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Short communication

Soil quality assessment of *Pokkali* lands (AEU 5) in the post (2018) flood scenario of Kerala

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Abstract

Kerala state witnessed large scale devastating flood in August 2018 due to intensive rainfall, causing significant damage to the agricultural sector and human life. One of the most affected districts was Ernakulam, especially *Pokkali* lands, agro ecological unit 5 (AEU 5). *Pokkali* lands represent the lowlands, often below sea level, in coastal areas of Ernakulam district and extending to parts of Thrissur and Alappuzha districts. The soils are hydromorphic, often underlain by potential acid-sulphate sediments with unique hydrological conditions. The study was undertaken to assess the soil quality in the post flood scenario of AEU 5. Initial survey was conducted and fifteen severely flood affected panchayats were selected. Geo-referenced composite soil samples were collected from these panchayats and were characterized for physical, chemical and biological properties. From these data, minimum data set (MDS) which highly influenced the soil quality was developed which included available Mg, pH, porosity, available Mn, organic carbon, microbial biomass carbon, available Cu and Fe. The highest soil quality index mean was observed in Chendamangalam (0.70). Based on the relative soil quality index values the panchayats were categorized into three groups, *i.e.*, poor, medium and good. Out of 15 panchayats 10 were listed under poor category and 5 under medium category. Four panchayats showed decrease in soil quality on comparison with pre flood data.

Key words: Minimum dataset, Soil quality index.

In August 2018, Kerala witnessed catastrophic flood due to very heavy rainfall. As per India meteorological department (IMD) data, Kerala received 2346.6 mm of rainfall from 1st June 2018 to 29th August 2018 against the normal value of 1649.5 mm. The disastrous flood caused great damage to the soil environment in different ways. In Ernakulam district, AEU 5 was one of the most affected areas. *Pokkali* lands comprise low-lying marshes and swamps situated near streams and rivers and are not too far from the sea. Generally *Pokkali* soils are water logged and ill-drained and are subjected to tidal actions throughout the year. These lands are prevalent in the coastal saline tracts of Kerala. The soils are acid saline in nature with pH ranging from 3.0 to 6.8 (Nair and Money, 1968). The electrical conductivity of soils during the high saline phase, i.e., November to May, ranges from 12 to 24 dS m^{-1} and during low saline phase i.e., June to October, varies from 0.01 to 7.8 dS m^{-1} (Sreelatha and Shylaraj, 2017). The soil consists of soluble salts mainly of chlorides and sulphates of Na, Mg and Ca. Integrated farming consisting of *Pokkali* rice cultivation followed by shrimp farming is practiced traditionally in these soils.

Initial survey was conducted to identify the flood affected areas of AEU 5. In each panchayat severely affected areas were selected based on consultation with agricultural officers. Representative geo-referenced composite soil samples were collected randomly from 36 locations (Table 1) at a depth of

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Table 1. Details of the locations of AEU 5

Sample No.	Name of the panchayats	N latitude	E longitude
1	Kadamakkudy	10°3'2.7638"	76°19'7.9062"
2	Kadamakkudy	10°3'57.4222"	76°15'45.3093"
3	Varapuzha	10°4'42.5753"	76°15'53.9866"
4	Varapuzha	10°3'46.1736"	76°16'42.8746"
5	Varapuzha	10°3'46.1738"	76°16'42.8748"
6	Kottuvally	10°7'6.564"	76°14'53.502"
7	Kottuvally	10°6'49.4020"	76°14'27.9596"
8	Kottuvally	10°6'49.40208"	76°14'27.95964"
9	Chittatukkara	10°8'43.8133"	76°12'6.9770"
10	Ezhikkara	10°6'44.3345"	76°13'38.2023"
11	Ezhikkara	10°6'20.8792"	76°13'51.4772"
12	Ezhikkara	10°6'19.1584"	76°14'21.1981"
13	Kadamakkudy	10°3'16.9053"	76°15'11.4899"
14	Mulavukad	9°59'23.1064"	76°14'59.8401"
15	Elamkunnapuzha	10°10'25.6152"	76°10'37.7726"
16	Njarakkal	10°2'8.8055"	76°13'51.2588"
17	Njarakkal	10°2'41.9037"	76°13'38.3454"
18	Nayarambalam	10°3'43.0916"	76°13'20.0828"
19	Edavanakkad	10°4'49.6313"	76°12'58.1568"
20	Edavanakkad	10°4'47.8470"	76°12'55.6177"
21	Edavanakkad	10°6'27.9919"	76°11'49.5179"
22	Edavanakkad	10°6'51.0251"	76°11'47.5888"
23	Kuzhuppilly	10°6'50.4957"	76°11'54.6666"
24	Kuzhuppilly	10°6'50.0360"	76°11'12.2179"
25	Pallippuram	10°8'5.1257"	76°12'7.4692"
26	Puthenvelikkara	10°9'53.8923"	76°14'32.901"
27	Puthenvelikkara	10°9'49.635"	76°14'48.9242"
28	Chendamangalam	10°10'13.3441"	76°14'1.9767"
29	Chendamangalam	10°10'26.5180"	76°14'6.62352"
30	Chendamangalam	10°10'11.7236"	76°13'59.2971"
31	Chendamangalam	10°10'32.4130"	76°14'18.6723"
32	Vadakekkara	10°10'18.3385"	76°12'43.1247"
33	Vadakekkara	10°10'37.6849"	76°15'20.5336"
34	Vadakekkara	10°10'25.8884"	76°12'42.4911"
35	Vadakekkara	10°10'25.9704"	76°12'44.2909"
36	Vadakekkara	10°9'45.4978"	76°12'42.8817"

0-15 cm using soil auger during June 2019.The samples were analysed for physical (bulk density, particle density, porosity, water holding capacity, soil moisture), chemical (pH, EC, exchangeable acidity, effective cation exchange capacity, available macro, secondary and micronutrients, N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B) and biological (organic carbon, dehydrogenase activity and microbial biomass carbon) attributes.

Soil quality was assessed by the method described by Andrews et al. (2002) which included (i) selection of a minimum data set (MDS) of indicators which included the most significant variables that best represented the soil functions, (ii) normalisation of the MDS indicators and assigning scores to each indicator and (iii) integration of the indicator scores and calculation of index of soil quality.

Principal component analysis (PCA) was performed for soil attributes to develop minimum data set (MDS) (Doran and Parkin, 1994). PCA is a statistical reduction technique, which helps to determine the principal components (PCs). Since the PCs with higher values best represent the systems, the PCs having eigen value more than one and variance greater than five per cent were selected. Eigen values are the special set of scalars which determine the variance of the data. MDS was developed by selecting highly weighted variables within 10 per cent of highest loading factor from each PC.

Soil quality index = $\sum_{i=1}^{n} Wi \times Si$

where Si is the score for the subscripted variable and Wi is the weighing factor obtained from the PCA. Weighing factors were calculated by dividing per cent of variance by cumulative per cent of PCs having eigen value > 1.

The relative soil quality index (RSQI) was calculated using the method given by Karlen and Scott (1994).

RSQI = Computed SQI / Theoretical maximum SQI × 100,

where computed SQI is the value of each soil variable and theoretical maximum SQI is maximum SQI obtained by calculating with maximum score of each variable.

The PCA of soil attributes carried out using SPSS version 16.0 resulted in seven principal components (PCs) with eigen value greater than one and variance greater than five per cent. The seven PCs namely PC 1, PC 2, PC 3, PC 4, PC 5, PC 6 and PC 7 explained about 36.98,14.59, 8.98, 7.83, 6.87, 5.85 and 5.10 per cent variance respectively (Table 2)

Table 2. Results of principal component analysis of AEU 5

Particulars	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7
Eigen values	8.506	3.358	2.067	1.802	1.581	1.346	1.174
% Variance	36.985	14.599	8.989	7.836	6.872	5.853	5.106
Cumulative %	36.985	51.583	60.572	68.409	75.281	81.134	86.240
Eigen vectors							
DHA	0.452	0.628	0.119	0.460	0.046	-0.046	-0.099
N	0.818	-0.410	-0.045	0.102	0.089	0.006	-0.047
P	0.729	-0.167	-0.020	0.284	-0.255	0.027	-0.048
K	0.208	0.606	0.346	-0.536	0.140	-0.026	-0.216
Ca	0.892	0.007	0.179	0.223	-0.058	0.096	0.000
Mg	0.933	0.182	0.195	0.080	0.119	0.073	0.003
S	0.806	-0.250	0.099	0.275	-0.077	0.212	0.131
Fe	-0.146	0.751	-0.122	0.042	0.364	-0.128	0.128
Mn	0.154	0.026	0.231	0.828	0.099	-0.285	-0.002
Zn	0.361	0.139	0.050	0.818	0.225	0.111	-0.063
Cu	-0.048	0.039	0.157	-0.039	-0.078	-0.152	0.943
B	0.416	0.415	0.176	0.294	0.413	0.308	0.094
pH	-0.208	0.833	0.010	0.036	-0.136	-0.139	-0.119
EC	0.070	-0.274	-0.202	0.044	0.545	0.200	0.643
Ex.acidity	-0.054	-0.771	0.135	-0.003	0.267	-0.218	-0.018
OC	0.132	-0.035	0.188	0.157	0.828	-0.031	-0.024
ECEC	0.932	0.147	0.171	-0.012	0.207	0.038	-0.032
BD	-0.404	0.087	-0.860	-0.122	-0.173	0.033	0.022
PD	-0.570	0.201	0.178	-0.130	-0.381	0.475	0.088
Porosity	0.224	-0.027	0.950	0.112	0.015	0.065	0.117
WHC	0.883	0.129	0.297	-0.028	0.167	-0.050	-0.057
Soil moisture	0.908	0.066	0.257	0.021	0.215	0.047	0.015
MBC	0.194	-0.087	0.001	-0.100	0.045	0.913	-0.103

with a cumulative percentage of 86.24 per cent. Each variable in a particular PC had a weight or loading factor which represented the contribution of each variable to the PC. The highly weighted variables within 10 per cent of highest loading factor were retained from each PC for the development of MDS, and when more than one variable had higher factor loading present within a particular PC, their correlation was checked. Correlation coefficient of the variables with a value less than 0.60 was retained and others were eliminated from MDS (Andrews et al., 2002).

Although available Ca, Mg, effective cation exchange capacity, maximum water holding capacity and soil moisture showed the highest loading factor in the first PC, only available Mg was selected. From the second PC even though available Fe, pH and exchangeable acidity registered the highest loading factor, only available Fe and pH were selected. From the third PC, porosity and bulk density had highest loading factor but only porosity was selected for MDS. In the fourth PC available Mn and Zn had the highest loading factor and available Mn was selected. Organic carbon was selected from the fifth PC. Microbial biomass carbon was selected from the sixth PC and from the seventh PC available Cu was selected for MDS. From the total of seven PCs eight attributes constituted the MDS (Table 3).

Table 3. Minimum data set indicators and weights of each principal component of AEU 5

Principal component (PC)	Minimum data set (MDS) indicators	Weight
PC 1	Available magnesium	0.43
PC 2	pH, Available iron	0.17
PC 3	Porosity	0.1
PC 4	Available manganese	0.09
PC 5	Organic carbon	0.08
PC 6	Microbial biomass carbon	0.07
PC 7	Available copper	0.05

After the development of MDS, the soil indicators were converted to unitless scores ranging from 0 to 1 using non-linear scoring function methods (Andrews et al., 2002). Non-linear scoring was fitted using the equation:

$S_{NL} = a/1+(X/X_m)^b$,

where S_{NL} is the score of the soil indicator, 'a' is the maximum score reached by the function which is equal to 1, 'X' is the soil indicator value, 'X_m' is the mean value of each soil indicator, and 'b' is the slope of the equation and is set as -2.5 for a "*more is better*" curve and 2.5 for *"less is better"* curve (Bastida et al., 2006). Three types of scoring functions were used "*more is better", "less is better"* and *"optimum"* curve, based on their performance on soil functions.

"*More is better"* function

"*More is better"* function was assigned for microbial biomass carbon, available B, Cu, Mg and organic carbon. This function was used for soil organic matter and water stable aggregates because of their role in soil fertility, water partitioning and stability of structure (Tiessen et al., 1994). The scoring curves were assigned to each soil attribute based on their influence on soil quality.

"*Less is better"* function

"*Less is better"* function was assigned for available Fe and Mn. The available Fe and Mn content were found in toxic range; hence the "*less is better"* function was used for scoring. Due to the inhibitory effect of higher bulk density on soil porosity and plant root growth, bulk density was scored under "*less is better"* function (Soil Survey Staff, 1998).

"*Optimum"* curve

"*Optimum"* curve was used for pH and porosity. Starting from the optimum level, scores were allotted to both tails of the values in a decreasing order of importance.

Computation of soil quality index

The SQI was calculated using the method described by Doran and Parkin (1994). Weights were determined by the fraction of per cent variance of the PC from which the MDS variables were chosen (Table 3). Since the soil quality index was the summation of score and weightage of soil indicators, the SQI was found to be in the range of 0.47 to 0.70 (Table 4).The highest mean of soil quality index was found in Chendamangalam (0.70) and lowest mean in Nayarambalam and Ezhikkara (0.47).The mean of soil quality index values of Kadamakkudy and Varapuzha were 0.59. Soil quality index mean of Kottuvally, Chittatukkara, Mulavukad, Elamkunnapuzha, Njarakkal, Puthenvelikkara, Edavanakkad, Kuzhuppilly, Pallippuram, and Vadakkekkara were 0.53, 0.51, 0.49, 0.56, 0.64, 0.54, 0.55, 0.57, 0.48 and 0.65 respectively (Table 4). A study on land use impact on soil quality in eastern Himalayan region of India revealed that SQI rating was the highest for least disturbed sites such as natural forest (0.93) and grasslands (0.87) and lowest for intensively cultivated sites (0.44) (Singh et al., 2014). Generally cultivated lands have low soil quality compared to least disturbed areas. Here majority of the panchayats were cultivated and showed low value for soil quality index.

The calculated relative soil quality index (RSQI) values helps in categorisation of soil to poor, medium and low soil quality. The RSQI values <50% were categorized as poor, 50-70% as medium and >70% as good (Karlen and Scott, 1994). The relative soil quality index values ranged from 37.07 to 62.94 per cent. The highest mean RSQI was recorded in Chendamangalam (56.54%) and the lowest mean in Nayarambalam (40.52%). Njarakkal, Varapuzha, Kadamakkudy, Vadakkekkara and Chendamangalam recorded medium soil quality and Kottuvally, Chittatukkara, Ezhikkara, Mulavukad, Elamkunnapuzha, Nayarambalam, Puthenvelikkara, Edavanakkad, Kuzhuppilly and Pallippuram recorded poor soil quality. High RSQI was not recorded in any of the panchayats (Table 4).

Organic carbon, microbial biomass carbon and porosity mainly drive the soil quality index. Major

Table 4. Soil quality index and relative soil quality index values of different panchayats of AEU 5

Name of panchayat	Soil quality index (SQI)	Relative soil quality index (RSQI) (%)	Rating
Kadamakkudy	0.59	50.86	Medium
Varapuzha	0.59	51.15	Medium
Kottuvally	0.53	45.69	Low
Chittatukkara	0.51	43.97	Low
Ezhikkara	0.47	40.82	Low
Mulavukad	0.49	42.07	Low
Elamkunnapuzha	0.56	48.27	Low
Njarakkal	0.64	55.61	Medium
Nayarambalam	0.47	40.52	Low
Puthenvelikkara	0.54	46.55	Low
Edavanakkad	0.55	46.59	Low
Kuzhuppilly	0.57	47.05	Low
Pallippuram	0.48	41.37	Low
Chendamangalam	0.70	56.54	Medium
Vadakekkara	0.65	54.36	Medium

limiting factors in MDS were pH, available Fe, Mn, Mg and Cu. Low availability of Mg and Cu, toxicity of available Fe and Mn and acidic pH were noticed in *Pokkali* soils. The order of contribution of soil attributes to soil quality index was: available Mg> available Fe = pH> porosity> available Mn> organic carbon> microbial biomass carbon> available Cu (Fig. 1). Joseph (2019) reported that organic carbon was in the range of 0.26 to 3.05 per cent in *Pokkali* soils before flood while it varied from 1.07 to 4.63 per cent after flood. This increase in organic carbon content might be due to the deposition of organic debris after the floods. About 75 per cent of the samples were found deficient in available Cu; this deficiency might be due to chelation of Cu by organic colloids. *Pokkali* soils are acid sulphate in nature; this is the reason for low pH. Available Fe and Mn showed extreme toxicity in all the soil samples collected after the flood. During submergence the availability of Fe and Mn increased (Ponnamperuma, 1972).

The results of the present study revealed that Kottuvally, Elamkunnapuzha, Nayarambalam and Kuzhuppilly panchayats were poor in relative soil quality index. Even though most of the nutrients recorded high status in the soils, the influence of MDS indicators such as low available Mg and Cu, toxicity of available Fe and Mn and acidic pH contributed to low relative soil quality index. This was different from the result obtained by Sreelatha and Joseph (2019). According to their pre flood data, medium soil quality index was recorded for these panchayats (Table 5). This shift in soil quality in

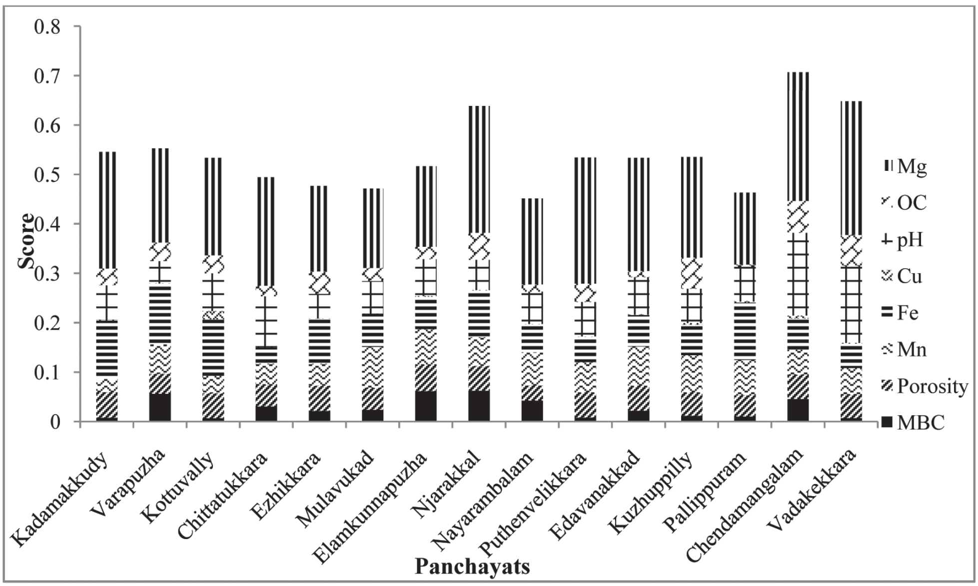

Figure 1. Contribution of each soil attribute in minimum data set towards soil quality index of AEU 5

Table 5. Comparison of the relative soil quality indexof AEU 5 with pre flood data

Panchayat	Relative soil quality index % (2013-14)	Relative soil quality index % (2018-19)
Kuzhuppilly	69.4	47.05
Nayaramabalam	72.5	40.5
Elamkunnapuzha	58.4	48.2
Kottuvally	62.7	45.6

these panchayats showed the change in indicators selected for MDS. The MDS indicators for the pre flood soils were available water, bulk density, organic carbon, pH, available S, Mn, Mg, base saturation, fine sand per cent, MBC, EC, aggregate stability and silt per cent while it has changed in the post flood assessment (Table 3). Even slight change in nutrient status of MDS indicators greatly affected the soil quality index.

The post flood study in AEU 5 revealed that drastic changes occurred in soil environment and 67 per cent of soil samples came under poor soil quality range. Among 15 panchayats the relative soil quality index of ten panchayats were under poor category and five were under medium category. The results clearly showed the decrease in soil quality after floods. Hence, adoption of site specific soil management practices is essential for improving the soil quality.

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