Medium	1.3	Low	1.9	Medium	2.4	High
Cheriyanad	1.8	Medium	1.1	Low	1.5	Medium	2.5	High
Venmony	1.8	Medium	1.0	Low	1.2	Low	2.2	Medium
Ala	1.7	Medium	1.2	Low	1.4	Medium	2.3	Medium

Conclusion

The results of the study reveal that the nutrient status were slightly altered in the soils of AEU 9 in Alappuzha 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 status andavailable K were increased after the floods in the area with deposits of silt and clay. Available P in soil was slightly reduced after the flood in areas with sand and silt deposits. Nutrient index for organic carbon and nitrogen were medium and low in all panchayaths. Nutrient index for phosphorous was low in Venmony panchayath while it was medium in all other panchayaths. Nutrient index for potassium was high in Ala and Mulakuzha panchayaths and medium in other panchayaths. The results outline the need for regular liming to control soil acidity and also application of recommended dose of N and P fertilizers are suggested to improve soil productivity in the study area.

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