ASSESSMENT OF SOIL QUALITY IN THE POST FLOOD SCENARIO OF AEU 13 IN PALAKKAD DISTRICT OF KERALA AND MAPPING USING GIS TECHNIQUES

By

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(2018-11-107)

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THESIS

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DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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2020

DECLARATION

I, GADHA V.P. (2018-11-107) hereby declare that this thesis entitled **"Assessment of soil quality in the post flood scenario of AEU 13 in Palakkad district of Kerala and mapping using GIS techniques"** is a bonafide record of research work done by me during the course of research and that the thesis has not been previously formed for the award of any degree, diploma, fellowship or other similar title, of any other university or society.

Vellanikkara

Date: 25/11/2020

GADHA V.P.

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CERTIFICATE

Certified that this thesis entitled **"Assessment of *soil quality in the post flood* scenario of AEU 13 in Palakkad District of Kerala *and mapping using GIS* techniques"** is a record of research work done independently by **Ms. GADHA V. P.** (2018-11-107) under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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1. Introduction

1. INTRODUCTION

Soil is the dynamic natural body found on the surface of the earth crust, differentiated into horizons in a profile, composed of minerals, organic matter and living forms which support plant growth. Soil quality is the capacity of a soil to function within boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health (Doran and Parkin, 1994). Apart from the widespread loss to life and property, natural disasters trigger alarming changes in soil quality. Kerala state experienced the most devastating flood of the century on 16th August 2018. The unprecedented heavy rainfall in monsoon caused severe flood and land slide throughout the state. Eventually hundreds of people died and a few were missing. Besides, thousands of people lost their shelter as well as possessions. The state economy was affected very badly by the flood especially due to losses in agricultural sector. According to the Kerala post disaster needs assessment, August 2018 report; agricultural flood damage amounted to 6281 crores. Two types of flood damages were noticed in agricultural lands. Fields near water bodies experienced heavy water flow as a result of which annual crops were wiped out and sand and silt depositions were noticed in low lying lands. The fields near hillside faced caustic landslides which cause complete demolishment of the whole area where rebuilding is a very difficult task. In the first case, soil environment was disturbed to a medium extent; whereas in latter, the whole land was degraded. However, high population density as well as low availability of agricultural land forced us to re-establish the ruined areas as farms or agricultural lands. As a first step, understanding the changes in soil quality is the prime requisite for introduction of management aspects for rejuvenation of the area. Soil quality indexing is the best way to establish the variation in soil properties which may further be evaluated and interpreted for post flood agricultural development.

AEU 13 (northern foot hills) is one of the major flood affected areas of Palakkad district which include ten panchayats in Mannarkkad and Sreekrishnapuram block. The AEU 13 in Palakkad district experienced the ill effects of landslide as well as river overflow. AEU 13 is surrounded by hills like Siruvani hill, Kalladikkodan hill, Anangan hill and Attappadi hill. Massive landslide occurred in the valleys of Anangan and Kalladikkodan hills (Kottopadam, Kanjirappuzha and Karimba panchayats) resulted in the conversion of hectares of cropping area to barren lands. Immediately after landslide, these areas were covered with broken rocks, clayey soil and salty fluid which made a dreadful appearance to the place. The main hands of Nila, Kanjirappuzha, Kunthippuzha, Nellippuzha etc. were the major rivers that put on a major role in the flood. Kanjirappuzha, Siruvani and Meenvallam dams also exist in AEU 13. The landscape has low hills and undulating to rolling topography. Soils are rich in organic matter, strongly acidic and dominated by low activity clays and suffer from multi-nutrient deficiencies. Seventy percentage of the study area was in general used for agriculture. Coconut, arecanut and rubber were the main upland crops and rice, banana and vegetables were mainly grown in low lands. As flood affects the soil quality, it is essential to analyze the post flood scenario of this area with respect to soil quality, which may help the farmers to adopt appropriate soil management practices so as to ensure better productivity.

The term soil quality is relatively new, it is well known that soils vary in quality and this soil quality changes in response to use and management. Soil quality can be defined as an inherent attribute of a soil that is inferred from its specific characteristics and observations (Parr *et al.*, 1992). Characterization of soil is achieved by quantifying different physical, chemical and biological attributes. A minimum data set is created with principle component analysis and SQI is calculated with the help of statistical modeling. Map is a useful aid to express the results in a simpler manner. Using ARC GIS software, GIS based thematic maps can be prepared which provide an easy way to understand the soil quality in the post flood scenario.

In this context the present study 'Assessment of soil quality in the post flood scenario of AEU 13 in Palakkad District of Kerala and mapping using GIS techniques' is undertaken with the following objectives:

1. Assessment of soil quality of post flood soils of AEU 13 (Northern foot hills) in Palakkad district of Kerala
2. Formulate minimum data set and workout soil quality index for the flood affected soils of the study area
3. Develop maps of the study area on soil properties and quality using GIS techniques

2. Review of literature

2. REVIEW OF LITERATURE

The present investigation entitled "Assessment of soil quality in the post flood scenario of AEU 13 in Palakkad District of Kerala and mapping using GIS techniques" was carried out at College of Horticulture and Regional Agricultural Research Station, Pattambi during 2018-2020 in order to meet the objectives as detailed in section 1. Literature related to Kerala flood and landslide, effects of flood on soil quality and soil quality assessment is discussed in this section under different headings:

2.1 Agro ecological unit (AEU) 13 in Palakkad district of Kerala

2.2 Kerala floods, 2018

2.3 Effect of flood and land slide on soil productivity

2.4 Nutrient indexing

2.5 Soil quality assessment

2.6 Generation of maps using GIS technique

2.1 Agro ecological unit (AEU) 13 in Palakkad district of Kerala

Kerala state is delineated into 23 agro ecological units. Each AEU is a homogeneous agricultural region with unique climate, soil and land form. AEU 13 i.e., northern foothills had low hills and undulating to rolling topography. Soils were rich in organic matter, strongly acidic and dominated by low activity clay and suffer from multi nutrient deficiencies (Rajashekharan *et al*., 2013). Seventy percentage of the area was used for agriculture. Coconut, arecanut and rubber were the main upland crops and banana, vegetables and rice were the main low land crops. AEU 13 belonges to Agro ecological zone 3 (AEZ 3) (Foot hills) and have 5 agro ecological sub units; forests, denudational hills, laterite plateau, laterite terrain and laterite valley. Among them laterite terrain covers the major portion of the unit (Nair *et al*., 2012).

In AEU 13, there were three type of soils - Laterite soil, virgin forest soil & alluvial soil. Laterite soils were predominant in midland whereas virgin forest soils were only seen in forest areas. Alluvial soils were found along the banks of

Bharathapuzha and its tributaries. In the valley portion valley fill deposits composed of talus and scree materials were observed (District survey report, 2016).

Karakurussi, Mannur, Uthrampallam and Agali were the four soil series found in the parts of AEU 13 in Palakkad district (table 2.1).

Soil series	**Order**	**Suborder**	**Greatgroup**	**Subgroup**	**Family**
Karakurussi	Entisol	Fluvents	Ustifluvents	Aquic ustifluvents	Coarse loamy,mixed, isohyperthermic
Mannur	Ultisol	Ustults	Kandiustults	Typic kandiustults	Clayey, mixed, isohyperthermic
Uthrampallam	Ultisol	Humults	Haplo humults	Ustic haplo humults	Clayey, mixed, isohyperthermic
Agali	Mollisol	Ustolls	Argiustolls	Pachic argiustolls	Fine loamy, mixed, isohyperthermic

Table 2.1 Details of soil series present in AEU 13 in Palakkad district of Kerala (SSOA, 2007)

Karakurussi soils were deep to very deep, strong to medium acidic, wetland soils with medium amount of nitrogen and phosphorus and low potassium. Mannur soils were found in southern parts of Mannarkkad block, which were moderately shallow to moderately deep, slightly gravelly and acidic. Here also medium amount of nitrogen and phosphorus and low potassium was found. Uthrampallam soils were the forest soils of Palakkad district having high nitrogen, medium to high phosphorus and medium potassium. The soils were deep, slightly to medium acidic and subject to severe moisture stress. Calcium carbonate nodules in the profile were the characteristic feature of Agali soils which were moderately shallow and moderately alkaline with medium nitrogen and phosphorus and low potassium content (SSOA, 2007).

According to the Palakkad district survey report of minor minerals 2016, hornblend-biotite gneiss, laterite, granite gneiss and magnetite quartzite were the major minerals found in AEU 13 of Palakkad district. Hornblende-biotite gneiss and pink granite gneiss of Peninsular Gneissic Complex were exposed in this area. Valleys were occupied by fluvial alluvium and laterization was common in the western part of the AEU.

2.2 Kerala floods, 2018

Frequent and extreme precipitation events cause flooding (Fowler *et al*., 2010), which was very common in certain areas of India (Mohapatra and Singh, 2003). However it was not a common feature in Kerala state. Kerala experienced extreme precipitation, landslides, and flood in august 2018. Kerala received 53% more rainfall between May 1 and August 21 in 2018 than its long-term mean for the same period. Besides that almost all the reservoirs were 90% full before the intense rain of 14 to 17 August, 2018. Table 2.2 showed the monthly average rain fall of Palakkad district during the period measured at Agromet observatory, RARS, Pattambi and it was clear that compared to the previous years high rainfall occurred during May to August in 2018. So a combined effect of above ordinary seasonal rainfall, high reservoir storage and heavy rain in the catchments upstream to major reservoirs might have played a major role in the large scale flooding in Kerala (Mishra *et al.,* 2018).

	May	June	July	August
2016	191.7	480.6	344.6	120.2
2017	190.6	550.5	354.4	412.9
2018	407.1	790.2	713.0	670.5

Table 2.2 Monthly average rain fall (mm) (May-August, 2016-18) of Palakkad district of Kerala

The Western Ghats, the bold westerly escarpment of India (Radhakrishna, 2001), bears the testimony of frequent landslides, especially during the monsoon season, and it caused widespread damage (Sajinkumar *et al*., 2011). Nearly eight percentage (1,400 km^2) of the area in the Western Ghats of Kerala was classified as a critical zone for mass movements. This region was characterized by rugged hills with steep long side slopes on which rests the loose unconsolidated soil and earth material which are reasonably susceptible to landslides (Thampi *et al*., 1995). Landslides may occur in different forms like rock fall, rock slide, debris slide, debris fall, debris flow, debris avalanche, and slump and creep (Anbazhagan and Sajinkumar, 2011). Most of the landslides occur during the monsoon season and hence, rainfall was considered as the dominant triggering mechanism. Landslides in Kerala, India, have been shown to be preceded not only by critical rainfall over a short period but also a much longer period of elevated pore pressure (Weidner *et al.*, 2018; Oommen *et al*., 2018). This condition enhances the chemical weathering and assists the formation of thick column of soil over the Precambrian crystallines. This unconformity, existing between the Precambrian crystallines and the overlying recent sediments, forms the slip plane for the landslides in Kerala. The typical landslide dynamic type occurring in Kerala was debris flow restricted to monsoon period (Sajinkumar and Anbazhagan, 2015). Hence, in most cases, the area now affected by landslides will be free from landslides in the future as the entire debris will be washed away by the landslides.

2.3 Effect of flood and land slide on soil productivity

The most prominent and direct impacts of flood on soils were deposition of sand and debris on productive lands, erosion of agricultural soils, flooded soil syndrome (loss of beneficial fungi which mobilize plant nutrients in soil) and nutrient imbalance. Natarajan *et al.* (2010) studied the soil and plant nutrient loss during the recent floods of north Karnataka and observed soil loss of 30 tonnes ha^{-1} in black soils and 20 tonnes ha^{-1} in red soils in the affected districts. The loss of black soil was almost three times more than that of red soil due to its poor infiltration rate, high clay and low organic matter content. Severe sheet erosion and formation of rills and gullies were also noticed in the flooded areas. Soil loss was also critical in the catchment areas adjoining seasonal streams, rivulets and agricultural fields that had been prepared and leveled on the natural drainage network. Total 10.75 m ha area was affected by flood in Karnataka which was almost half of the total geographical area of the state. From this area Rs 1625 crores worth of total soil nutrients were lost during flood period (Natarajan *et al*., 2010).

It is known that top soil of the Earth's surface was only a fertile one containing organic matter of small fraction (2% to 4%) of soil surface and it contributes to productivity through its effect on the physical, chemical and biological properties of the soil to support the plant growth. If this soil gets eroded due to flood there will be a serious impact on healthy growth of plants (Mahabaleshwara and Nagabhushan, 2014).

Flooding can lead to increase or decrease of the available nutrients in soil. When a soil is flooded, the oxygen cycle of the soil system is altered which cause reduction in soil quality; at the same time flood deposits organic materials, minerals, and essential nutrients from rivers and oceans into land which makes the soil richer, fertile and more productive in certain situations (Ubuoh *et al*., 2016).

It is evident that the land slide can alter soil quality by through changes in soil physical, chemical and biological properties. Blonska *et al.* (2017) reported such a wider diversification of soil attributes after landslide. Their study concluded that the landslide affected area became less fertile with low organic matter content which restricts biological activity. They suggested that the biochemical parameters like microbial biomass C, available N and dehydrogenase activity can be regarded as the useful tool for evaluating the changes taken place in soil after landslide. The results of Singh *et al.* (2001) gave information that landslide affected soil was low in available N, P, organic C and extractable nutrients like available Ca, K and Mg compared to the soils of near by areas which were not subjected to landslide. Bulk density and soil pH were high but water holding capacity was low in landslide affected soils.

2.3.1 Effect on soil physical parameters

Water logging conditions drastically alter the soil properties, these changes in soil adversely affect the capability of a plant to survive in such situations (Dat *et al*., 2004) Ubuoh *et al.*, 2016 studied the effect of flood on soil quality of Nigeria and concluded that the soils became more fertile after flood. The bulk density showed significant change compared to the non flooded area. Bulk density decreased where as infiltration rate, porosity and water holding capacity increased after floods. Similar trends were reported by Akpoveta *et al* (2014) in their study related to post flood effects on soil quality in Nigeria. Nelson and Terry (1996) observed that soil properties such as bulk density and porosity had a large influence on denitrification activities of flooded soils.

According to the Impact assessment of flood/landslides on biodiversity and ecosystem of Idukki district and Kuttanad, Kerala State Biodiversity Board, 2018, there was a noticeable change in the water holding capacity of both flooded and landslide affected soils which indirectly remarks the change in density, porosity and soil structure.

However there were diverse reports also. Long periods of flooding alter the physical properties, by increase in bulk density, with the consequent decrease of the total porosity and aeration, affecting oxygen concentration in the soil, necessary for the normal development of the plants (Rodrigues *et al.*, 2016). There were some significant correlations observed in the post flood soil quality index study done by Istijono *et al.*, 2019.

2.3.2 Effect on soil chemical parameters

A study conducted by Tsheboeng *et al.* (2014) related to flood variation and nutrient content gave some information regarding the nutrient status and dynamics after flood. Soil nutrient content varied after low and high floods. With the exception of P, soil nutrient content generally increased with decreasing flooding depth and duration. Phosphorus content increases after a high flood. It could be expected that during high flood more soil nutrients dissolve in water and were lost through leaching as water infiltrates the soil. Another reason for the reduction of nutrient is the deceleration of decomposition of organic matter in flooded soils due to lack of dissolved oxygen as well as aerobic microbes.

The results obtained from the study of Ubuoh *et al.* (2016) showed that most of the available nutrients added to the soil during the flooding were washed down slope to the lower course of the river. Akpoveta *et al.* (2014) mentioned that there were considerable decrease ranging from 4% to 53% in the values of pH, total organic carbon, total organic matter, total nitrogen, total phosphorus and cation exchange capacity in the flood affected farmlands when compared to the control farmland. But there was a drastic increase in the electrical conductivity. Flood had impact on availability of micronutrients. There was an increase in metal concentration except potassium. High concentration of some micronutrients like manganese, copper, nickel and heavy metals like lead and cadmium tending towards undesirable level were observed. But there was a reduction in cation exchange capacity.

2.3.3 Effect on soil biological parameters

There were a number of articles showing the increase in organic matter content after flood. Flood cause deposition of organic matter in the affected area and lead to an increase in organic carbon in soil (Brady, 1984; Boyd, 1995). Increase in organic matter content increases the nutrient concentration and cause reduction in bulk density (Chaudhari *et al*., 2013). Organic carbon alters many soil characters like color, density, nutrient holding capacity, which in turn influence aeration and water relations (Pluske *et al*., 2003). But Saint-Laurent *et al.* (2016) reported reduction in organic carbon after flood. This was due to the absence of ground litter in the frequent flood zones which helps to decrease the input of organic matter in the surface horizons and ultimately results in soil depletion.

Findings of Chendrayan *et al.* (1980) denoted that soil water content and temperature influences the dehydrogenase activity in soil. The flooded condition alters the oxidation-reduction status of soil which cause decrease in redox potential and oxygen diffusion rate, indirectly resulting an increase in dehydrogenase activity. Gu *et al.* (2009) also recorded higher dehydrogenase activity in flooded soils compared to non flooded soils.

2.4 Nutrient indexing

To assess the soil fertility, many researchers and government agencies followed nutrient indexing method. Nutrient index (NI) of organic C, available P and K provide an overall idea about the present status of soil and it helps to fix the reclamation strategies (Yuossef *et al*., 2016). Ravikumar and Somashekar (2013) computed the NI of OC, available P and K and made comments on soil fertility of Varahi river basins of Karnataka, and the area was characterized as low-medium-low (OC-P-K) category. Similarly Abah and Petja (2015) also evaluated the nutrient index of OC, available P and K in the lower river Benue basin and they suggested that besides the NI, evaluation of soil pH, exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) will provide a complete picture of soil fertility in the study area which helps for taking further action regarding management aspects.

2.5 Soil quality assessment

Recent interest in evaluating the quality of our soil resources has been stimulated by increasing awareness that soil is a critically important component of the earth's biosphere, functioning not only in the production of food and fiber but also in the maintenance of local, regional, and worldwide environmental quality. The term soil quality is relatively new, it is well known that soils vary in quality and that soil quality changes in response to use and management.

Soil quality can be defined as an inherent attribute of a soil that is inferred from its specific characteristics and observations (Parr *et al.*, 1992). The rationale is that a quantitative index of soil quality may serve as an indicator of a soil's capacity for sustainable production of crops and animals in an economically sound, socially acceptable, and environment-friendly manner. Soil quality is affected by natural and human induced processes (Karlen *et aI.*, 1992). Soil quality primarily describes the combination of chemical, physical, and biological characteristics that enables soils to perform a wide range of ecological functions (Karlen *et al.*, 1997). So these attributes are called soil quality indicators (Wander and Bollero, 1999) (Table 2.3). Soil quality cannot be measured directly; similarly an individual soil property could not be used to assess soil quality. Integrated soil quality indicators based on a combination of soil properties can better reflect the status of soil quality than individual parameters. The type of indicator chosen to evaluate soil quality depends on the soil function and the size of the area in which the evaluation is made.

Physical indicators	Chemical indicators	Biological indicators
Field, Farm or Watershed indicators		
Passage of air	Base saturation percentage	Soil organic carbon
Structural stability	Cation exchange capacity	Microbial biomass carbon
Bulk density	Contaminant availability	C and N oxidizable carbon
Clay mineralogy	Contaminant concentration	Total biomass
Colour	Contaminant mobility	Bacterial count
Consistence	Contaminant presence	Fungal biomass
Depth of root limiting layer	Electrical conductivity	Potentially mineralizable N
Hydraulic conductivity	Exchangeable sodium percentage	Soil respiration
Oxygen diffusion rate	Nutrient cycling rates	Enzymes
Particle size distribution	pH	Dehydrogenase
Penetration resistance	Plant nutrient availability	Phosphatase
Pore conductivity	Plant nutrient content	Arylsulphatase
Pore size distribution	Sodium adsorption ratio	Total organic respiration
Soil strength		Microbial community finger printing
Soil tilth		Substrate utilization
Structure type		Fatty acid analysis
Temperature		Nucleic acid analysis
Total porosity		
Water holding capacity		
Regional or national level		
Desertification	Organic matter trends	Productivity
Vegetative cover	Acidification	Taxonomic diversity at

		group level
Water erosion	Salanisation	Species richness diversity
Wind erosion	Change in water quality	Keystone species and ecosystem engineers
Siltation of river and lakes	Change in air quality	Biomass density and abundance
Sediment load in rivers		

Table 2.3 List of soil quality indicators

(Singer and Ewing, 2000); Nayak *et al.*, 2016

2.5.1 Soil quality index (SQI)

Estimation of soil quality index is a complex and difficult task which includes three steps. The steps are selection of minimum data set (MDS) of indicators that best represent soil function, score the MDS indicators based on their performance of soil functions and integrate the indicators into a comparative index of soil quality (Rahmanipour *et al.*, 2014).

There are three methods to compute the soil quality index. In simple additive SQI method, soil parameters were given threshold values based primarily on the literature review and expert opinion of the authors. The sum of individual index values provides the total SQI (Amacher and Ferry, 2007).

Total SQI = Σ individual soil property index values

In the second approach, that is weighed additive SQI, each soil parameter were first assigned unit less score ranging from o to 1 by employing linear scoring functions. Soil parameters were divided into groups based on three mathematical algorithm functions, ‘more is better’, ‘optimum’ and ‘less is better’. The scores were given and integrated into a single index value for each soil using a weighted additive approach initially suggested by Karlen and Stott, (1994) but modified later by Fernandes *et al*. (2011).

In the third method, a statistics-based model was used to estimate SQI using principal component analysis (PCA). To reduce the indicator load, a minimum data set is created using a number of statistical tools. PCA method was preferred as a data reduction tool to select the most appropriate indicators to represent and estimate SQI (Navas *et al*., 2011). Mukherjee and Lal (2014) compared the three SQI methods and articulate that the third method can be regarded as the best and easiest model with relatively less expensive procedure over time compared to the first and second models.

2.5.2 Minimum data set (MDS)

A minimum data set for assessing soil quality should have the characteristics (Doran and Parkin, 1994) like easy to measure, detect changes in soil function, integrate soil physical, chemical, and biological properties and processes, accessible to many users and applicable to field conditions, sensitive to variations in management and climate, encompass ecosystem processes and relate to process oriented modeling and where possible, be components of existing soil data bases. By two ways we can select the MDS. One is based on expert opinion and the other is using statistical models.

Principal component analysis (PCA) is the method for reducing correlated variables to a small set of statistically independent linear combinations having certain unique properties with regard to characterizing individual differences. After a set of statistical analysis, principal component (PCs) groups are obtained. PCs are the linear combinations of the variables that account for maximum variance within the set (Dunteman, 1989). Each PC explains a certain amount of variation (%) in the total data set; this percentage provided the weight for variables chosen under a given PC. The final PCA based soil quality equation is as follows:

$SQI = \Sigma W \times S$

Where,

S = score for the subscripted variable

W = weighing factor derived from PCA

(Andrews *et al.*, 2002)

2.5.3 Relative soil quality index (RSQI)

To compare SQI of one soil with another in a particular region, an index called relative soil quality index (RSQI) (Ray *et al.*, 2014) is used and it is obtained as

RSQI = (SQI of the reference soil / SQI which has the highest value in the region) × 100

An optimal soil in any region will have a normalized RSQI of 100, but in reality soils will have lower values which indicate directly their difference from the optimal soil. By computing RSQI values, soil quality in different regions can be compared even if they were computed with different evaluation systems, weightings, and classes (Wang and Gong, 1998). The difference in RSQI (ΔRSQI) is a standard for evaluating soil quality changes over time. According to Wang and Gong, combination of a soil change database with a GIS has proved an effective method for evaluating and mapping changes in soil quality at small scales. RSQI could serve as a unified criterion for comparing regional soil quality, and ΔRSQI provides a standard for the evaluation of soil quality changes.

Pham *et al.* (2015) proposed a new approach to assess the soil quality by aggregate indices using the Relative Soil Quality Index (RSQI) which simplifies the calculation of the weighting factors of total content of bio elements, content of available forms of bio elements, exchangeable acidity and heavy metal groups. Here the authors applied the RSQI to assess the soil environmental quality of rice intensive cultivation areas and the RSQI values are simulated on digital land use map by GIS technology. The map which is developed from the aggregate SQ assessment approach by using RSQI provides an overview of the level of soil degradation before promptly taking appropriate measures to prevent or reduce the changes. They asserts that their results were consistent and therefore, the calculation method using individual indices qi and the aggregate index RSQI has a scientific basis and high accuracy; the method could be applied in warning service and environmental management at the provincial scale.

2.6 Generation of maps using GIS technique

Geographical Information System (GIS) is a technology that provides the means to collect and use geographic data to assist in the development of Agriculture. GIS is a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modeling, representation and display of geo referenced data to solve complex problems regarding planning and management of resources (NCGIA, 1990). It is the system for capturing, storing, analyzing and managing data and associated attributes, which are spatially referenced to the Earth and also called as geographic information system or geospatial information system. This information system is capable of integrating, storing, editing, analyzing, sharing, and displaying geographically referenced information. It had emerged in the last decade as an essential tool for urban and resource planning and management and now it used for land use planning, utilities management, ecosystems modeling, landscape assessment and planning, transportation and infrastructure planning, market analysis, visual impact analysis, facilities management, tax assessment, real estate analysis and many other applications (Escobar *et al.*, 2008).

GIS have four components. They were software, hardware, data, people and methods. GIS software provides the functions and tools needed to store, analyze, and display geographic information. Hardware is the computer on which a GIS operates. There were two types of data used in GIS, geographical or spatial data and tabular or attribute data. There are various types of users and methods for GIS based on the purpose (Escobar *et al.*, 2008).

Many researchers, who were worked in GIS for soil quality index mapping used ArcGIS software. Ozsahin *et al.* (2017) analyzed the soil quality index of Tekirdag province (Turkey) using GIS. Image analyses in the study were performed using ArcGIS 10.3 while statistical analyses were conducted via Statistical Package for Social Sciences (SPSS) software. To study the land and soil quality indicators of Indo - Gangetic plains of India, Ray *et al.* (2014) used GIS and SOTER to show the SQI and RSQI dataset spatial distribution. Pham *et al.* (2015) created the Soil Environmental Quality (SEQ) map of Haiduong province, Vietnam using GIS technology. Wang and Gong (1998) assessed the soil quality changes after eleven years of reclamation in subtropical China with the assistance of GIS. They stated in their conclusion that combination of a soil change database with a GIS has proved an effective method for evaluating and mapping changes in soil quality at small scales. A few researchers used some softwares other than ArcGIS. For soil quality indexing and mapping of lake Victoria microcatchment ferralsol, Wanyama *et al.* (2005) used Integrated Land and Water Information Systems (ILWIS) 3.0 software.

3. *Materials & Methods*

3. MATERIALS AND METHODS

The present investigation entitled "Assessment of soil quality in the post flood scenario of AEU 13 in Palakkad District of Kerala and mapping using GIS techniques" was carried out at College of Horticulture and Regional Agricultural Research Station, Pattambi during 2018-2020 in order to meet the objectives as detailed in section 1. The materials and methods used for this experiment were detailed below under different headings:

3.1 Survey and collection of soil samples

3.2 Analysis of soil quality

3.3 Comparison of post flood analytical results with pre flood data

3.4 Nutrient indexing

3.5 Formulation of MDS and SQI

3.6 Generation of maps using GIS technique

3.1 Survey and collection of soil samples

3.1.1 Survey

The area of study included ten panchayats belonging to Mannarkkad and Sreekrishnapuram blocks. As a preliminary step, a discussion was made with all Agricultural officers of individual panchayats**.** Separate visits were made to respective krushibhavans and the data related to agricultural losses due to flood (August 2018) were collected. According to the area and number of farmers affected by flood, the targeted 101 samples were distributed among ten panchayats of Mannarkkad block (Table 3.1) (Fig.4.32). The staff of Department of Agriculture and Agricultural Technology Management Agency were consulted for selecting the fields for sampling. Primary information was collected directly from the farmer.

Panchayat	Total geographical area (km^2)	Major crops cultivated	No of samples collected from the flood affected area
Alanallur	58.24	Banana, Arecanut	13
Kanjirappuzha	27.00	Rubber, Coconut	12
Karimba	69.20	Rubber, Arecanut	10
Kottappadam	79.81	Vegetables, Banana	19
Kumaramputhur	37.25	Paddy, Banana	10
Mannarkkad	58.44	Banana, Arecanut	15
Thachampara	31.40	Paddy, Banana, Rubber	09
Thachanattukara	35.04	Paddy,Banana, Arecanut	05
Thenkara	53.97	Banana, Arecanut	04
Karakkurussi	16.62	Banana, Arecanut	04

Table 3.1 Sample distribution in different panchayats of AEU 13 in Palakkad district of Kerala

3.1.2 Collection of soil samples

One hundred and one composite soil samples were collected in summer season of 2019 from ten panchayats belong to Mannarkkad and Sreekrishnapuram blocks. At every location, a single composite sample was made out of many soil samples collected from different spots according to the size of the field. Soil samples were collected from a depth of 15-20 cm. After thorough mixing, quartering method was followed to reduce the sample size and to arrive at the composite samples. Proper labels were given and GPS readings were recorded. Apart from the soil samples collected from 15-20 cm depth, the undisturbed samples were collected using core sampler from each and every location.

3.1.3 Processing of the soil samples

The clods in the soil sample were broken using wooden mallet and the soil samples were allowed to dry under shade. The samples were passed through 2 mm sieve after drying under shade. A portion of each sample was ground and made to pass through 0.5 mm sieve for size reduction for organic carbon estimation. The processed samples were stored in transparent polythene covers with proper labels.

3.2 Soil quality analysis

The collected 101 soil samples were analyzed for physical, chemical and biological attributes to assess the soil quality index of AEU 13 in Palakkad district of Kerala.

3.2.1 Physical parameters

3.2.1.1 Bulk density (BD)

A known volume of core sample was dried in the hot air oven at 105^0C to get a constant weight. The ratio of dry soil mass to total volume of soil that is the inner volume of core sampler provided dry bulk density of the sample (Blake and Hartge, 1986)

.3.2.1.2 Particle density (PD)

Particle density is the ratio of dry soil mass to the volume of soil solids. A known amount of dried soil (Ws) was put in 25 ml volumetric flask. After pouring some water the flask was heated to expel the air trapped in soil pores. The volume was made up with distilled water and weights were recorded (Wsw). The contents were poured out and the volume of flask was filled with water alone and recorded the weight (Ww). Using these values particle density calculated.

Particle density = Ws/ [Ws - (Wsw-Ww)]

3.2.1.3 Total porosity

Porosity is an index of relative pore volume. It is the percentage of volume occupied by pores in unit volume of soil. Porosity was calculated by using bulk density and particle density.

Porosity (%) = [1- BD/PD] ×100

BD= Bulk density

PD= Particle density

3.2.1.4 Soil moisture content

Fresh weight and oven dry weight of the soil samples were measured and the moisture content of the sample was calculated and is expressed in percentage.

3.2.1.5 Maximum water holding capacity (MWHC)

Keen Raczkowski box (KR box) method (Black, 1965) was performed to measure the amount of water held in the soil at zero tension, *ie*., maximum water holding capacity. KR box was a one side open cylinder with holes on the bottom side. A filter paper was fixed at the bottom of the KR box and weight was recorded. Then the box was packed with air dried soil and again the weight recorded. The KR box with soil were kept overnight in a tray containing water to a height of at least ½ inch. The weight was recorded next day and WHC was calculated from the readings.

3.2.2 Chemical parameters

3.2.2.1 Soil pH

pH of the soil sample was determined by electrometric method. Electrode assembly of a pH meter was dipped into a soil - water suspension of 1:2.5. The potential difference was measured as Hydrogen ion (H+) activity.

3.2.2.2 Electrical Conductivity (EC)

In conductometric method, the conductivity cell of a conductivity meter was dipped into the soil – water (1: 2.5) supernatant fluid. The electrical conductivity is directly proportional to salt concentration of the solution which is expressed as $dS\ m^{-1}$.

3.2.2.3 Available nitrogen

Potassium permanganate in alkaline medium oxidizes the available nitrogen to ammonia which was distilled, condensed and trapped in boric acid. This content was titrated against standard sulfuric acid and available nitrogen in soil was calculated (Subbiah and Asija, 1956).

3.2.2.4 Available phosphorus

Entire soil samples were acidic in nature. So Bray- Kurtz method was followed (Bray and Kurtz, 1945) for estimation of available P. Using Bray's reagent, available phosphorus was extracted and estimated colorimetrically by ascorbic acid method. Intensity of blue color was measured in spectrophotometer at 660 nm.

3.2.2.5 Available potassium

Available potassium was extracted with the help of neutral normal ammonium acetate and determined by flame photometric method which came under emission spectroscopy.

3.2.2.6 Available calcium and magnesium

The same extract of potassium was used to estimate exchangeable calcium and magnesium, but the estimation was done using atomic absorption spectrophotometer (AAS) which is based on absorption spectroscopy.

3.2.2.7 Available sulphur

Available sulphur was extracted from soil samples using 0.15 percent calcium chloride. Sulphate in the filtrate was estimated turbidometrically. Barium chloride was the reagent added to produce turbidity. This turbidity (optical density) was measured at 440 nm wavelength of light using spectrophotometer (Tabatabai, 1982).

3.2.2.8 Available cationic micronutrients (Fe, Mn, Cu, Zn)

Available cationic micronutrients in soil were extracted using 0.1 M hydrochloric acid and estimated separately in atomic absorption spectrophotometer with respective lamps of specific wavelength.

3.2.2.9 Available Boron

Azomethane-H indicator was added to the hot water extract of soil. In aqueous medium, azomethane-H reacts with boric acid to form a stable and soluble yellow colored complex (John *et al*., 1975). The intensity of yellow color is proportional to the concentration of boric acid and it was measured at 420 nm wavelength using spectrophotometer.

3.2.2.10 Exchangeable acidity (EA)

Exchangeable acidity or actual acidity is the acidity released upon exchange by standard potassium chloride solution. The extract was titrated against sodium hydroxide using phenolphthalein indicator (Gillman, 1979).

3.2.2.11 Effective Cation Exchange Capacity (ECEC)

The exchangeable cations in the soil were extracted with 0.1M $BaCl_2$ solution (Hendershot and Duquette, 1986). The estimation of exchangeable cations were done with suitable estimation methods. ECEC was calculated as the sum of exchangeable K, Ca, Mg and Na, cationic micronutrients and exchangeable acidity and is expressed in cmol kg^{-1}.

3.2.3 Biological parameters

3.2.3.1 Soil Organic carbon (OC)

Walkley - Black's method (Walkley and Black, 1934) was carried out to determine soil organic carbon. Wet oxidation with chromic acid followed by back titration provides organic carbon or organic matter status in soil.

3.2.3.2 Dehydrogenase activity (DHA)

Dehydrogenase activity in soil was determined by the method suggested by Casida (Casida *et al.,* 1964). Colorimetric determination of 2,3,5- triphenyl formazan (TPF) produced by the reduction of 2,3,5- triphenyl tetrazolium chloride (TTC) by soil microorganisms was undertaken.

3.3 Comparison of post flood analytical results with pre flood data

The results obtained after soil testing were compared with the pre flood data collected from District Soil Testing Laboratory (DSTL), Pattambi and the analytical results of a multi institutional project jointly implemented by Department of Agriculture, KAU, ICAR and IITMK (Rajasekharan *et al*., 2013). For this comparison, 100 soil health cards (2017-18) from the study area were randomly collected from DSTL, Pattambi, tabulated and categorized based on the status of soil attributes. The results of eleven soil parameters *ie.* Soil pH, EC, organic C, available P, K, S, Fe, Mn, Zn, Cu and B from soil health card were analyzed for the comparison. But the pre flood data of available Ca and Mg were not there in soil health cards, so the results of Rajasekharan *et al*. (2013) were used for comparison of the available cationic secondary nutrients. The pre flood data of soil physical properties, available N, effective cation exchange capacity and exchangeable acidity were not available for comparison.

3.4 Nutrient indexing

Nutrient index was calculated for organic carbon, available N, P and K. After the analysis of these parameters the soil samples were grouped into low, medium and high classes based on the respective nutrient status in the sample. Using the number of samples belonging to each class the NI was calculated (Parker *et al*., 1951).

$NI = (N_L + 2N_M + N_H) / N$

N_L= number of samples under low class

N_M= number of samples under medium class

N_H= number of samples under high class

N = total number of samples

Based on the standard ratings given by Ramamoorthy and Bajaj, (1969) the NI of the study area was interpreted as high, medium or low.

3.5 Formulation of MDS and SQI

Minimum data set (MDS) was established with principle component analysis (PCA) for soil quality assessment. This was called statistics based model to create soil quality index (SQI). All measured soil properties were compared in PCA and only the factors with eigen value > 1 were selected as MDS. The statistical analysis was conducted with the help of a software OPSTAT. After fixing parameters for MDS, nonlinear scoring function was operated. Using scoring curves three type standard scoring functions were generated - more is better, less is better and optimum is better. After transforming the numerical scores which ranges from 0-1, a weighed additive approach was used and SQI was calculated using the equation.

$$SQI = \Sigma \text{ weight} \times \text{individual soil parameter score}$$

The calculated soil quality index was compared with a theoretical maximum soil quality index and expressed in percentage which is known as relative soil quality index (RSQI).

3.6 Generation of maps using GIS technique

The most common use of GIS (Geographic Information System) is to produce data visualization in the form of a map. Among different kinds of maps, quantity maps were created using ARC GIS software with the SQI data obtained in previous section.

Plate 3.1 Visit to Krishibhavan

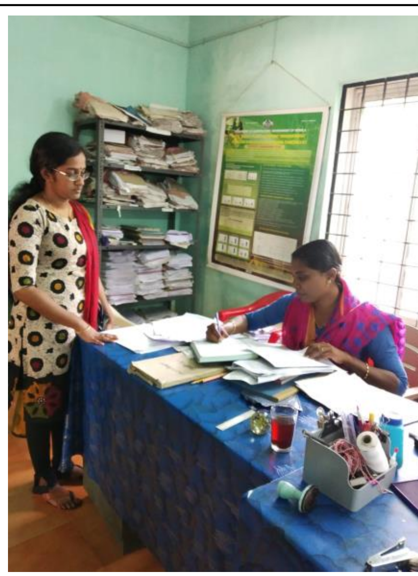
 

Plate 3.2 interaction with Agricultural officers

Plate 3.3 Interaction with farmer

Plate 3.4 Collection of geo referenced soil samples

4. Results

4. RESULTS

The present investigation entitled "Assessment of soil quality in the post flood scenario of AEU 13 in Palakkad district of Kerala and mapping using GIS techniques" was carried out at College of Horticulture and Regional Agricultural Research Station, Pattambi during 2018-2020 in order to meet the objectives as detailed in section 1. The results of various soil analyses conducted as part of the investigation are detailed below under different headings:

4.1 Assessment of soil quality

4.2 Soil attributes in flooded and landslide affected area

4.3 Formulation of MDS

4.4 Scoring of MDS parameters

4.5 Computation of soil quality index (SQI)

4.6 Relative Soil Quality Index (RSQI)

4.7 Nutrient Index (NI)

4.1 Assessment of soil quality

The assessment of soil quality was carried out by analyzing the soil physical, chemical and biological attributes and further soil quality index was calculated and GIS maps were prepared.

4.1.1 Soil physical attributes

The soil samples were analyzed for five physical attributes (bulk density, particle density, porosity, maximum water holding capacity, and moisture content) for assessing the soil quality of flood affected areas of AEU 13 in Palakkad district of Kerala.

4.1.1.1 Bulk density (BD)

The average bulk density and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.1. The average dry bulk density of the total area considered for the study was 1.38 Mg m^{-3}. When averaged over different panchayats the highest dry BD was observed in Thachanattukara (1.52 Mg m^{-3}) and lowest in Thachampara (1.26 Mg m^{-3}) (figure 4.1).Wet bulk density ranged from 1.25 Mg m^{-3} (Thachmpara) to 2.17 Mg m^{-3} (Thachanattukara) and dry BD from 1.06 Mg m^{-3} (Kumaramputhur) to 1.69 Mg m^{-3} (Kanjirappuzha). The results of correlation analysis showed that BD is significantly correlated with PD, porosity and MWHC.

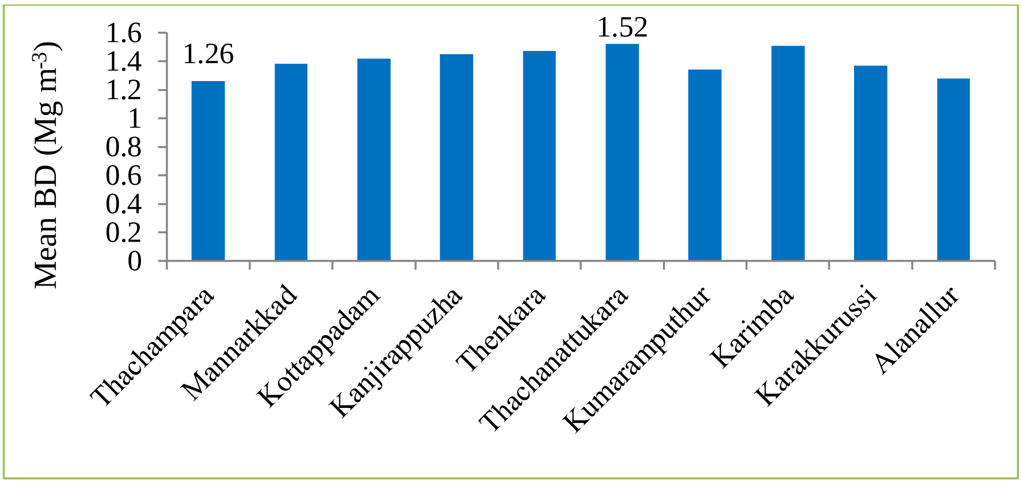


Fig. 4.1 Mean bulk density (Mg m^{-3}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Wet BD (Mg m^{-3})		Dry BD (Mg m^{-3})	
	Mean	Range	Mean	Range
Thachampara	1.43	1.25-1.74	1.26	1.10-1.49
Mannarkkad	1.58	1.31-1.96	1.38	1.17-1.60
Kottappadam	1.65	1.38-1.88	1.42	1.19-1.63
Kanjirappuzha	1.75	1.49-1.96	1.45	1.20-1.69
Thenkara	1.83	1.49-2.01	1.47	1.24-1.65
Thachanattukara	1.88	1.50-2.17	1.52	1.19-1.63
Kumaramputhur	1.64	1.48-1.87	1.34	1.06-1.50

Karimba	1.93	1.55-2.03	1.51	1.34-1.63
Karakkurussi	1.91	1.69-1.87	1.37	1.23-1.50
Alanallur	1.42	1.33-1.87	1.28	1.21-1.54

Table 4.1 Bulk density (Mg m^{-3}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.1.2 Particle density (PD)

The average particle density and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.2. The particle density of the selected area varied from 1.95 Mg m^{-3} (Alanallur) to 2.76 Mg m^{-3} (Kanjirappuzha). Average PD of the entire area was 2.513 Mg m^{-3}. When averaged over different panchayats, the highest PD was 2.38 Mg m^{-3} (Thachampara) and lowest was 2.63 Mg m^{-3} (Karimba) (figure 4.2). the results of correlation analysis indicated that PD is positively correlated with BD and negatively correlated with available Cu.

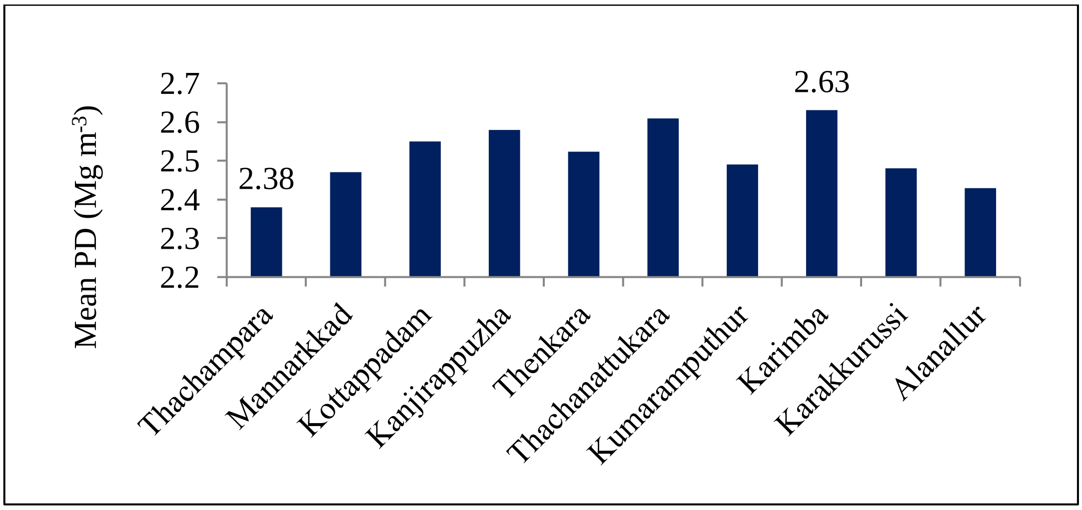


Fig. 4.2 Mean particle density (Mg m^{-3}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean (Mg m^{-3})	Range (Mg m^{-3})
Thachampara	2.38	2.23-2.61
Mannarkkad	2.47	2.26-2.67
Kottappadam	2.55	2.23-2.74
Kanjirappuzha	2.58	2.43-2.76
Thenkara	2.52	2.43-2.65
Thachanattukara	2.61	2.47-2.72
Kumaramputhur	2.49	2.38-2.68
Karimba	2.63	2.35-2.72
Karakkurussi	2.48	2.38-2.64
Alanallur	2.43	1.95-2.63

Table 4.2 Particle density (Mg m^{-3}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.1.3 Porosity

The average porosity and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.3. Porosity of the entire area ranged from 10% (Thenkara) to 59% (Thachampara). The average porosity of the study area was 44.7%. When averaged over different panchayats, lowest mean average value was recorded from Thachanattukara (42%) and highest was recorded in Alanallur and Thachampara panchayats (47%) (figure 4.3). Correlation analysis showed that porosity is significantly correlated with particle density, water holding capacity and DHA.

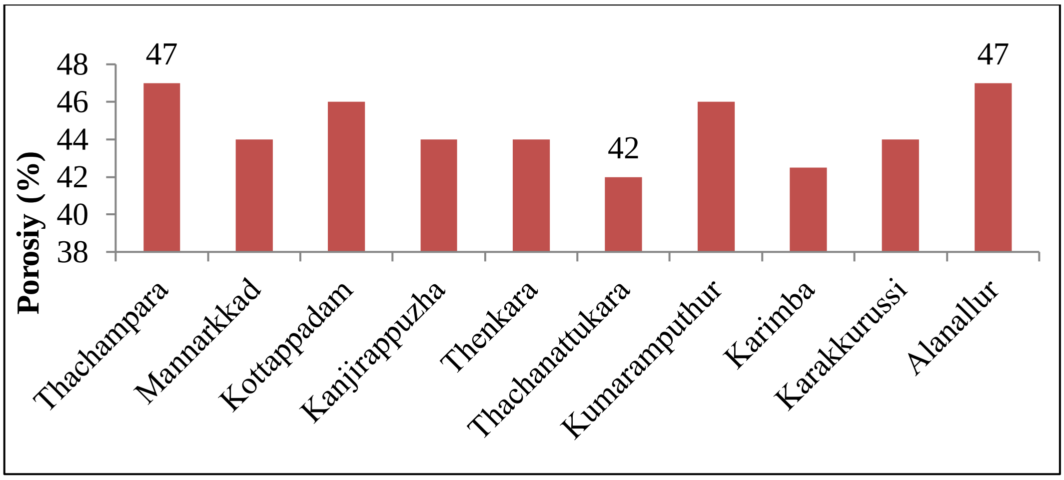


Fig.4.3 Mean porosity (%) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (%)**	**Range (%)**
Thachampara	47	39 - 59
Mannarkkad	44	32 - 51
Kottappadam	46	38 - 50
Kanjirappuzha	44	37 - 51
Thenkara	44	10 - 51
Thachanattukara	42	35 - 51
Kumaramputhur	46	42 - 52
Karimba	43	34 - 50
Karakkurussi	44	36 - 48
Alanallur	47	40 - 52

Table 4.3 Porosity in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.1.4 Maximum Water Holding Capacity (MWHC)

The average MWHC and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.4. Maximum water holding capacity of the selected area varied from 9.47% (Kumaramputhur) to 57.8% (Thenkara). The average MWHC in different panchayats ranged from 30.69% (Karimba) to 47.09% (Alanallur) (figure 4.4). The results of correlation analysis indicated that maximum water holding capacity was significantly correlated with bulk density and porosity.

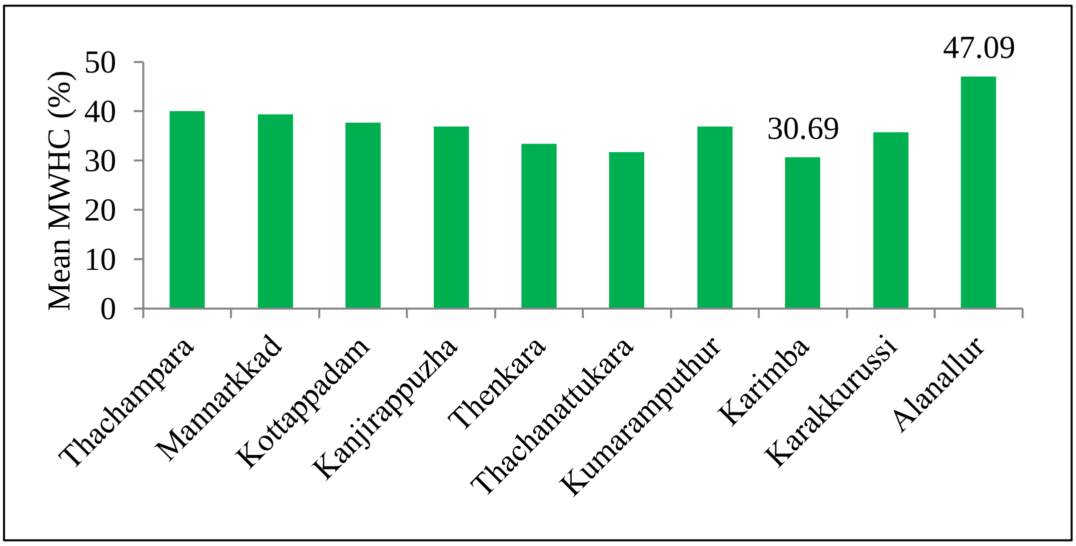


Fig.4.4 Mean MWHC (%) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean (%)	Range (%)
Thachampara	40.06	32.09-48.05
Mannarkkad	39.41	31.88-46.31
Kottappadam	37.76	30.53-46.00
Kanjirappuzha	36.98	29.26-45.54

Thenkara	33.36	18.10-57.80
Thachanattukara	31.75	11.55-53.40
Kumaramputhur	36.91	09.47-45.12
Karimba	30.69	14.61-39.01
Karakkurussi	35.78	26.00-39.94
Alanallur	47.09	31.94-55.55

Table 4.4 MWHC (%) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.1.5 Soil moisture content

Moisture content at the time of collection of soil samples were measured and the average and range of its values were depicted in table 4.5. Highest moisture content was found in the sample collected from Thenkara (43.72%) panchayat and a very low moisture content of 2.48% was observed in a soil sample from Alanallur panchayat. When averaged over different panchayats, the moisture content of the sample at the time of collection varied from 13.5 % (Thachampara) to 27.34 % (Thachanattukara) (figure 4.5). The mean values were exhibiting slight variation between panchayats. The average moisture content at the time of collection of soil samples for the whole area was 38.02%. The results of correlation analysis indicated no correlation with other soil attributes.

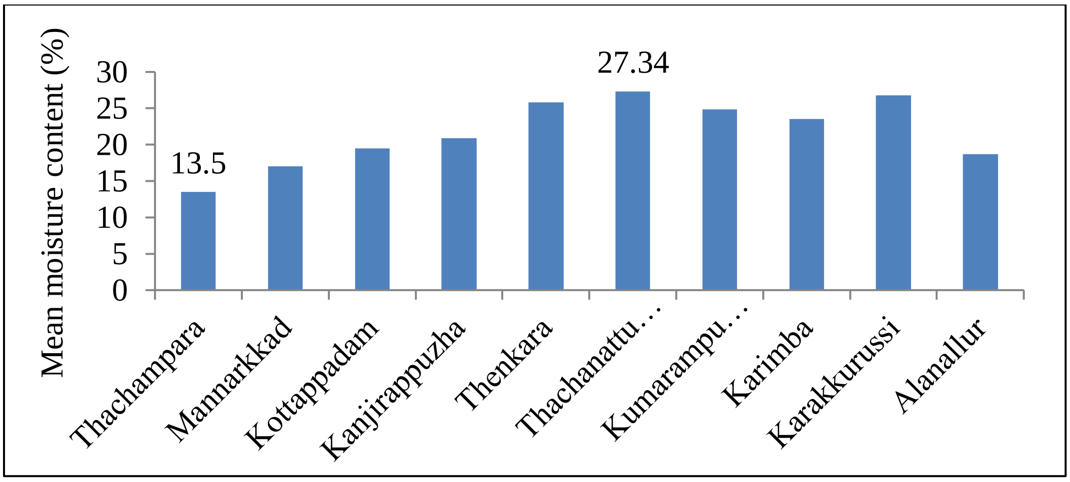


Fig. 4.5 Mean moisture content (%) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean (%)	Range (%)
Thachampara	13.50	09.23-14.97
Mannarkkad	17.03	09.29-26.45
Kottappadam	19.45	12.01-26.20
Kanjirappuzha	20.92	14.50-25.40
Thenkara	25.80	18.26-43.72
Thachanattukara	27.34	13.32-36.74
Kumaramputhur	24.86	09.45-31.37
Karimba	23.51	07.90-41.03
Karakkurussi	26.76	15.90-33.06
Alanallur	18.72	02.48-39.19

Table 4.5 Moisture content (%) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2 Soil chemical attributes

Fifteen chemical attributes were estimated for the soil samples taken from flood affected areas of AEU 13 (Mannarkkad and Sreekrishnapuram block) in Palakkad district.

4.1.2.1 Available Nitrogen

The average available N and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.6. The available nitrogen of the area varied from 81.75 to 472.5 kg ha^{-1} while the mean value of the available nitrogen in different panchayats of the area ranged from 131.1 (Karimba) to 273.5 kg ha^{-1} (Alanallur). The highest available Nitrogen was detected in Mannarkkad panchayat (472.5 kg ha^{-1}) and the lowest was observed in Karimba panchayat (81.75 kg ha^{-1}). The average available N of the entire study area was 238.2 kg ha^{-1}. The results of correlation analysis indicated that available N has a significant correlation with organic carbon. The map of available N in flood affected soils of AEU 13 in Palakkad district of Kerala (figure 4.33) was prepared using GIS technique.

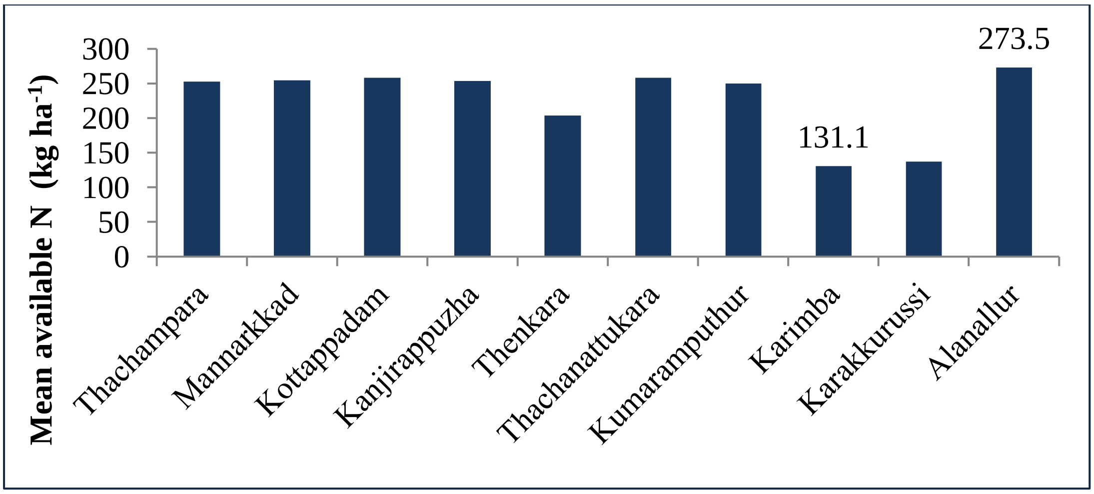


Fig.4.6 Mean available N (kg ha^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean (kg ha^{-1})	Range (kg ha^{-1})
Thachampara	252.6	155.1-457.9
Mannarkkad	254.2	94.18-472.5
Kottappadam	258.3	95.40-438.7
Kanjirappuzha	253.5	100.4-432.1
Thenkara	203.8	156.8-263.4
Thachanattukara	258.4	200.7-345.0
Kumaramputhur	249.5	144.0-344.6
Karimba	131.1	81.75-250.9
Karakkurussi	137.4	104.1-181.9
Alanallur	273.5	169.3-388.6

Table 4.6 Available N (kg ha^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.2 Available phosphorus

The average available P and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.7. The available P varied widely among the samples. The highest available P (108.9 kg ha^{-1}) was observed in the soil sample collected from Mannarkkad panchayat and the lowest available P (12.06 kg ha^{-1}) was also observed in the soil sample from the same panchayat. The mean available P varied from 34.62 kg ha^{-1} (Kumaramputhur) to 59.80 kg ha^{-1} (Kottopadam) (figure 4.7). An average of 47.42 kg ha^{-1}available P was recorded in the flooded areas of AEU 13. Amount of available P was not showed significant correlations with other soil properties. The map of available P in flood affected soils of AEU 13 in Palakkad district of Kerala (figure 4.34) was prepared using GIS technique.

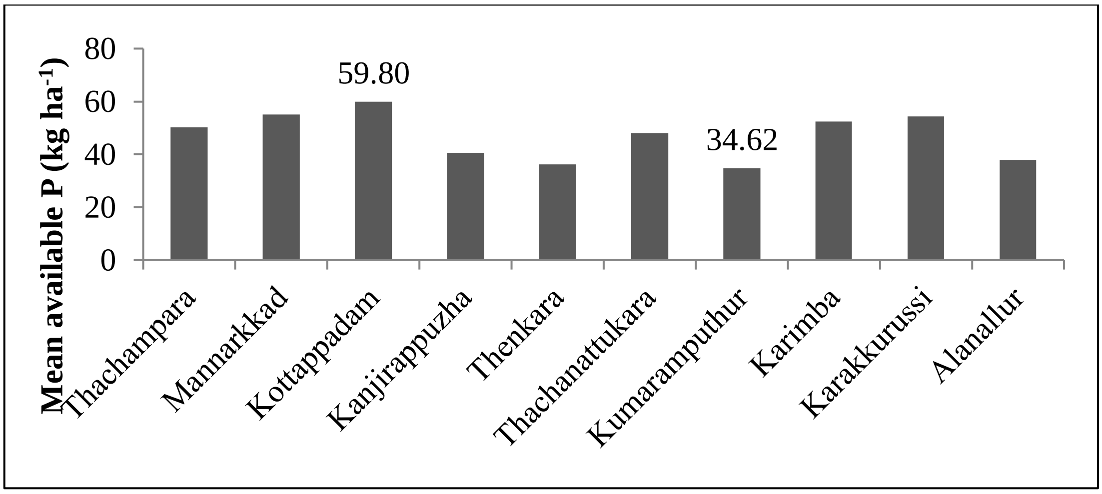


Fig. 4.7 Available P (kg ha^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (kg ha^{-1})**	**Range (kg ha^{-1})**
Thachampara	50.33	17.10-88.46
Mannarkkad	55.16	12.06-108.9
Kottappadam	59.80	23.59-95.24
Kanjirappuzha	40.57	19.06-81.46
Thenkara	36.17	18.75-63.45
Thachanattukara	48.16	21.56-68.43
Kumaramputhur	34.62	12.68-57.62
Karimba	52.35	16.49-91.05
Karakkurussi	54.39	19.96-51.20
Alanallur	37.97	16.88-78.61

Table 4.7 Available P in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.3 Available potassium

The average available K and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.8.The available potassium computed from 101 soil samples showed extensive variation. The lowest available K was observed in the sample from Thenkara (126.7 kg ha^{-1}) and highest available K was observed in the sample from Kumaramputhur (1079 kg ha^{-1}). Average amount of available K in different panchayats showed less variation from 380.1 kg ha^{-1} (Karakkurussi) to 532.9 kg ha^{-1} (Thachanattukara) (figure 4.8). The average available K of the surveyed area was 453.3 kg ha^{-1}. The results of correlation analysis of available K with other soil attributes exhibited a very significant positive correlation with available calcium, soil pH and effective cation exchange capacity and negative correlation with available Fe. The map of available K in flood affected soils of AEU 13 in Palakkad district of Kerala (figure 4.35) was prepared using GIS technique.

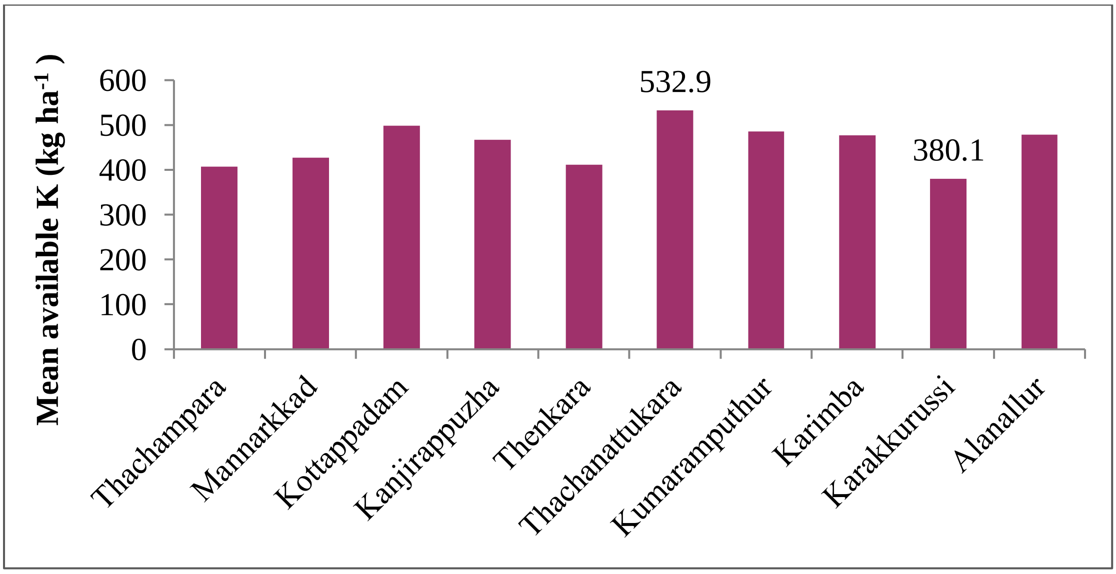


Fig.4.8 Mean available K (kg ha^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean (kg ha^{-1})	Range (kg ha^{-1})
Thachampara	385.6	134.1-848.1
Mannarkkad	427.1	151.5-911.1
Kottappadam	498.8	140.2-965.8
Kanjirappuzha	466.8	175.1-726.0
Thenkara	410.9	126.7-968.7
Thachanattukara	532.9	309.3-735.6
Kumaramputhur	485.8	171.8-1079
Karimba	477.6	210.6-878.7
Karakkurussi	380.1	251.5-575.9
Alanallur	478.5	167.1-1005

Table 4.8 Available K (kg ha^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.4 Available calcium

The average available Ca and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.9. Estimated over the entire set of data, the highest available Ca (957.4 mg kg^{-1}) was found in a soil sample from Kumaramputhur panchayat and lowest (106.1 mg kg^{-1}) in a soil sample from Mannarkkad panchayat. The mean available Ca of the selected area was 439.4 mg kg^{-1}. When averaged over different panchayats highest mean available Ca was observed in Kumaramputhur (600.1 mg kg^{-1}) and lowest in Mannarkkad (340.7 mg kg^{-1}) (figure 4.9). The results of correlation analysis indicated that available Ca was significantly correlated with soil pH, available potassium, zinc, copper and effective cation exchange capacity.

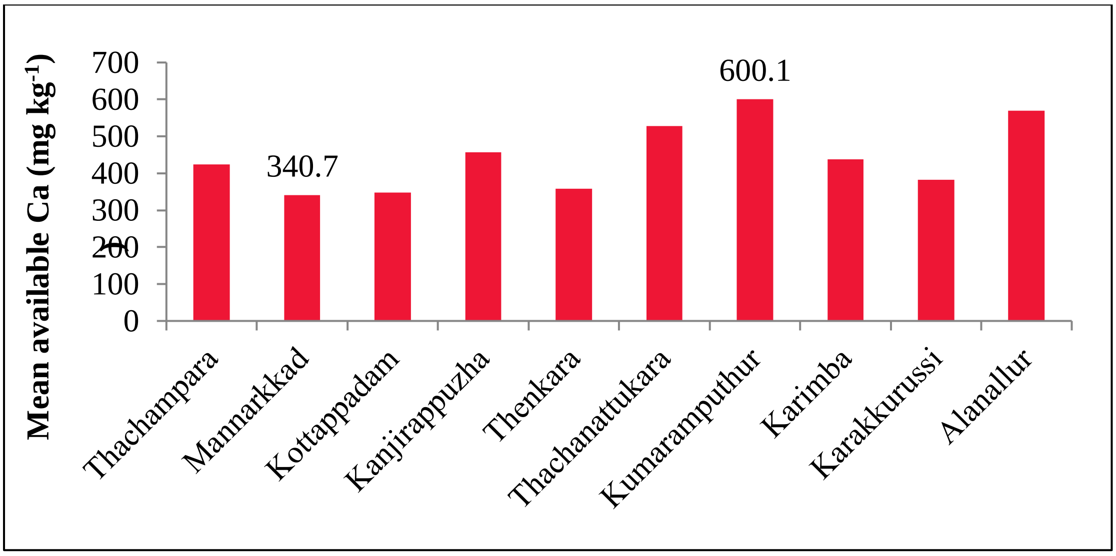


Fig.4.9 Mean available Ca (mg kg^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (mg kg^{-1})**	**Range (mg kg^{-1})**
Thachampara	423.8	293.7-520.4
Mannarkkad	340.7	106.1-659.4
Kottappadam	346.9	196.7-853.4
Kanjirappuzha	457.4	292.5-931.9
Thenkara	358.7	172.6-651.1
Thachanattukara	527.8	226.4-809.6
Kumaramputhur	600.1	299.6-957.4
Karimba	437.9	285.3-744.0
Karakkurussi	383.2	196.3-479.1
Alanallur	570.3	234.1-904.1

Table 4.9 Available Ca **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.5 Available Magnesium

The average available Mg and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.10. The average available Mg content of the soil samples of the chosen locality was 114.9 mg kg^{-1} and the values ranged from 16.62 mg kg^{-1} (Thenkara) to 360.2 mg kg^{-1} (Thachanattukara). When averaged over different panchayats the highest mean available Mg was observed in Thachanattukara panchayat (188.8 mg kg^{-1}) and the least value of mean available Mg was found in Thenkara panchayat (87.25) (figure 4.10). Available Mg content is significantly correlated with ECEC and available Ca. The map of available Mg in flood affected soils of AEU 13 in Palakkad district of Kerala (figure 4.35) was prepared using GIS technique.

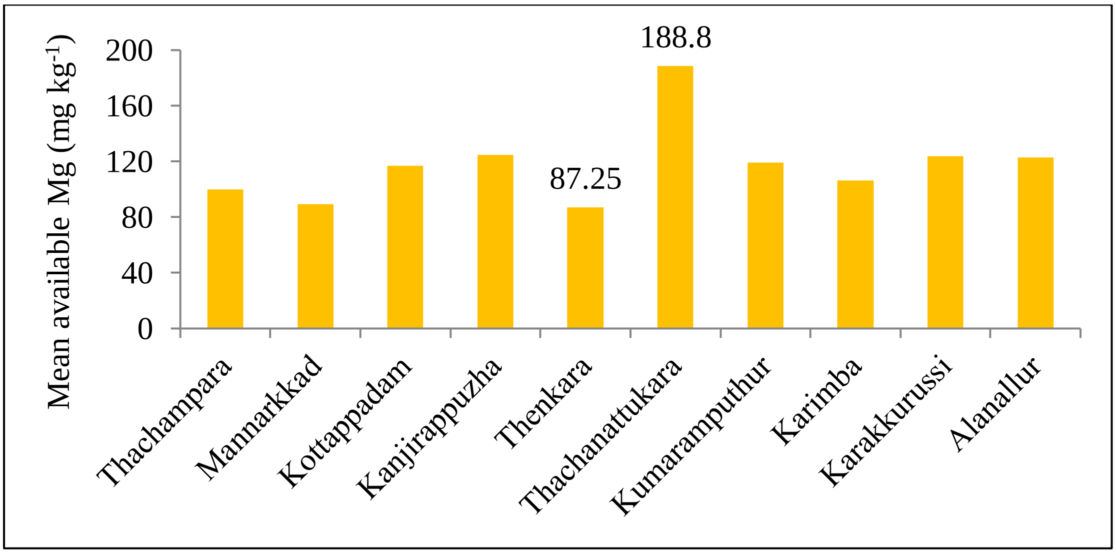


Fig. 4.10 Mean available Mg **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean (mg kg^{-1})	Range (mg kg^{-1})
Thachampara	100.1	30.39-125.9
Mannarkkad	89.28	46.14-145.1
Kottappadam	116.8	22.51-244.6
Kanjirappuzha	124.8	52.50-208.7
Thenkara	87.25	16.62-144.6
Thachanattukara	188.8	78.12-360.2
Kumaramputhur	119.3	42.85-227.9
Karimba	123.9	74.40-278.6
Karakkurussi	106.2	33.81-193.9
Alanallur	123.1	34.10-255.6

Table 4.10 Available Mg **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.6 Available Sulphur

The average available S and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.11. The available S content in the studied area varied from 11.53 mg kg^{-1} (Kanjirappuzha) to 82.10 mg kg^{-1} (Kottappadam) with a mean average value of 43.09 mg kg^{-1} for the entire area. When averaged over different panchayats, Mannarkkad had the lowest (36.12 mg kg^{-1}) and Karakkurussi had the highest (62.62 mg kg^{-1}) available S (figure 4.11). Ninety five percentage of the soil samples contained high amount of S whereas the remaining 5% had adequate S content. Available sulphur did not show a significant correlation with other soil attributes.

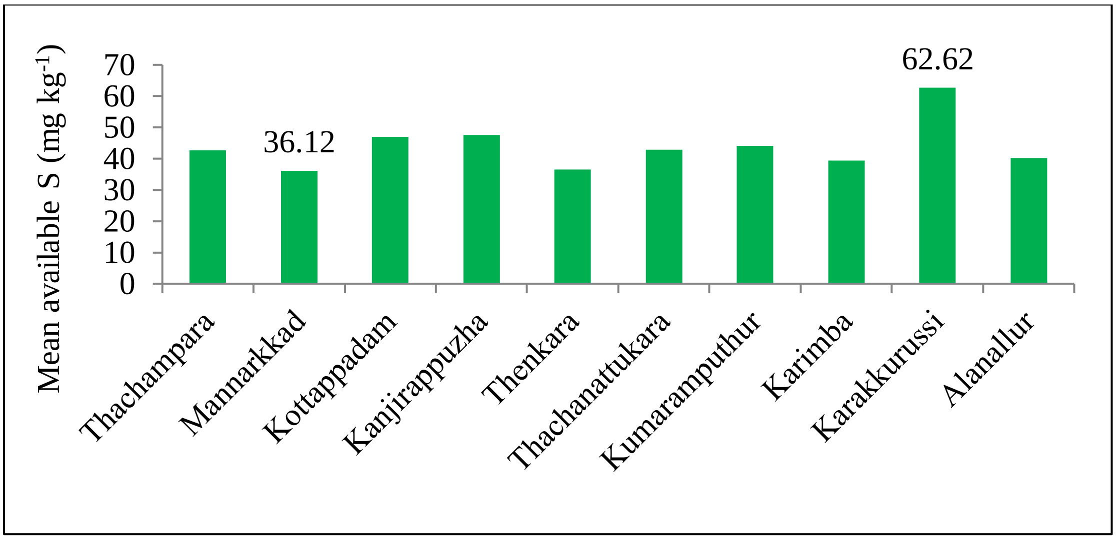


Fig. 4.11 Mean available S (mg kg^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (mg kg^{-1})**	**Range (mg kg^{-1})**
Thachampara	42.58	16.52-64.95
Mannarkkad	36.12	15.46-53.61
Kottappadam	47.02	26.10-82.10
Kanjirappuzha	47.47	11.53-62.41
Thenkara	36.45	31.45-42.60
Thachanattukara	42.77	34.61-53.48
Kumaramputhur	44.04	26.55-64.72
Karimba	39.28	24.15-68.51
Karakkurussi	62.62	58.44-67.09
Alanallur	40.11	28.95-55.83

Table 4.11 Available S **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.7 Available iron

The average available Fe and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.12. An extensive variation was observed in case of available iron content in the flood affected soils of AEU 13. It ranged from 12.95 mg kg^{-1} (Kumaramputhur) to 146.6 mg kg^{-1} (Thachampara). The mean average iron content of the area was 56.71 mg kg^{-1}. When averaged over different panchayats, Kanjirappuzha had the lowest (35.37 mg kg^{-1}) and Thachanattukara had the highest (62.62 mg kg^{-1}) available Fe (figure 4.12)

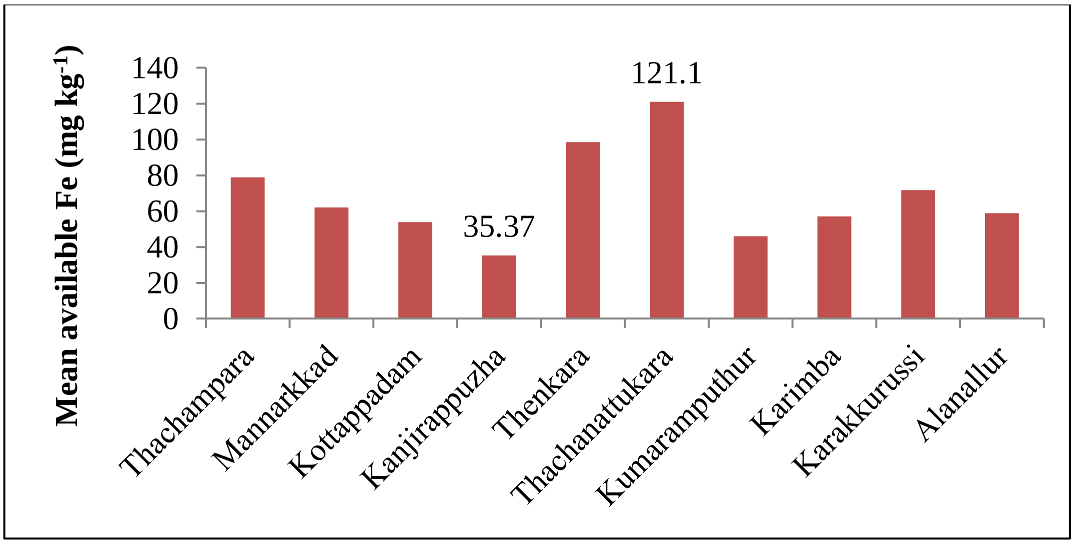


Fig. 4.12 Mean available Fe **(**mg kg^{-1}**)** in flood affected soils different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (mg kg^{-1})**	**Range (mg kg^{-1})**
Thachampara	78.78	33.55-146.5
Mannarkkad	61.88	17.20-125.6
Kottappadam	53.92	15.52-105.2

Kanjirappuzha	35.37	14.65-57.50
Thenkara	98.50	48.44-116.6
Thachanattukara	121.1	39.81-129.1
Kumaramputhur	45.86	12.95-81.57
Karimba	56.85	30.00-102.3
Karakkurussi	71.49	62.80-104.9
Alanallur	58.73	20.19-110.2

Table 4.12 Available Fe **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.8 Available manganese

The average available Mn and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.13. Available Mn in the soil samples of the study area varied from 8.35 mg kg^{-1} (Thachampara) to 187.8 mg kg^{-1} (Karimba) with a mean value of 58.14 mg kg^{-1}. When averaged over different panchayats, Thenkara (28.04 mg kg^{-1}) and Karakkurussi (103.7 mg kg^{-1}) had lowest and highest mean available Mn respectively (table 4.13 and figure 4.13). The results of correlation analysis showed that available manganese has high correlation with ECEC.

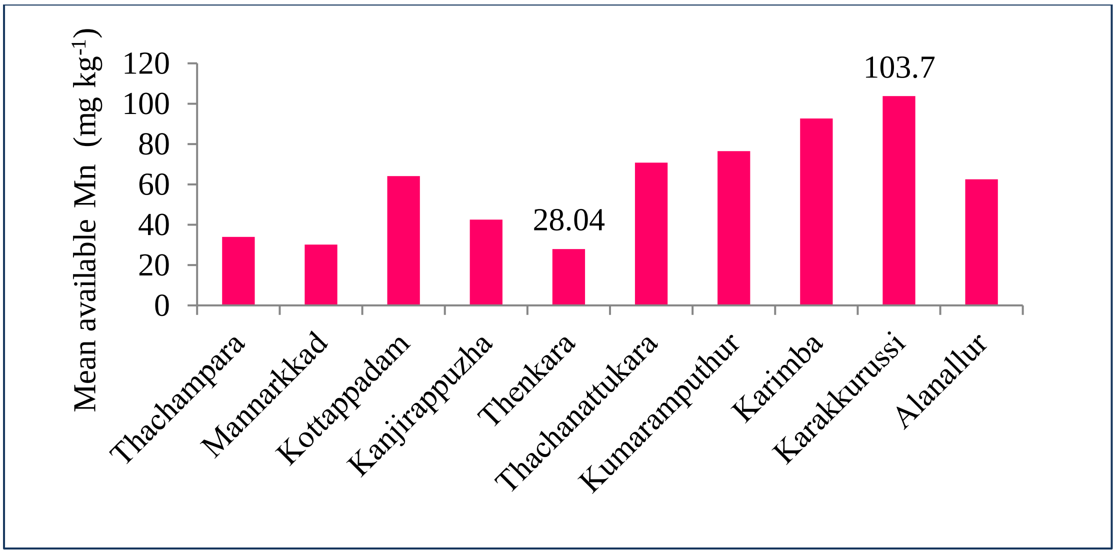


Fig.4.13 Mean available Mn (mg kg^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (mg kg^{-1})**	**Range (mg kg^{-1})**
Thachampara	33.84	08.35-76.03
Mannarkkad	30.11	12.85-52.24
Kottappadam	64.13	10.49-147.8
Kanjirappuzha	42.43	18.09-96.35
Thenkara	28.04	15.67-46.29
Thachanattukara	70.81	46.31-115.9
Kumaramputhur	76.60	18.93-120.5
Karimba	92.62	17.47-187.8
Karakkurussi	103.7	65.70-136.9
Alanallur	62.67	19.08-122.5

Table 4.13 Available Mn **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.9 Available copper

The average available Cu and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.14. The available Cu was adequate in all soil samples. The average available Cu content of the flood affected area was 3.993 mg kg^{-1}. Cu content ranged from 1.31 mg kg^{-1} (Mannarkkad) to 8.41 mg kg^{-1} (Mannarkkad) among the samples. When averaged over the ten panchayats, Kanjirappuzha (2.94 mg kg^{-1}) had lowest and Thachanattukara (5.93 mg kg^{-1}) had highest available Cu (figure 4.14). Correlation analysis indicated that the parameter is significantly correlated with particle density, dehydrogenase activity and ECEC.

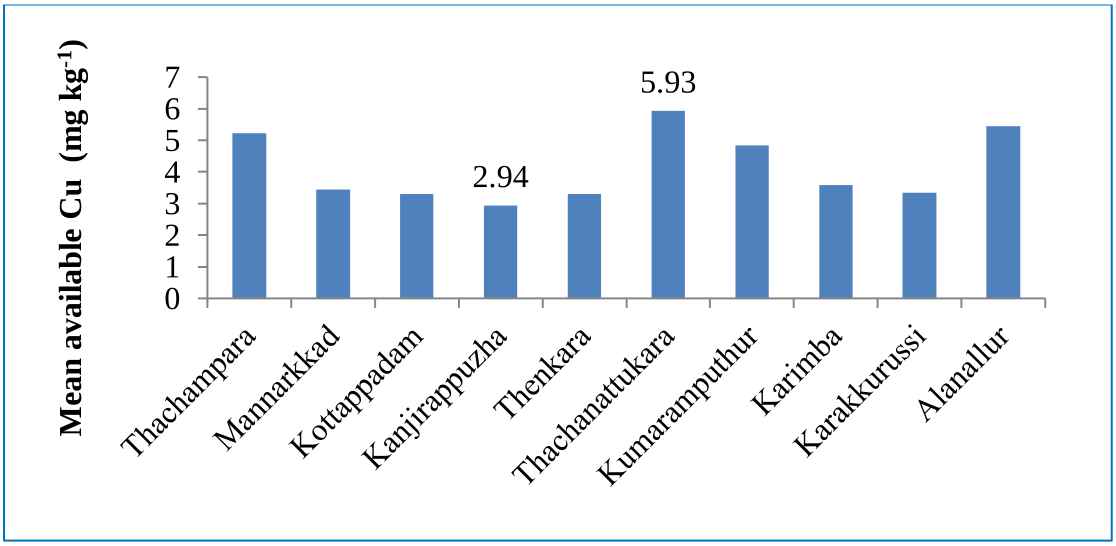


Fig. 4.14 Mean available Cu **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (mg kg^{-1})**	**Range (mg kg^{-1})**
Thachampara	5.22	2.47-7.28
Mannarkkad	3.44	1.31-8.41

Kottappadam	3.30	1.52-4.30
Kanjirappuzha	2.94	1.50-4.40
Thenkara	3.30	2.51-3.91
Thachanattukara	5.93	5.05-7.86
Kumaramputhur	4.83	2.28-6.55
Karimba	3.58	2.23-5.31
Karakkurussi	3.35	2.64-4.71
Alanallur	5.44	3.45-8.15

Table 4.14 Available Cu (mg kg^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.10 Available zinc

The average available Zn and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.15. The available Zn was recorded over the entire study area ranged between 1.4 mg kg^{-1} (Karimba) to 38.9 mg kg^{-1} (Kumaramputhur) with an average of 5.015 mg kg^{-1}. When averaged over the ten panchayats, Karakkuurussi (2.72 mg kg^{-1}) had lowest and Kumaramputhur (9.53 mg kg^{-1}) had highest available Zn (figure 4.15). The results of correlation analysis indicated that available zinc has significant correlation with available Ca and ECEC.

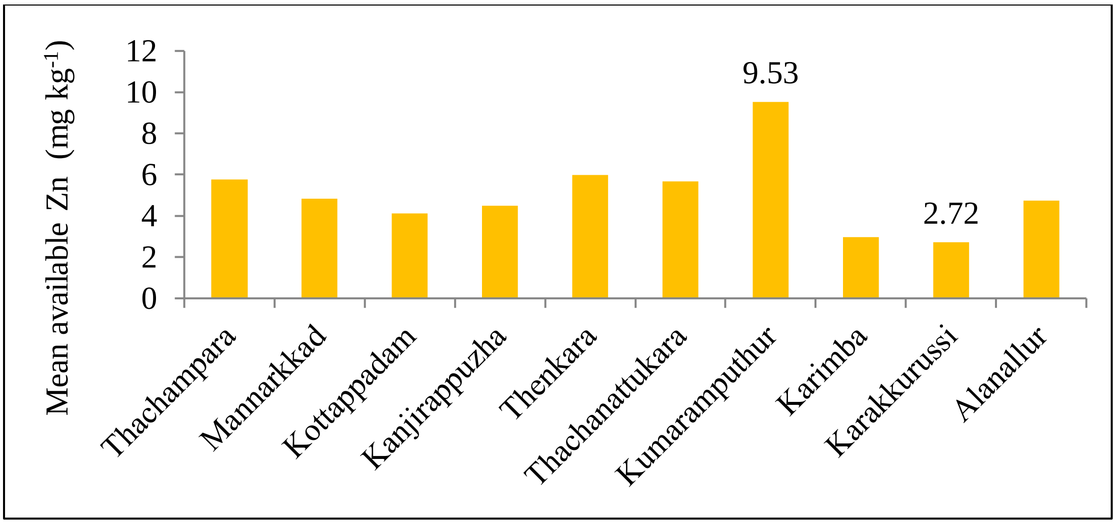


Fig.4.15 Mean available Zn **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (mg kg^{-1})**	**Range (mg kg^{-1})**
Thachampara	5.77	2.78-6.55
Mannarkkad	4.82	2.65-10.5
Kottappadam	4.12	1.80-9.19
Kanjirappuzha	4.48	2.23-12.2
Thenkara	5.98	3.78-7.57
Thachanattukara	5.68	2.75-8.76
Kumaramputhur	9.53	2.72-38.9
Karimba	2.98	1.40-4.95
Karakkurussi	2.72	1.60-3.19
Alanallur	4.74	1.79-9.01

Table 4.15 Available Zn **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.11 Available boron

The average available B and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.16. Available B measured in the soil samples varied from 0.08 mg kg^{-1} (Karakkurussi) to 0.92 mg kg^{-1} (Mannarkkad) with an average value of 0.227 mg kg^{-1} for the entire area. The average available B for different panchayats indicated higher mean value in Mannarkkad (0.31 mg kg^{-1}) and lower value in Alanallur (0.17 mg kg^{-1}) (figure 4.16). Available B was not significantly correlated with other tested soil attributes.

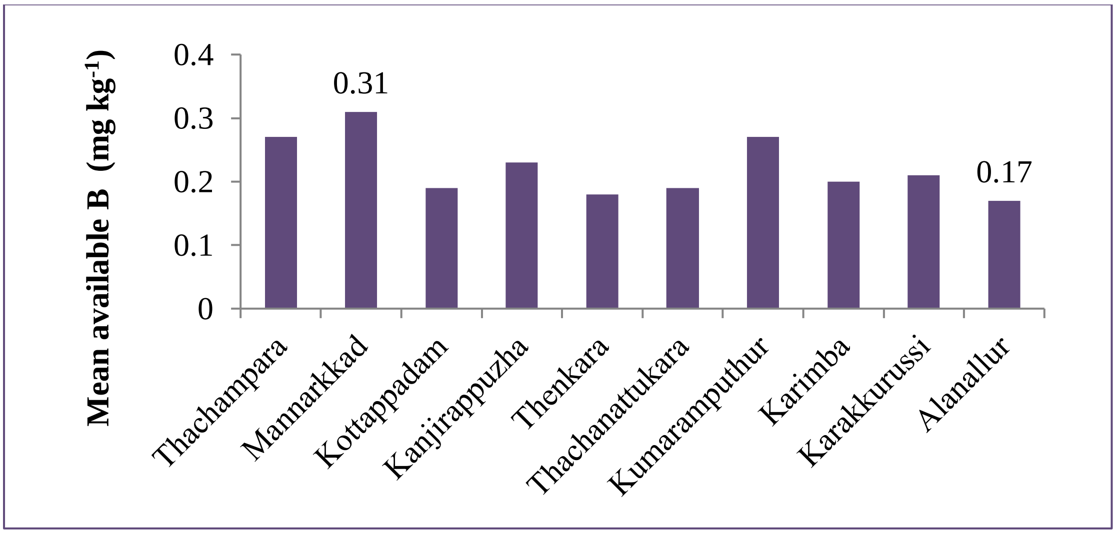


Fig. 4.16 Mean available B **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean (mg kg^{-1})	Range (mg kg^{-1})
Thachampara	0.27	0.21-0.37
Mannarkkad	0.31	0.17-0.92
Kottappadam	0.19	0.09-0.31

Kanjirappuzha	0.23	0.13-0.32
Thenkara	0.18	0.11-0.29
Thachanattukara	0.19	0.13-0.28
Kumaramputhur	0.27	0.14-0.31
Karimba	0.20	0.11-0.25
Karakkurussi	0.21	0.08-0.30
Alanallur	0.17	0.10-0.30

Table 4.16 Available B **(**mg kg^{-1}**)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.12 Soil reaction (pH)

The average soil pH and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.17. All samples were acidic in reaction and the pH ranged from 3.86 (Alanallur) to 6.77 (Mannarkkad). The average pH observed in the whole area was 5.26. The mean value of soil pH of different panchayats varied from 4.99 (Karakkurussi) to 5.48 (Kanjirappuzha) (figure 4.17). Available Ca, K, Mg and exchangeable acidity were very well correlated with soil pH. The map of soil pH in flood affected soils of AEU 13 in Palakkad district of Kerala (figure 4.37) was prepared using GIS technique.

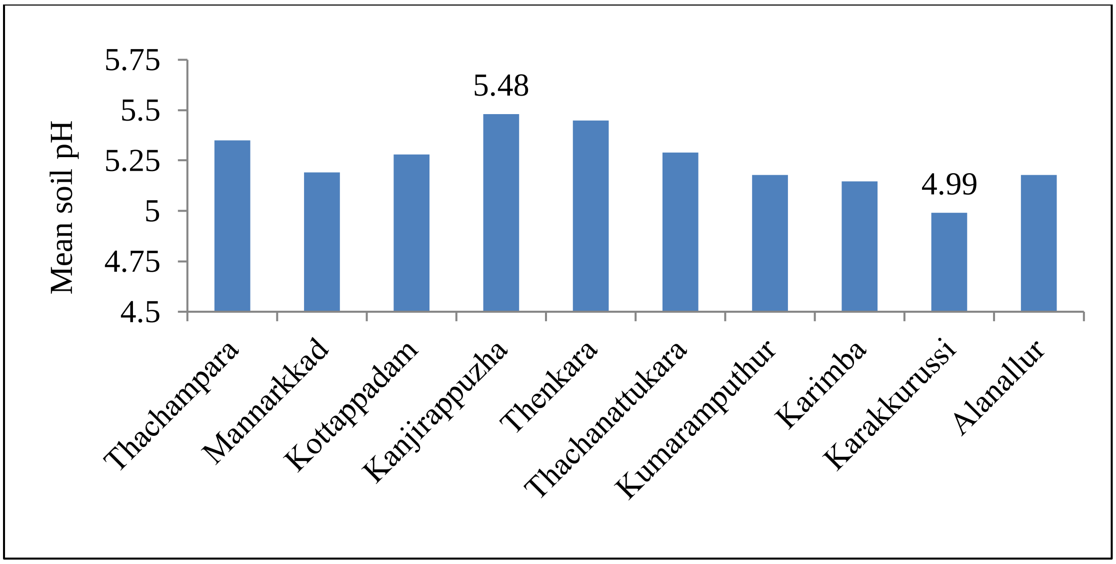


Fig. 4.17 Mean soil pH in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean**	**Range**
Thachampara	5.35	4.68-5.73
Mannarkkad	5.19	4.18-6.77
Kottappadam	5.28	4.62-6.08
Kanjirappuzha	5.48	4.67-6.18
Thenkara	5.45	4.89-6.36
Thachanattukara	5.29	4.31-6.34
Kumaramputhur	5.18	4.25-6.20
Karimba	5.15	4.08-6.24
Karakkurussi	4.99	4.35-6.07
Alanallur	5.18	3.86-5.94

Table 4.17 Soil pH in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.13 Electrical conductivity (EC)

The average EC and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.18. All soil samples collected from the study area showed very low EC values with a mean EC of 0.077 dS m^{-1}. The highest EC (0.301 dS m^{-1}) was found in soil sample from Thenkara and lowest (0.010 dS m^{-1}) from Kottapadam (figure 4.18). Highest average EC recorded in Thenkara (0.168 dS m^{-1}) and lowest in Kottapadam (0.041 dS m^{-1}).

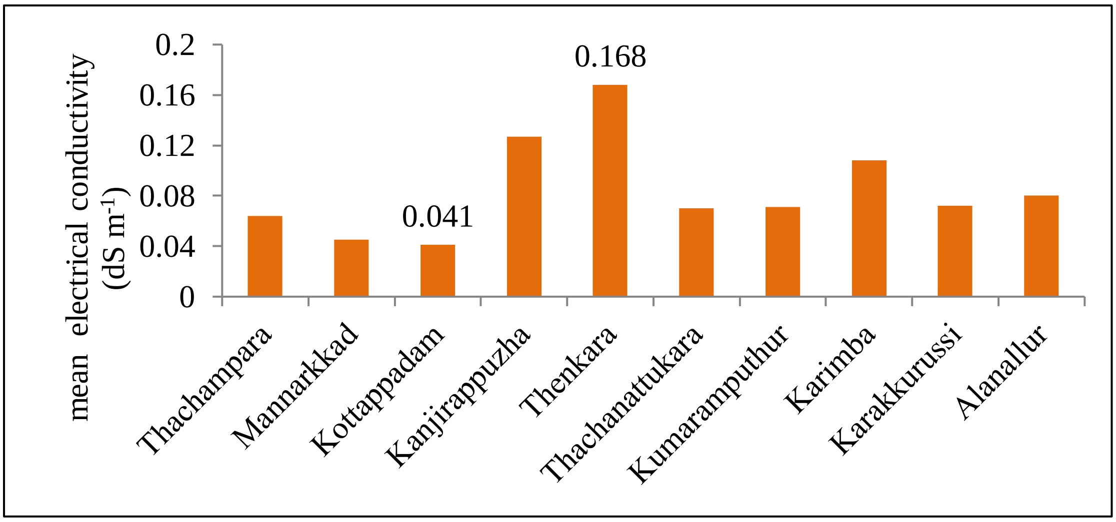


Fig. 4.18 Mean electrical conductivity (dS m^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean (dS m^{-1})	Range (dS m^{-1})
Thachampara	0.064	0.035-0.140
Mannarkkad	0.045	0.023-0.120
Kottappadam	0.041	0.010-0.078
Kanjirappuzha	0.127	0.051-0.189

Thenkara	0.168	0.117-0.301
Thachanattukara	0.070	0.056-0.090
Kumaramputhur	0.071	0.037-0.135
Karimba	0.108	0.039-0.195
Karakkurussi	0.072	0.062-0.088
Alanallur	0.080	0.043-0.131

Table 4.18 Electrical conductivity (dS m^{-1}) in flood affected soils of different panchayats in AEU 13 Palakkad district of Kerala

4.1.2.14 Exchangeable acidity (EA)

The average EA and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.19. The exchangeable acidity of the soil samples varied from 0.016 cmol kg^{-1} to 0.660 cmol kg^{-1}. Exchangeable acidity was high in Mannarkkad panchayat with an average of 0.221 cmol kg^{-1} and low in Kanjirappuzha with an average of 0.088 cmol kg^{-1} (figure 4.19). The mean exchangeable acidity of the area is 0.154 cmol kg^{-1}. The results of correlation analysis showed a high correlation between exchangeable acidity and soil reaction (pH).

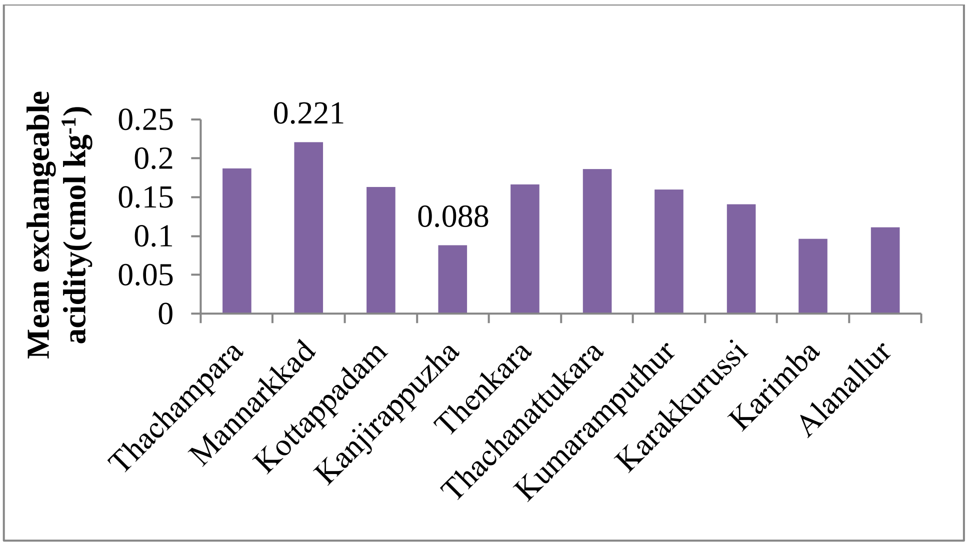


Fig. 4.19 Mean exchangeable acidity (cmol kg^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (cmol kg^{-1})**	**Range (cmol kg^{-1})**
Thachampara	0.187	0.016-0.330
Mannarkkad	0.221	0.016-0.660
Kottappadam	0.163	0.016-0.467
Kanjirappuzha	0.088	0.016-0.166
Thenkara	0.166	0.033-0.366
Thachanattukara	0.186	0.033-0.330
Kumaramputhur	0.160	0.050-0.330
Karakkurussi	0.141	0.033-0.300
Karimba	0.096	0.017-0.133
Alanallur	0.111	0.016-0.330

Table 4.19 Exchangeable acidity (cmol kg^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.2.15 Effective Cation Exchange Capacity (ECEC)

The average ECEC and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.20. An average ECEC of 8.365 cmol kg^{-1} found in the study area. When averaged over different panchayats, mean value ranged from 6.97 cmol kg^{-1} (Thenkara) to 9.78 cmol kg^{-1} (Alanallur) (figure 4.20). The ECEC observed in the entire area ranged from 5.65 cmol kg^{-1} (Thenkara) to 14.09 cmol kg^{-1} (Alanallur). ECEC was significantly correlated with a number of other attributes like available K, Ca, Mg, Mn and Zn. It also showed a medium correlation with available Cu.

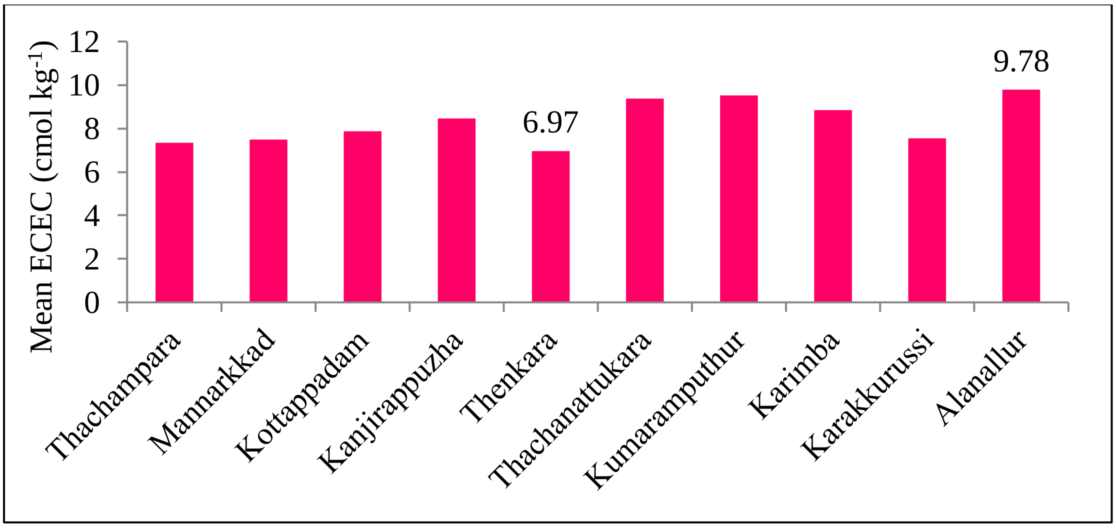


Fig. 4.20 Mean ECEC (cmol kg^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (cmol kg^{-1})**	**Range (cmol kg^{-1})**
Thachampara	7.34	5.70-9.02
Mannarkkad	7.50	5.76-9.51
Kottappadam	7.87	5.93-10.7

Kanjirappuzha	8.47	6.55-11.3
Thenkara	6.97	5.65-9.43
Thachanattukara	9.37	6.98-10.5
Kumaramputhur	9.52	6.82-10.8
Karimba	8.85	5.87-10.4
Karakkurussi	7.55	6.53-8.56
Alanallur	9.78	7.94-14.1

Table 4.20 ECEC (cmol kg^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.3 Soil biological attributes

Two foremost important biological attributes, organic carbon (OC) content and dehydrogenase enzyme activity (DHA) were computed by analyzing the 101 samples taken randomly from the flood affected areas of AEU 13 in Palakkad district of Kerala.

4.1.3.1 Organic carbon (OC)

The average OC and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.21. The average organic carbon of the soil samples collected from the area was 0.859%, which came under the medium category. Organic carbon in the soil samples ranged from 0.35% (Kanjirappuzha) to 1.78% (Kottappadam). The average values of different panchayats varied from 0.51% (Karimba) to 1.12% (Kottappadam) (figure 4.21). The results of correlation analysis indicated that the OC has a positive correlation with available N.

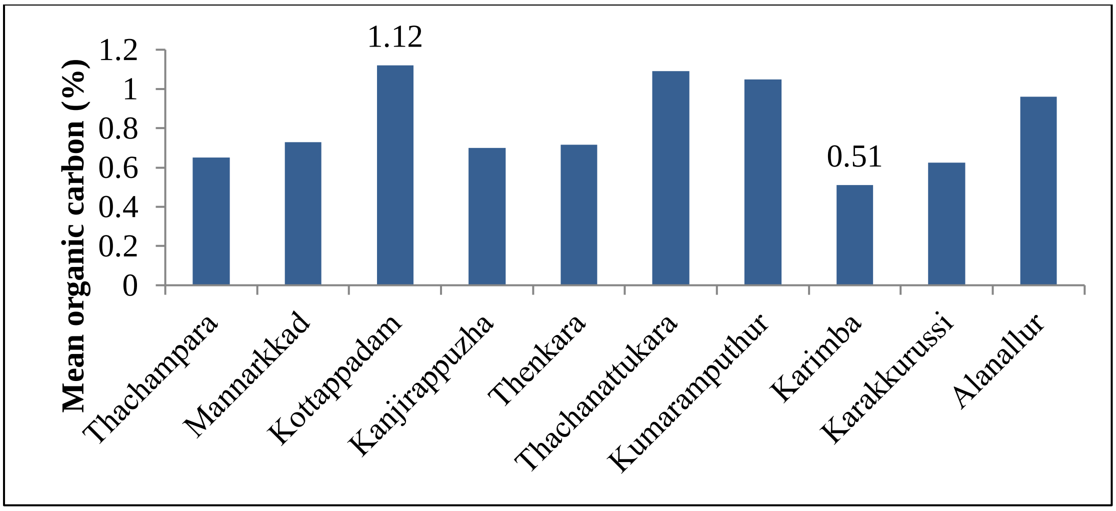


Fig. 4.21 Mean OC (%) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean (%)	Range (%)
Thachampara	0.65	0.42-0.83
Mannarkkad	0.73	0.38-1.24
Kottappadam	1.12	0.39-1.78
Kanjirappuzha	0.70	0.35-1.45
Thenkara	0.72	0.54-0.81
Thachanattukara	1.09	0.86-1.23
Kumaramputhur	1.05	0.84-1.30
Karimba	0.51	0.57-1.18
Karakkurussi	0.63	0.36-1.35
Alanallur	0.96	0.57-1.65

Table 4.21 Organic C (%) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

4.1.3.2 Dehydrogenase activity (DHA)

The average DHA and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.22. The mean dehydrogenase activity of the selected location was 129.0 µg TPF g soil^{-1}day^{-1}. Both the highest and lowest values of dehydrogenase activity were found in soil samples from Mannarkkad panchayat (462.6 µg TPF g soil^{-1}day^{-1} and 14.3 µg TPF g soil^{-1}day^{-1}). When averaged over panchayats, the highest DHA value was obtained from Thachanattukara (238.9 µg TPF g soil^{-1}day^{-1}) and lowest from Thenkara (91.81 µg TPF g soil^{-1}day^{-1}) (figure 4.22). The results of correlation analysis showed a strong correlation between DHA and available Cu.

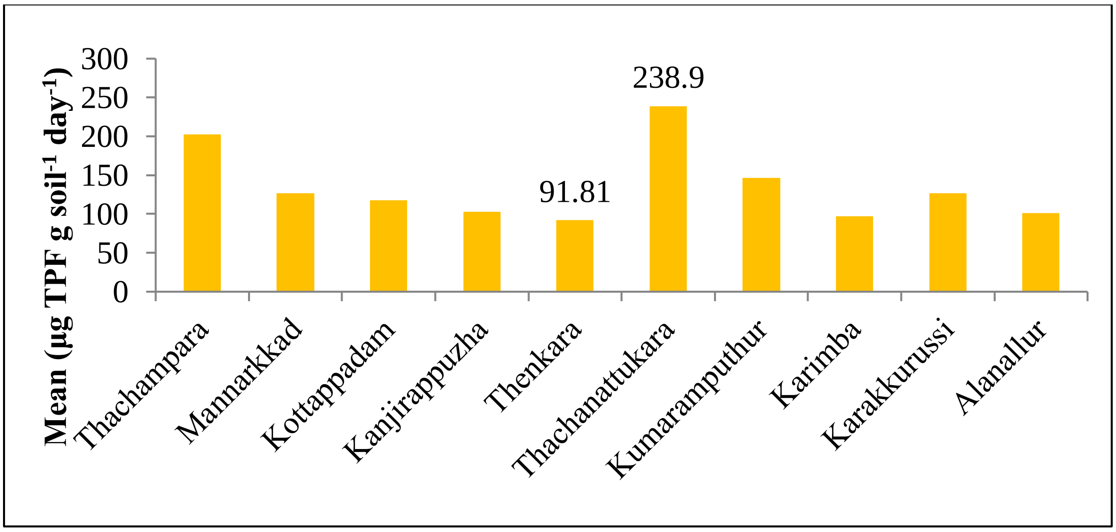


Fig. 4.22 Mean DHA (µg TPF g soil^{-1}day^{-1}) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	**Mean (µg TPF g soil^{-1}day^{-1})**	**Range (µg TPF g soil^{-1}day^{-1})**
Thachampara	202.7	59.50-437.1
Mannarkkad	126.6	14.30-462.6
Kottappadam	118.1	15.63-279.7

Kanjirappuzha	103.1	28.91-297.0
Thenkara	91.81	21.34-148.0
Thachanattukara	238.9	54.73-356.9
Kumaramputhur	146.9	67.12-261.5
Karimba	97.04	45.78-163.8
Karakkurussi	126.4	53.70-203.4
Alanallur	101.4	28.23-161.7

Table 4.22 DHA (µg TPF g $soil^{-1}hour^{-1}$) in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

	No. of samples	**Mean**	**Standard deviation**	**Standard error**
BD (Mg m^{-3})	101	1.390	0.147	0.124
PD (Mg m^{-3})	101	2.510	0.159	0.100
Porosity	101	0.450	0.054	0.080
MC (%)	101	19.79	7.552	1.697
MWHC (%)	101	38.02	8.779	1.424
pH	101	5.360	0.600	0.259
EC (dS m^{-1})	101	0.074	0.037	0.135
Available N (kg ha^{-1})	101	238.2	91.11	5.903
Available P (kg ha^{-1})	101	47.02	23.21	3.385

Available K (kg ha^{-1})	101	459.3	229.7	10.72
Available Ca (mg kg^{-1})	101	439.4	196.4	9.369
Available Mg (mg kg^{-1})	101	114.9	61.84	5.770
Available S (mg kg^{-1})	101	43.10	13.90	2.117
Available Fe (mg kg^{-1})	101	59.71	33.82	4.377
Available Mn (mg kg^{-1})	101	58.14	39.01	5.117
Available Zn (mg kg^{-1})	101	5.015	4.191	1.872
Available Cu (mg kg^{-1})	101	3.993	1.620	0.811
Available B (mg kg^{-1})	101	0.227	0.103	0.215
OC (%)	101	0.860	0.365	0.394
DHA (µg TPF g $soil^{-1}$ day^{-1})	101	129.0	92.30	8.126
ECEC (cmol kg^{-1})	101	8.365	1.550	0.536
EA (cmol kg^{-1})	101	0.152	0.144	0.368

Table 4.23 Descriptive statistics of the entire data

4.2 Soil attributes in flooded and landslide affected area

Among the 101 samples collected from different panchayats of AEU 13 in Palakkad district of Kerala, 87 were affected by overflow of rivers and 14 were landslide affected areas (samples from Kottapadam, Kanjirappuzha and Karimba panchayats). The table 4.24 shows the mean value of soil attributes of the samples from flood affected areas and landslide affected areas separately.

Soil attribute	Mean	
	Flood affected	Land slide affected
BD (Mg m^{-3})	01.36	01.53
PD (Mg m^{-3})	02.49	02.62
Porosity	0.450	0.420
MC (%)	19.39	22.27
MWHC (%)	38.82	33.03
pH	05.34	05.49
EC (dS m^{-1})	0.074	0.070
Available N (kg ha^{-1})	251.2	157.4
Available P (kg ha^{-1})	47.09	46.55
Available K (kg ha^{-1})	453.3	496.9
Available Ca (mg kg^{-1})	444.8	405.9
Available Mg (mg kg^{-1})	117.1	100.7
Available S (mg kg^{-1})	40.97	56.36
Available Fe (mg kg^{-1})	58.91	64.65
Available Mn (mg kg^{-1})	53.36	87.81
Available Zn (mg kg^{-1})	05.32	03.11
Available Cu (mg kg^{-1})	04.16	02.92
Available B (mg kg^{-1})	0.224	0.240
OC (%)	0.910	0.490

DHA (µg TPF g soil^{-1}day^{-1})	123.4	139.2
ECEC (cmol kg^{-1})	8.392	8.190
EA (cmol kg^{-1})	0.160	0.104

Table 4.24 Mean soil attributes of flood affected and land slide affected soils

Considering the table 4.24, there were some appreciable changes in the average of soil attributes between flood affected and landslide affected soils. In case of physical properties, BD and PD were higher in landslide affected soils while water holding capacity was higher in flood affected soils. Organic carbon content and available N were high in flood affected soils (0.91% and 251.2 kg ha^{-1}) compared to landslide affected soils (0.49% and 157.4 kg ha^{-1}). Available Ca, Mg, Zn and Cu also were more in flooded soils than land slide affected soils. Available S, Fe and Mn were higher in landslide affected soils.

4.3 Formulation of mean data set

Principal component analysis (PCA) was the statistical tool used to develop mean data set for soil quality assessment. For this 22 soil attributes of 101 samples were considered and statistically analyzed. The attributes were bulk density, particle density, porosity, maximum water holding capacity, soil moisture content, organic tcarbon content(OC), dehydrogenase activity, available N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, pH, EC, exchangeable acidity and effective cation exchange capacity.

The PCA analysis carried over the measured set of parameters resulted in seven PCs with Eigen value more than one and percentage variance of 15% to 5.3% with a cumulative percentage of 62.3% (Table 4.25). From these PCs highly weighed variables were selected as MDS. The highly weighed variables were chosen by following the suggestions of Andrew *et al.* (2002). So the attribute with highest factor loading and an attribute having factor loading within ten percentage of highest factor loading based on the absolute value of factor loading were selected using table 4.26.

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigen values	3.304	2.715	1.857	1.730	1.636	1.291	1.176
Proportion of Variance	0.150	0.123	0.084	0.079	0.074	0.059	0.053
Cumulative Proportion	0.150	0.274	0.358	0.437	0.511	0.570	0.623

Table 4.25 Principle component groups resulted from the PCA of the 22 attributes of the entire soil samples collected from the study area

	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
BD	0.22	**-0.459**	0.231	-0.046	0.141	-0.054	0.175
PD	0.163	-0.136	**0.454**	0.066	-0.102	-0.195	-0.065
Porosity	-0.121	**0.431**	0.073	0.099	-0.24	-0.07	-0.263
MC	-0.024	-0.175	0.084	-0.267	-0.108	-0.16	-0.318
WHC	-0.244	0.372	-0.069	0.075	-0.16	0.027	-0.098
OC	-0.214	0.184	0.362	-0.188	0.359	-0.161	0.093
Ph	-0.315	-0.204	0.006	**0.428**	-0.082	0.098	-0.113
EC	-0.101	-0.176	-0.296	0.021	-0.186	-0.138	0.414
Available N	-0.238	0.223	0.271	0.001	**0.432**	-0.079	0.064
Available P	0.072	0	0.017	0.172	0.328	0.233	0.04
Available K	-0.296	-0.088	0.228	-0.101	-0.106	0.253	0.048
Available Ca	**-0.451**	-0.189	-0.069	0.089	-0.071	0.042	-0.041
Available Mg	-0.304	-0.212	0.156	0.077	0.094	-0.296	-0.135
Available S	0.043	-0.178	0.074	-0.073	-0.017	0.353	**-0.413**
Available Fe	0.108	-0.128	-0.293	-0.043	0.068	-0.266	-0.315
Available Mn	-0.059	-0.093	0.183	-0.38	-0.327	0.281	-0.13
Available Zn	-0.179	-0.048	-0.191	-0.122	0.14	**0.387**	0.313
Available Cu	-0.177	0.008	-0.373	-0.187	0.212	-0.226	-0.174
Available B	0.113	0.042	0	0.252	0.228	**0.412**	-0.219

DHA	-0.071	-0.205	-0.206	-0.057	0.379	0.047	-0.31
ECEC	-0.339	-0.124	-0.017	-0.381	-0.025	0.045	0.07
EA	0.191	0.23	-0.081	**-0.41**	0.113	0.107	-0.014

Table 4.26 Eigen vectors of correlation matrix for the attributes

In the first PC group available Ca was the highly weighed variable with a loading of -0.451; hence available Ca was selected for MDS from the first PC. Similarly in the second PC, BD and porosity had high factor loading values but they were significantly correlated, so BD, with factor loading more than porosity is taken to MDS. Highest weighed variable of PC3, PC4, and PC5 were PD, pH and available N respectively. From PC6 both available B and available Zn were selected because they did not have a significant correlation. But in case of PC7 both EC and available S had high weightage as well as low correlation, only available S was taken for MDS because EC was not a limiting factor of soil quality in the study area. Finally 8 attributes were regarded as minimum data set (MDS) and taken for further analysis (table 4. 27).

PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
Available Ca	BD	PD	Soil P^H	Available N	Available B	Available S
					Available Zn	

Table 4.27 Minimum data set (MDS) developed for the study area over the measured range of different attributes

4.4 Scoring of MDS parameters

The selected eight MDS parameters were grouped in to three categories based on their influence on soil fertility and the current status in the soil. The three categories were more is better, less is better and optimum is better. The scoring has been done to each parameter based on the category to which it belongs.

4.4.1 More is better function

Scoring of available N, available B and available Ca was done based on 'more is better' function. These three parameters were estimated low to medium in the samples but a higher value was desirable for good quality. So the function was chosen and scores were given in 0 to 1 range. In case of available N, 0.85 was the highest score obtained for a sample with 472.5 kg ha^{-1} available N content and the lowest score was 0.065 for a sample with 81.75 kg ha^{-1} available N (figure 4.23). Available B scores ranged from 0.085 to 0.971 for 0.08 to 0.92 mg kg^{-1} available B (figure 4.24). The range of scores obtained for available Ca was 0.028 (106.1 mg kg^{-1}) to 0.875 (957.4 mg kg^{-1}) (figure 4.25). Among them available Ca from first PC group with high weightage will contribute more to SQI.

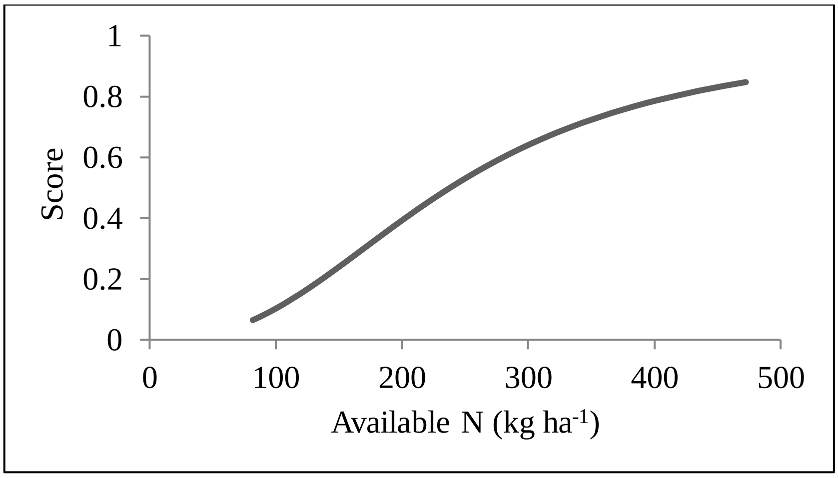


Fig.4.23 Score curve for available N

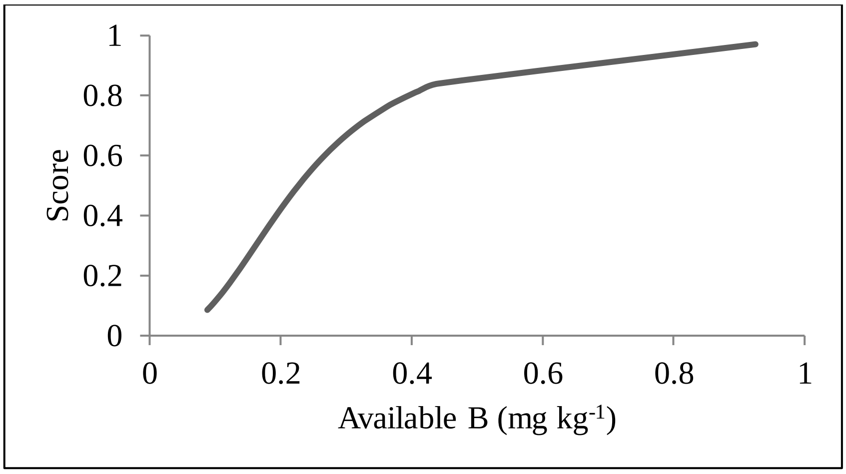


Fig.4.24 Score curve for available B

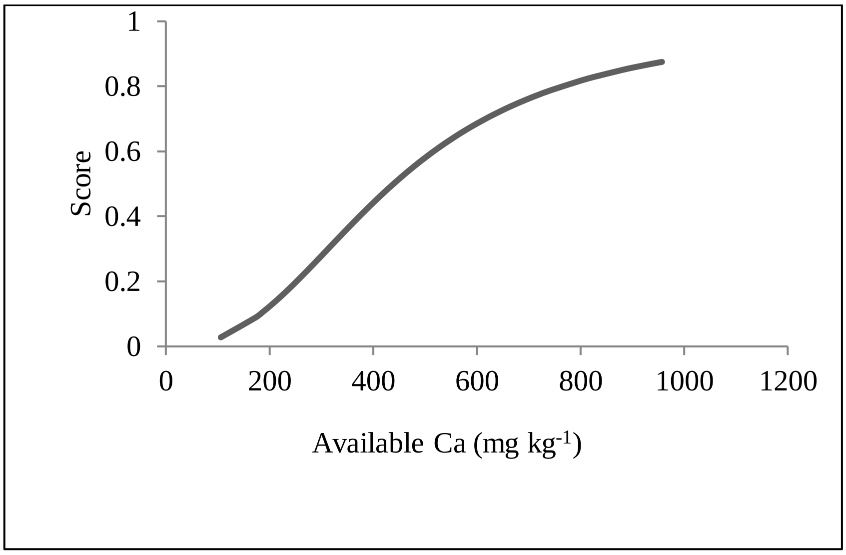
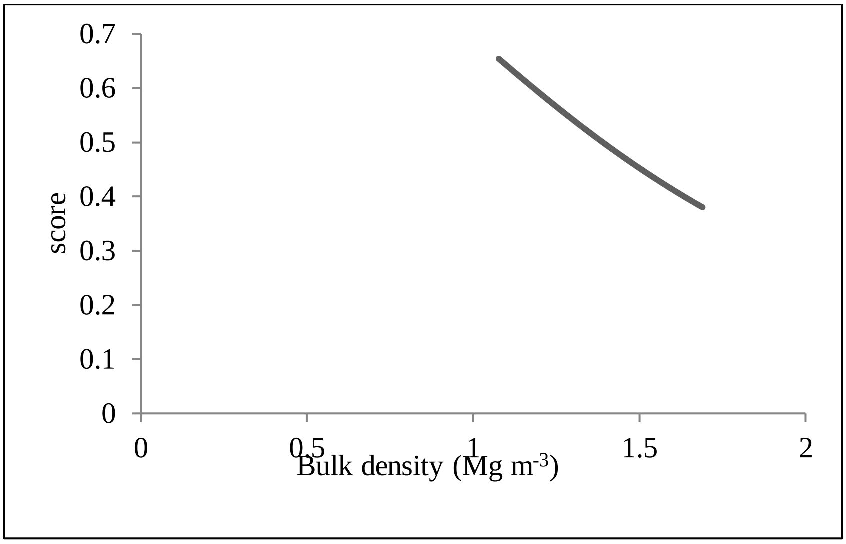


Fig.4.25 Score curve for soil available Ca

4.4.2 Less is better function

'Less is better' function was applied to score BD, When analyzed over the estimated range, lower value of the parameter was desirable for a healthy soil. The scores obtained for BD ranged from 0.38 to 0.65 having 1.69 Mg m^{-3} and 1.08 Mg m^{-3} bulk density respectively (figure 4.26). Almost 66% of samples had a BD >1.33 Mg m^{-3}, which was not desirable in the aspect of soil quality.



Fig, 4.26 Score curve for bulk density

4.4.3 Optimum is better function

Soil pH, particle density, available Zn and S were scored using optimum function. An optimum value suitable for plant growth was fixed for these indicators. For soil pH 7 was taken as optimum value and for particle density 2.65 Mg m^{-3} was selected as optimum value. The upper critical limit for available Zn and S were taken as 10 mg kg^{-1} and 25 mg kg^{-1} respectively. The observations above and below the optimum value were subjected to 'more is better' and 'less is better' scoring functions respectively. For each observation 0 to 1 scores were provided. For soil pH 0.32 to 0.64 were the scores allotted (figure 4.27) and particle density acquired scores between 0.1 and 0.85 (figure 4.28). Available Zn obtained the scores ranging from 0.034 (1.4 mg kg^{-1}) to 0.84 (9.73 mg kg^{-1}) (figure 4.29). High score of available S was 0.81 (25.66 mg kg^{-1}) and low score was 0.036 (11.53 mg kg^{-1}) (figure 4.30).

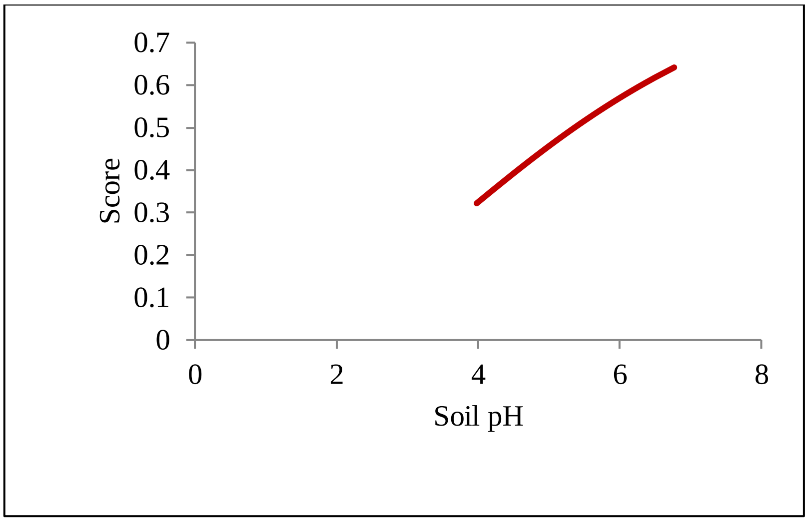
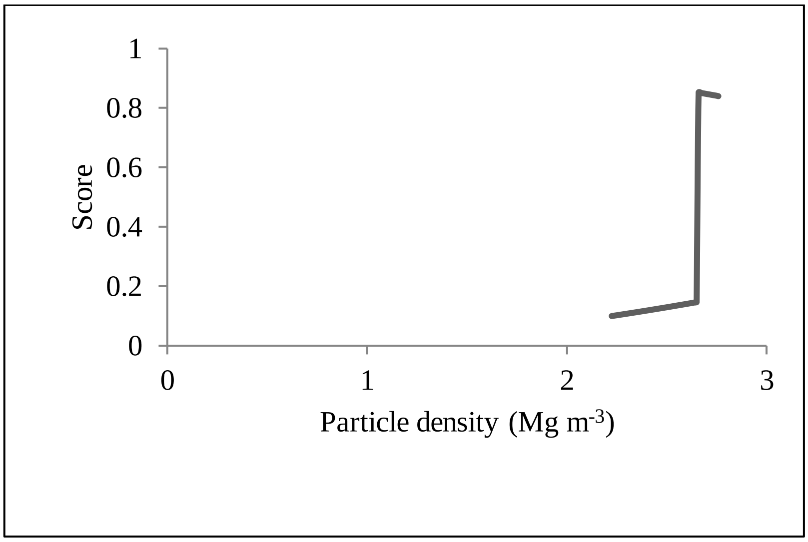
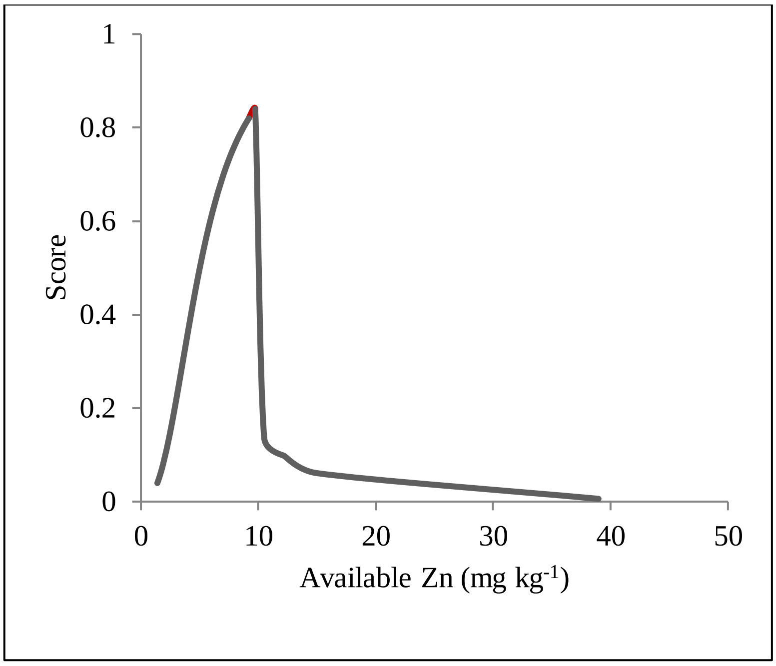


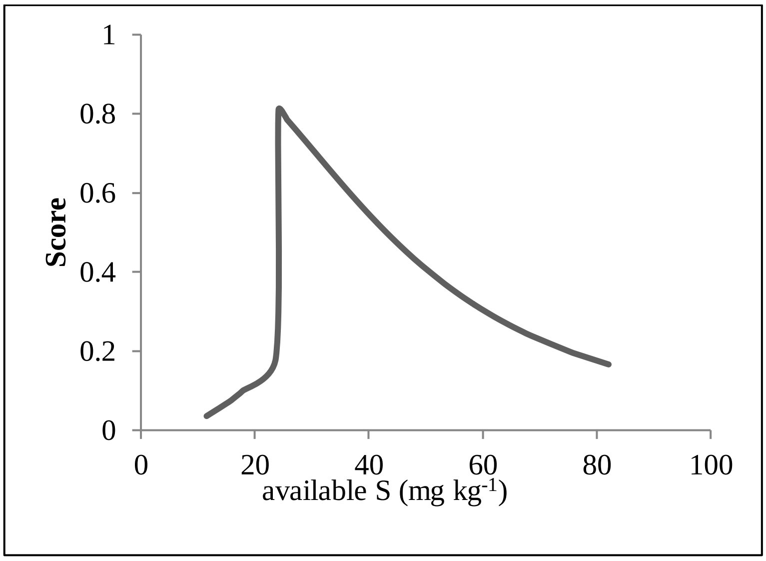
Fig. 4.27 Score curve of soil pH



Fig, 4.28 Score curve for PD



Fig, 4.29 Score curve for available Zn



Fig, 4.30 Score curve for available S

4.5 Computation of soil quality index (SQI)

As described in section 3 soil quality index was computed using the formula

SQI = Σ weight × individual soil parameter score.

Weight is a specific value for each PC group which is given in the table 4.28

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Weight	0.224	0.184	0.125	0.118	0.110	0.088	0.079

Table 4.28 Weights of each PC group

Weight of each PC group was calculated by dividing the variance proportion of each PC group to the cumulative variance proportion of the PC groups selected for MDS (Table 4.28).

The average SQI and range of its values observed in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala were depicted in table 4.29. The highest SQI was found in Alanallur panchayat (0.703) and the lowest value was in Karakurissi panchayat (0.314). When averaged over different panchayats, highest value was obtained from Kumaramputhur (0.539) and lowest from Karakkurissi (0.408).

Panchayat	**Mean SQI**	**Range**
Thachampara	0.507	0.397-0.63
Mannarkkad	0.456	0.324-0.645
Kottappadam	0.437	0.332-0.611
Kanjirappuzha	0.488	0.350-0.563
Thenkara	0.449	0.363-0.604
Thachanattukara	0.511	0.420-0.637
Kumaramputhur	0.539	0.365-0.648
Karakkurussi	0.408	0.314-0.479
Karimba	0.462	0.388-0.510
Alanallur	0.532	0.389-0.703

Table 4.29 SQI of different panchayats in AEU 13 of Palakkad district of Kerala

4.6 Relative Soil Quality Index (RSQI)

Soil quality index was compared with the theoretical maximum soil quality index (1.093) and expressed as percentage. The average RSQI of panchayats in AEU 13 of Palakkad district of Kerala indicated that all the ten panchayats came under poor soil quality class. The lowest average RSQI was in Karakurissi (37.36%) and highest in Kumaramputhur (49.36%) (figure 4.31 and table 4.30). The average RSQI of our study area was 43.92%. The map of RSQI in flood affected soils of AEU 13 in Palakkad district of Kerala (figure 4.38) was prepared using GIS technique.

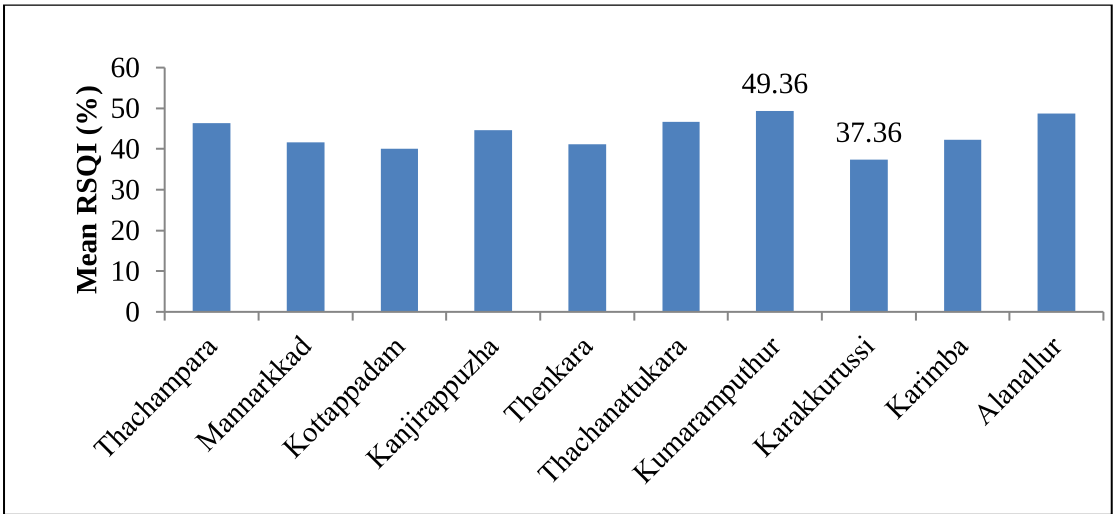


Fig 4.31 Mean RSQI **(%)** in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

Panchayat	Mean RSQI (%)	Soil quality class
Thachampara	46.41	Poor
Mannarkkad	41.69	Poor
Kottappadam	40.03	Poor

Kanjirappuzha	44.61	Poor
Thenkara	41.11	Poor
Thachanattukara	46.73	Poor
Kumaramputhur	49.36	Poor
Karakkurussi	37.36	Poor
Karimba	42.28	Poor
Alanallur	48.67	Poor

Table 4.30 Mean RSQI (%) of different panchayats in AEU 13 of Palakkad district of Kerala

4.7 Nutrient Index (NI)

The nutrient index of four important soil attributes were given in table 4.31. Total 101 samples were classified according to the nutrient content and NI was calculated. The NI less than 1.67 came under low fertility status. The available N and OC for the entire study area came in low category with NI 1.25 and 1.62 respectively. NI between 1.67 and 2.33 come under medium category and NI more than 2.33 come under high category. The nutrient index calculated for available P (2.82) and K (2.76) recorded by the soil samples collected from the study area came under high category (Table 4.31) (Ramamoorthy and Bajaj, 1969).

Parameter	No of samples			Nutrient index	Fertility status
	Low	Medium	High		
Available N	76	25	0	1.25	Low
Available P	0	18	83	2.82	High
Available K	0	24	77	2.76	High
Available OC	44	51	6	1.62	Low

Table 4.31 Nutrient index of available N, P, K and organic C in flood affected soils of AEU 13 in Palakkad district of Kerala

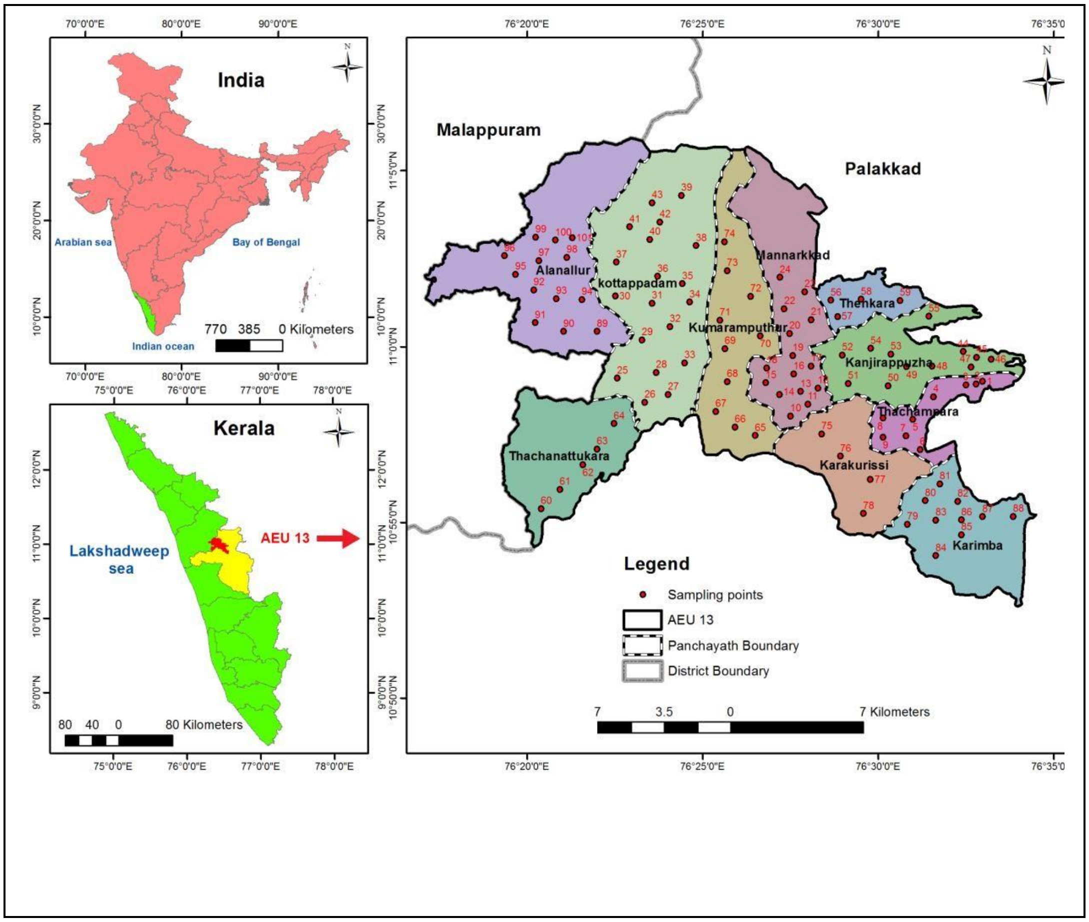


Fig. 4.32 Sample distribution in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

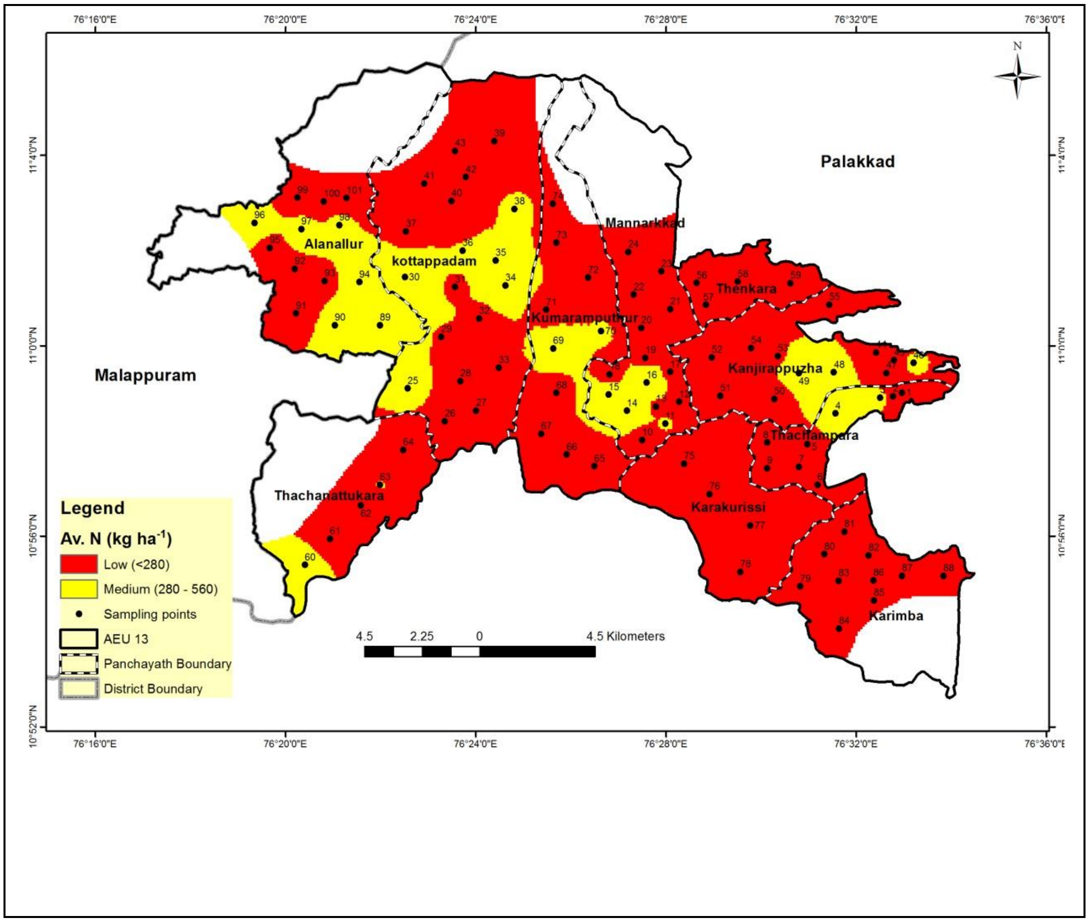


Fig. 4.33 Available N in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

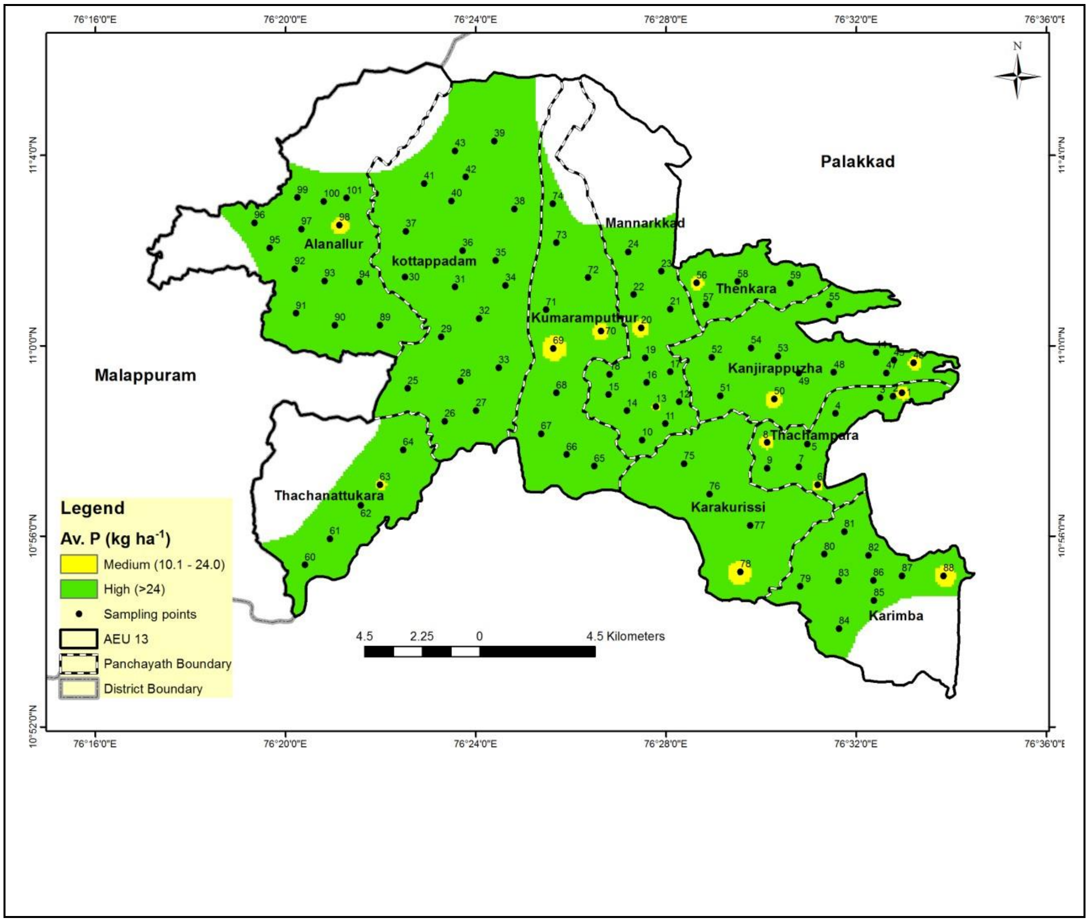


Fig. 4.34 Available P in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala.

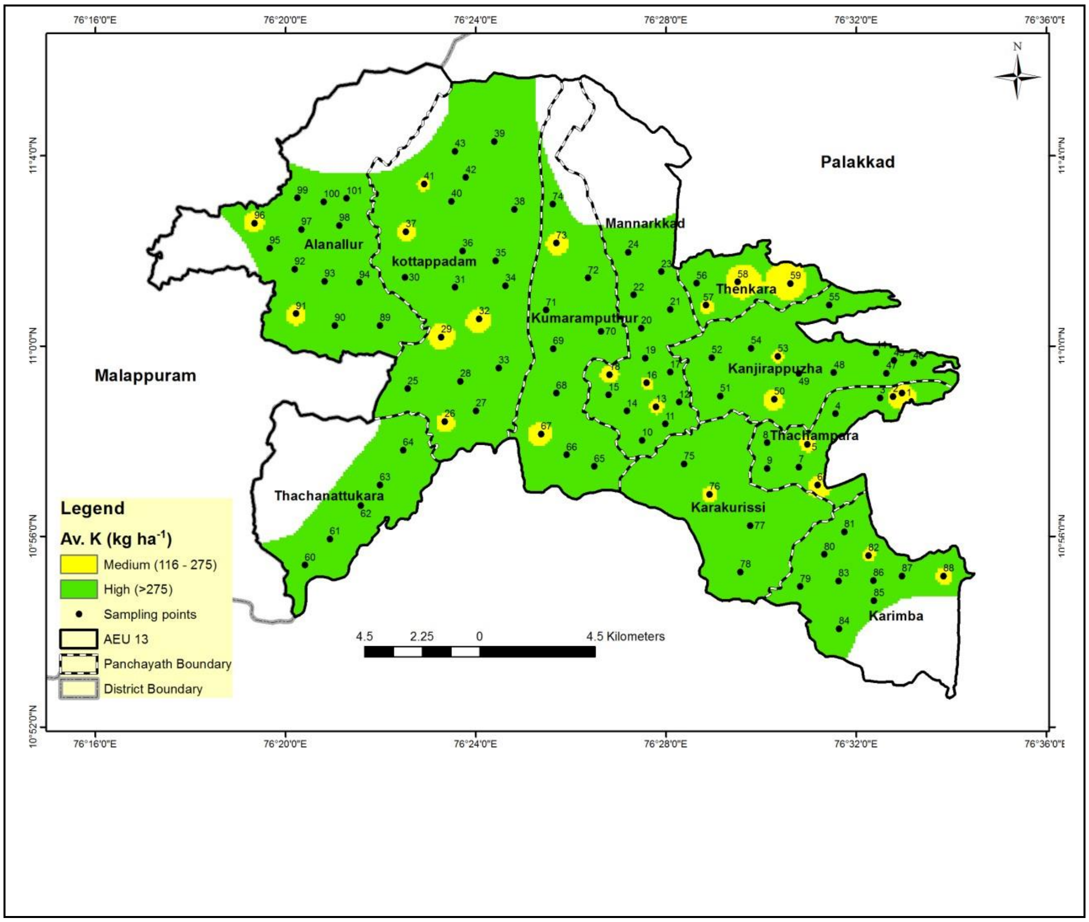


Fig. 4.35 Available K in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

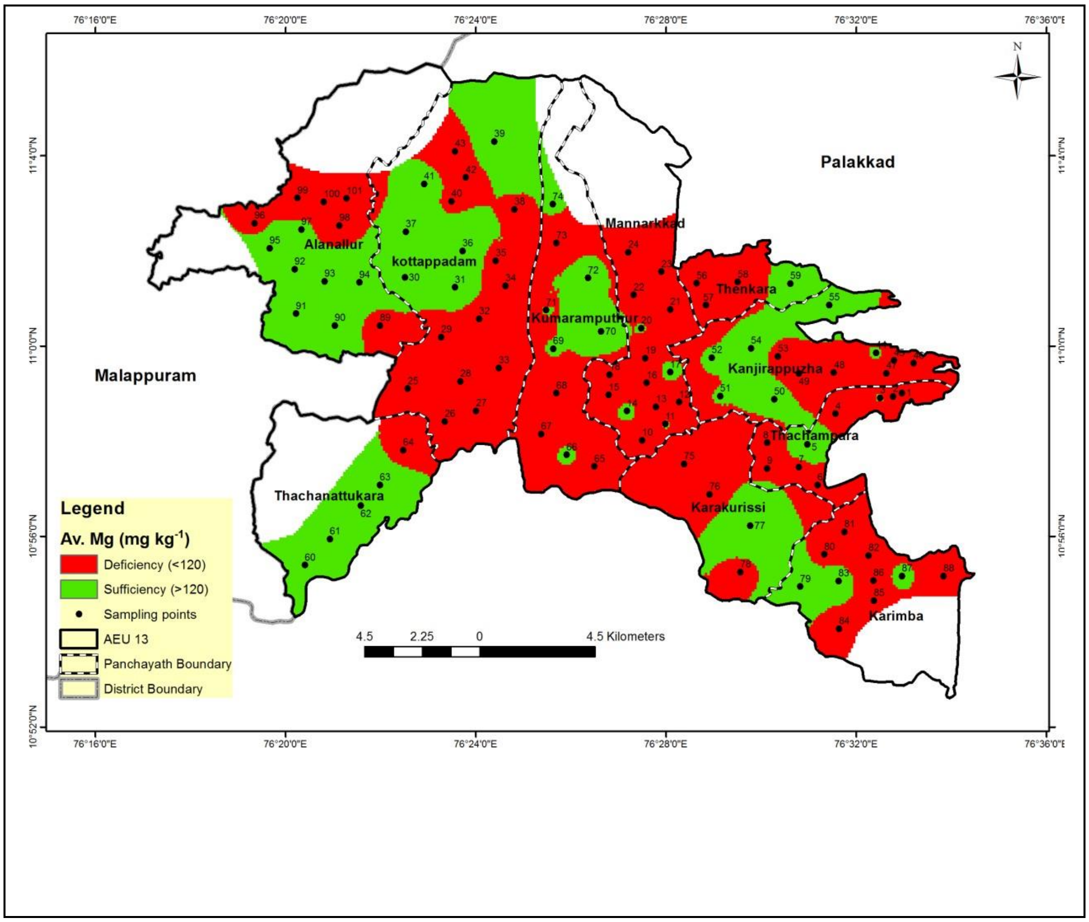


Fig 4.36 Available Mg in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

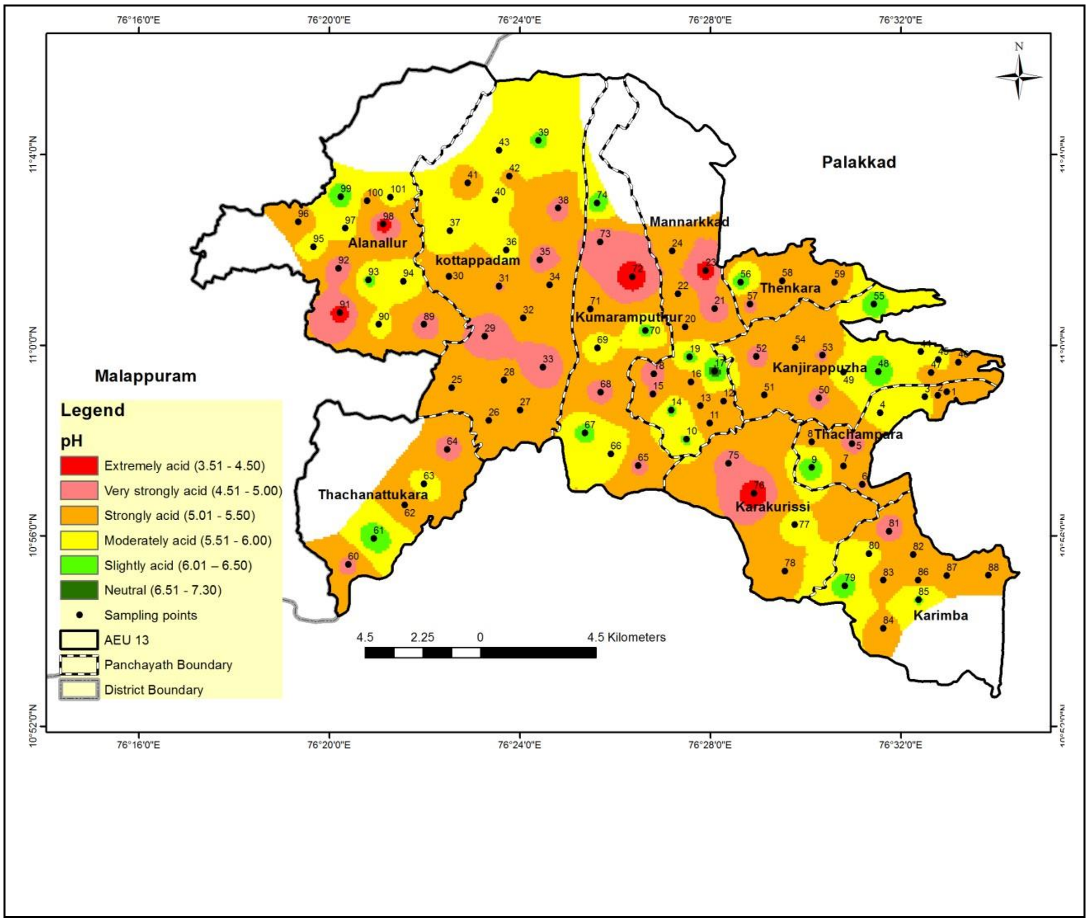


Fig. 4.37 Soil pH in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

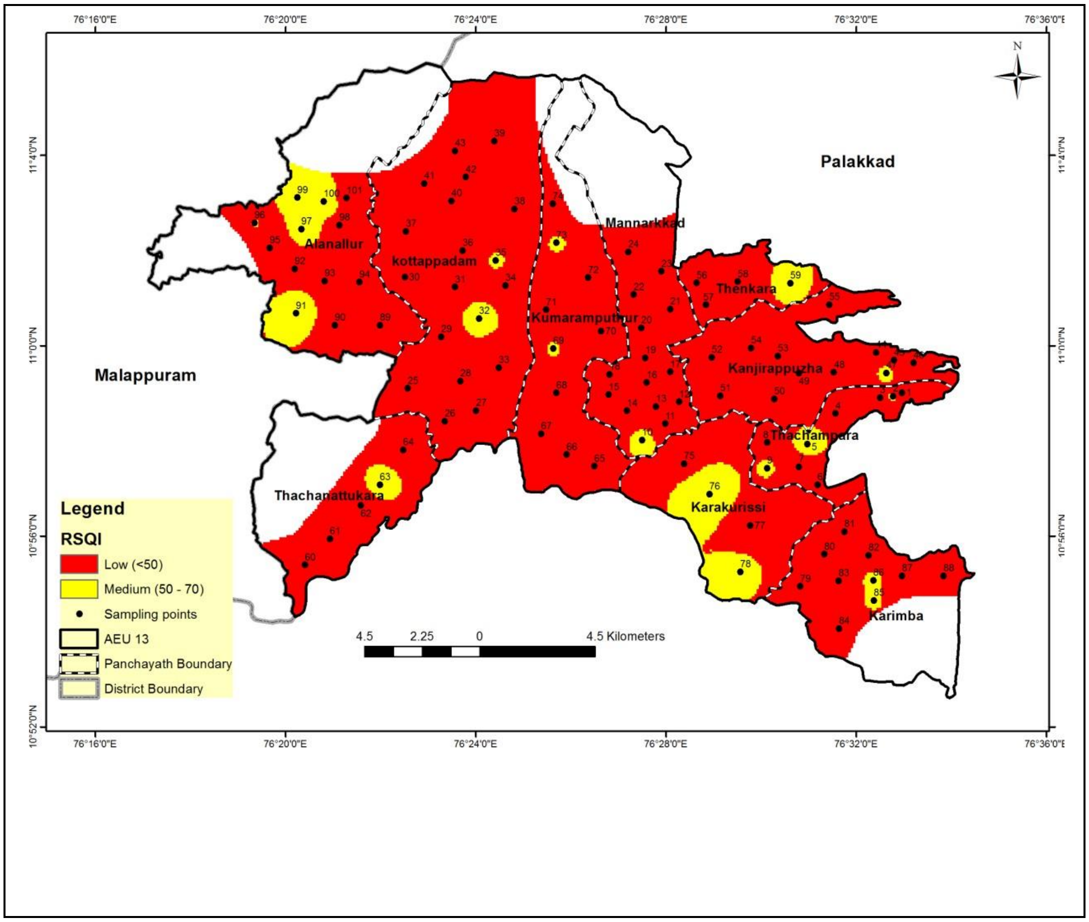


Fig. 4.38 RSQI in flood affected soils of different panchayats of AEU 13 in Palakkad district of Kerala

5. Discussion

5. DISCUSSION

The present investigation entitled "Assessment of soil quality in the post flood scenario of AEU 13 in Palakkad district of Kerala and mapping using GIS techniques" was carried out at College of Horticulture and Regional Agricultural Research Station, Pattambi during 2018-2020 in order to meet the objectives as detailed in section 1. The details pertaining to the various findings were discussed below in different headings:

5.1 Assessment of soil quality

5.2 Comparison between the analytical data of the soil samples collected from flood and landslide affected areas

5.3 SQI and RSQI

5.4 Nutrient indexing

5.1 Assessment of soil quality

To assess the soil quality of the flood affected soils of AEU 13 in Palakkad district of Kerala. 22 soil attributes (physical, chemical and biological attributes) were analyzed and the results are discussed below.

5.1.1 Physical attributes

5.1.1.1 Bulk density

The average dry bulk density of the area considered for the study was 1.38 Mg m^{-3} which came under the medium class (1.2-1.4 Mg m^{-3}). The dry bulk density ranges from 1.10 Mg $m^{-3}$to 1.69 Mg m^{-3}. Non flooded soils normally had a density range of 1.0-1.6 Mg m^{-3} (Brady, 1984). Bulk density was influenced by the amount of organic matter in soil, soil texture, mineral constitution and porosity. Askin and Ozdemir (2003) studied the relationship of BD with other parameters and stated that bulk density increases with increase in sand content and decrease in organic matter content. Avnimelech *et al.* (2001) recorded a high BD of 1.776 Mg $m^{-3}$for flooded soil having very low organic carbon content (1mg g^{-1}). Sand deposition due to river overflow was prominent in our study area and generally low to medium organic carbon content was noticed. Twelve percentage of the samples had low BD (<1.2 Mg

m^{-3}). Thirty four percentage had medium, 44% had high and 10% samples had very high BD values (Figure 5.1).

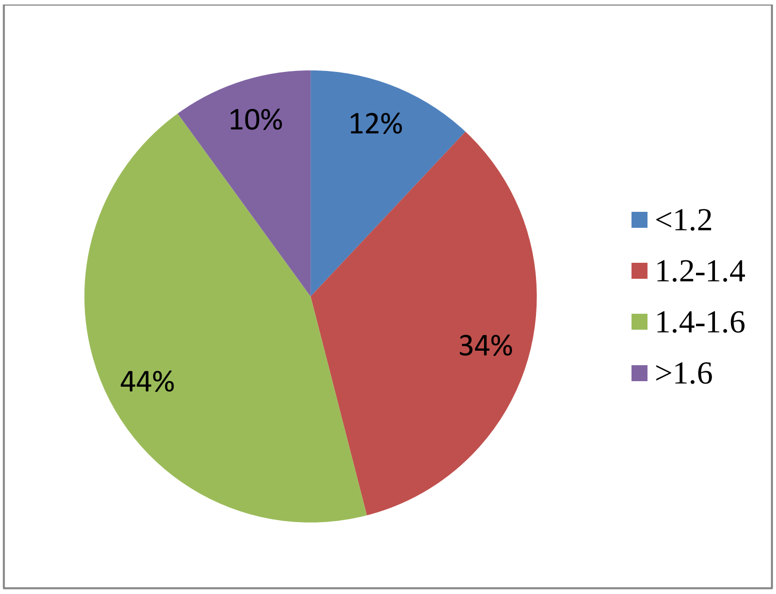


Fig 5.1 Frequency distribution of bulk density (Mg m-^{3}) in the post flood soils of AEU 13 in Palakkad district of Kerala

5.1.1.2 Particle density

Particle density ranged from 1.95 Mg $m^{-3}$to 2.76 Mg m^{-3} in the study area. Average mean value of the surveyed area was 2.513 Mg m^{-3}. Here 32% of the samples came under high particle density class (>2.6). Only one percentage of the samples had low PD while 24 % and 43% samples were in low and medium class respectively (figure 5.2). The mean values computed over different panchayats indicated that 7 of the 10 panchayats came under medium class. Particle density exhibited significant correlation with bulk density. The average PD of an inorganic soil was 2.65 Mg m^{-3} (Brady, 1984) where as PD for organic matter was reported to be 1.25 Mg m^{-3} (Hakanson and Jansson, 1983). So addition of lighter materials results a decrease in PD, while incorporation of minerals with high density results an increase in particle density (Avnimelech *et al*., 2001). This might be the reason for a low average PD of 2.49 Mg m^{-3}detected in river overflow affected soils than land slide affected soils (2.62 Mg m^{-3}).

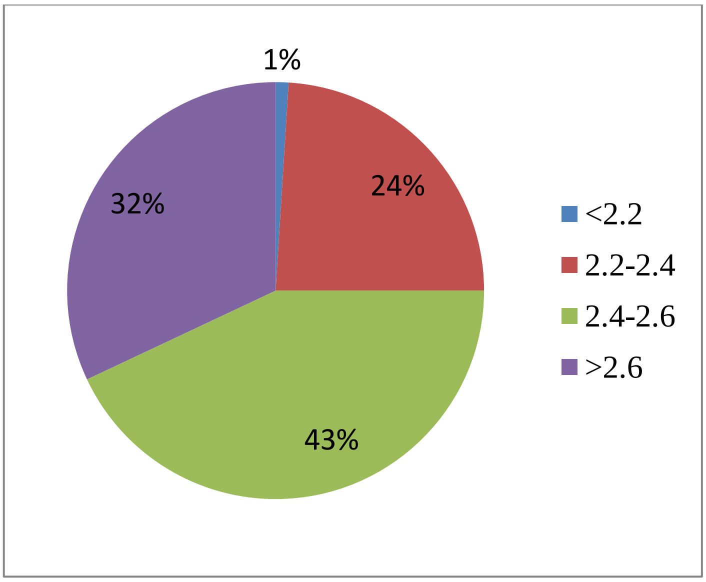


Fig 5.2 Frequency distribution of particle density (Mg m^{-3}) in the post flood soils of AEU 13 in Palakkad district of Kerala

5.1.1.3 Porosity

Regarding porosity estimated over the surveyed range of soil samples, 83% came under optimum category while 16% came under high and only 1% under low category (figure 5.3). The porosity ranged from 17.31% to 56.5% with an average value of 44.7% in the study area. . Porosity was related to PD and BD (Hillel, 1982). Rodriguez *et al.* (2016) studied the disturbances caused by floods on soil physical properties and pointed out a considerable decrease in total and aeration porosity. This may be due to the changes occurred in soil texture, structure, permeability and aggregate stability due to water logging (Reddy and Delaune, 2008). Porosity was significantly correlated with bulk density and water holding capacity. It also shows a low correlation with DHA.

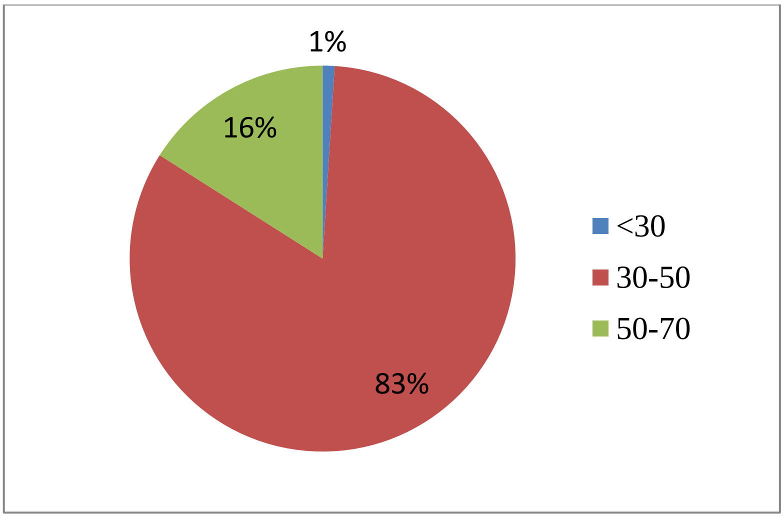


Fig 5.3 Frequency distribution of porosity (%) in the post flood soils of AEU 13 in Palakkad district of Kerala

5.1.1.4 Maximum water holding capacity

Maximum water holding capacity estimated over the study area ranges from 9.47% to 50.43%. Eighty five percent of the samples had optimum MWHC. Twelve percentage of samples had low and 3% had high water holding capacity (figure 5.4). Water holding capacity showed significant correlation with bulk density. PD and porosity. Mitch and Gosselink (1993) stated that flood increases water holding capacity and water availability for plants. Water holding capacity was detected more for flood affected samples than landslide affected samples.

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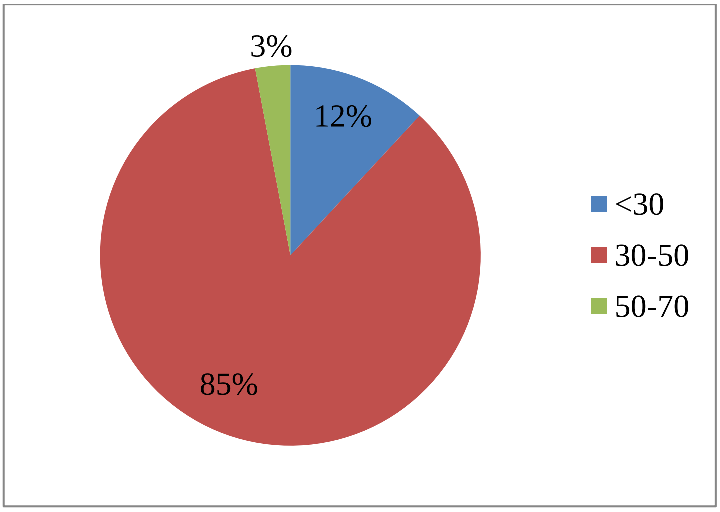

Fig 5.4 Frequency distribution of water holding capacity (%) in the post flood soils of AEU 13 in Palakkad district of Kerala

5.1.1.5 Moisture content.

The average moisture content at the time of selection of soil sample from the selected locality was 19.79%. Highest moisture content observed was 38.93% (figure 5.5). Even though there was a wide range of moisture, the mean values of different panchayats exhibited slight variation. Eleven percentage of samples had low, 19 % had medium, 45% had high and 26% had very high gravimetric moisture content. Soil moisture is a main mediator in between soil and atmospheric interaction. The moisture content of soil vary with climate especially rainfall pattern, movement of water and crop root uptake (Venkatesh, 2011). It majorly depends on the time and season of soil sample collection also. So it is difficult or meaningless to compare the moisture content before and after flood. Ubuoh *et al.* (2016) reported an increase in moisture content of flooded area compared to control in Nygeria. This rise was due to high retention of water brought about by the flooding. However, moisture content is not a permanent character.

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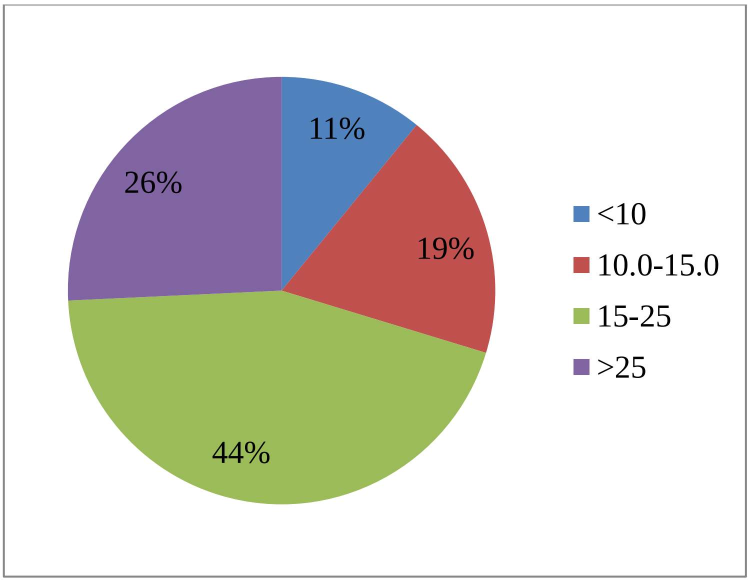


Fig 5.5 Frequency distribution of gravimetric soil moisture content (%) in the post flood soils of AEU 13 in Palakkad district of Kerala.

5.1.2 Soil chemical attributes

5.1.2.1 Available Nitrogen

The available nitrogen in the studied area ranged from 81.75 to 472.5 kg ha^{-1}. The average available N of the study area was 238.2 kg ha^{-1}. Most of the samples (75%) contained low available nitrogen and remaining 25% had medium available N (figure 5.6). Available N had positive correlation with organic carbon. Koschorreck and Darwich (2003) studied the nitrogen dynamics of seasonally flooded soils. According to them the condition of alternate aquatic and terrestrial phase promotes denitrification and mineralization which leads to an ultimate reduction in available N. Reddy and Patrick in 1984 noticed very evident reduction in nitrate and increase in ammonium ions after flood. In anaerobic condition after depletion of oxygen, nitrate act as electron accepter and dentrification occurs with the help of some obligate respiratory bacteria (Knowles, 1982) which cause depletion of nitrate in soil.

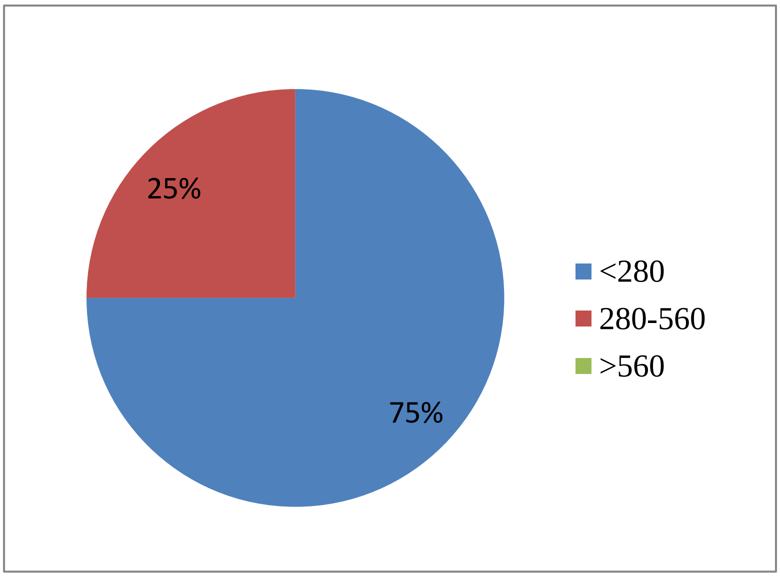


Fig 5.6 Frequency distribution of available N (kg ha^{-1}) in the post flood soils of AEU 13 in Palakkad district of Kerala

5.1.2.2 Available phosphorus

The available phosphorus content was high in flood affected samples compared to pre flood data. The data collected from DSTL on pre flood analysis indicated that 11% of the soil samples came in low, 50% in medium and 39% in high class (figure 5.7). The post flood analysis indicated that a large proportion of samples from flooded area came in high class (66%). Two percentage of samples came in very high class; however none of the samples were in very high class before flood. Many authors reported high available P after flood. This is due to high affinity of P (as PO_4^{3-}) to soil clay (Harry *et al.*, 2006). Sediments deposited after flood was reported to be rich in available P and it was high in acidic soils of pH<7 (Ross *et al.*, 2008). Prolonged water logging and anaerobic condition leads to mobilization of P. However in normal condition P associate to Ca, Fe or Al and form complexes. In anaerobic condition Fe was reduced and P was released from iron- phosphate complex (Gallardo, 2003). The same reasons can also be attributed to the increase in available P in the samples collected from study area.

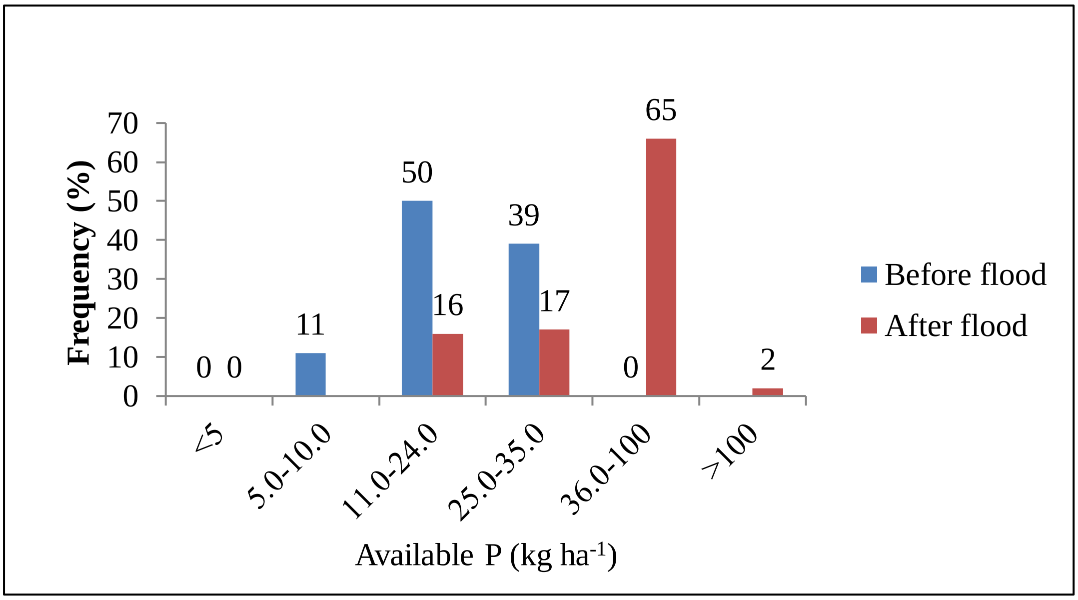


Fig 5.7 Frequency distribution of available P (kg ha^{-1}) before and after flood in soils of AEU 13 in Palakkad district of Kerala

5.1.2.3 Available potassium

The results of the study provided clear evidence of increase in available potassium in flood affected soils. There were no samples under very low and low classes of available K. Twenty five percentage and 23% of the samples came under medium and high class respectively. Forty seven percentage of the samples came under very high and 5% under extremely high class. Regarding the pre flood data on soil analysis collected from DSTL, Pattambi, almost three fourth of the samples came under low and medium class thus indicating the increase in available K after flood (figure 5.8). The average available K of the selected area was 463.8 kg ha^{-1} which also came under very high class. The soil test results of Jacob *et al*. (2016) reported medium available K (203 kg ha^{-1}) in AEU 13. The rise of available K may be attributed to the mineralogical composition or changes after flood or due to the application of fertilizers immediately after flood.

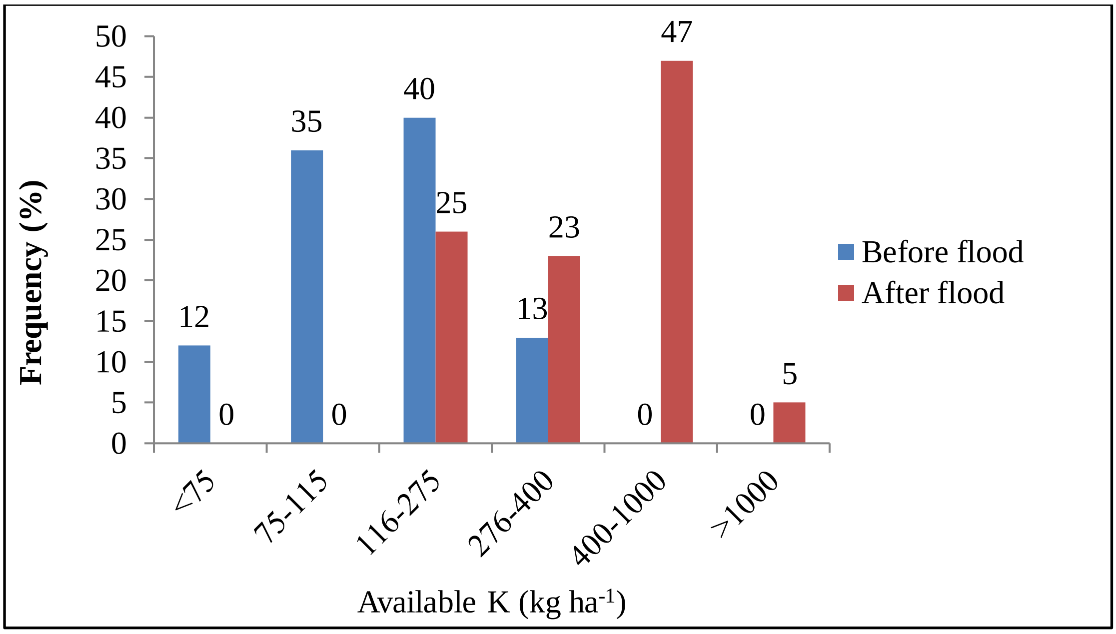


Fig 5.8 Frequency distribution of available K (kg ha^{-1}) before and after flood in soils of AEU 13 in Palakkad district of Kerala

5.1.2.4 Available calcium

The frequency distribution of available Ca before and after flood in soils of the study area is given in figure 5.9. Available calcium was found adequate in 70% of the soil samples collected from the study area. In the remaining samples, 29% had low and 1% had very low available Ca (figure 5.9). The highest available Ca (957.4 mg kg^{-1}) was found in Kanjirappuzha and lowest (106.1 mg kg^{-1}) in Mannarkkad panchayat. The mean available Ca of the surveyed area is 439.4 mg kg^{-1}. Compared to the pre flood data (2013-14) (Rajasekharan *et al*., 2013, the frequency of the samples under deficiency category increased in post flood samples (figure 5.9). The works of Alfaiya and Falcao (1993) and Hamphries (2008) reported that available Ca reduced with increase in moisture content. Available Ca may get easily leached out from the soil especially in acidic pH condition. A positive correlation between available Ca and pH was observed in our study area.

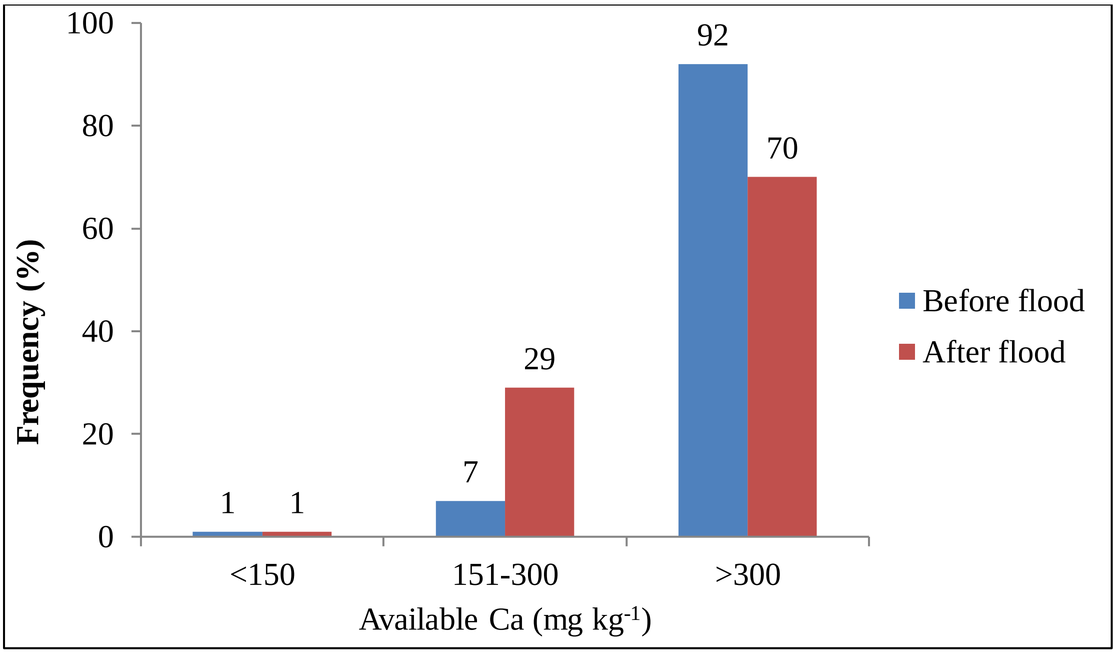


Fig 5.9 Frequency distribution of available Ca (mg kg^{-1}) before and after flood in soils of AEU 13 in Palakkad district of Kerala

5.1.2.5 Available magnesium

The frequency distribution of available Mg before and after flood in soils of the study area is given in figure 5.10. The average available Mg of the chosen locality after flood was 114.9 mg kg^{-1}which came under deficiency class; but 40% of the samples came under adequate category regarding available Mg. In case of samples showing deficiency, 41% came under low and 19 % under very low category. The secondary data collected on soil analysis of the samples before flood (2013-14) (Rajasekharan *et al.*, 2013) also indicated the prevalence of Mg deficiency in the surveyed area. But the proportion of deficient samples increased after flood (42% to 60%). Available Mg was highly correlated with available Ca. So as like Ca, Mg might have leached out from the soil after flood.

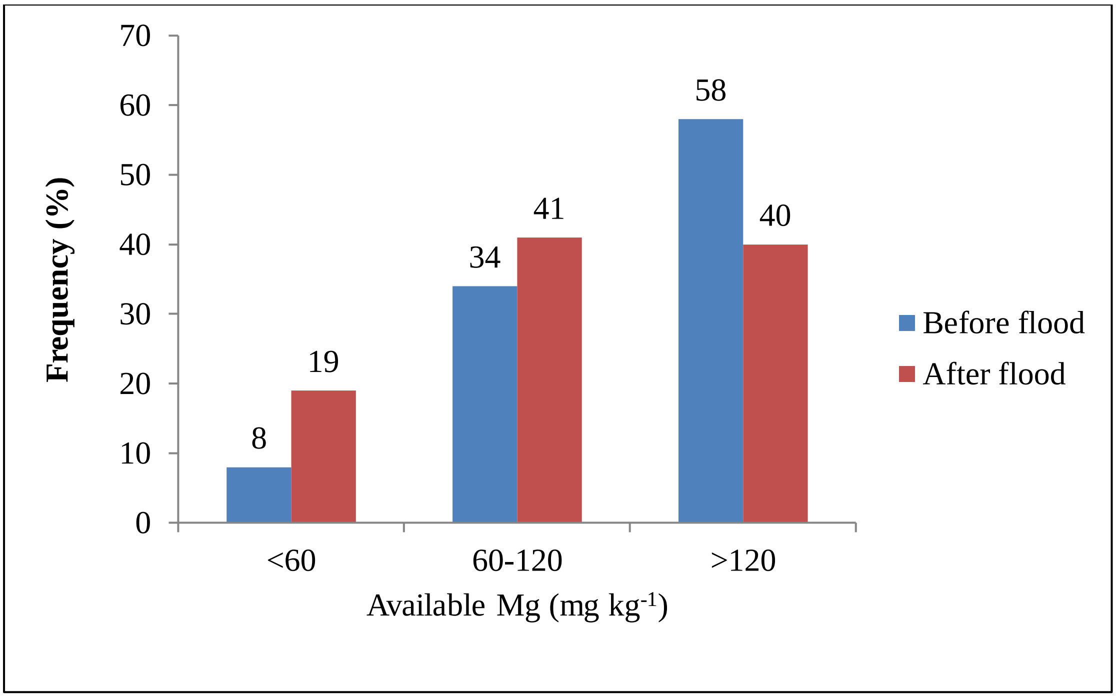


Fig 5.10 Frequency distribution of available Mg (mg kg^{-1}) before and after flood in soils of AEU 13 in Palakkad district of Kerala

5.1.2.6 Available Sulphur

The frequency distribution of available S before and after flood in soils of the study area is given in figure 5.11. The available S content varied from 11.53 mg kg^{-1} (Kanjirappuzha) to 82.1 mg kg^{-1} (Karimba) with a mean value of 43.09 mg kg^{-1} in the study area. The major proportion of samples (95%) contained high available S, whereas the remaining 5% had adequate S. The data collected from DSTL, Pattambi on pre flood analysis of soil samples indicated that 15% came under low category, 42% under medium 40% under adequate and 4% under high category. A tremendous increase of available S in flood affected area was evident from the analytical results of the samples collected from the present study area with majority of the samples (95%) coming under high category. According to Kertesz and Mirleau (2014) the available S was controlled by balancing the mineralization of organic S and immobilization of soluble S in soil. These processes depend on soil organic matter content, soil moisture, soil pH and microbial diversity (Eriksson *et al.*, 1960). High moisture content and a soil pH of 6-7 with adequate micro flora will increase mineralization of S.

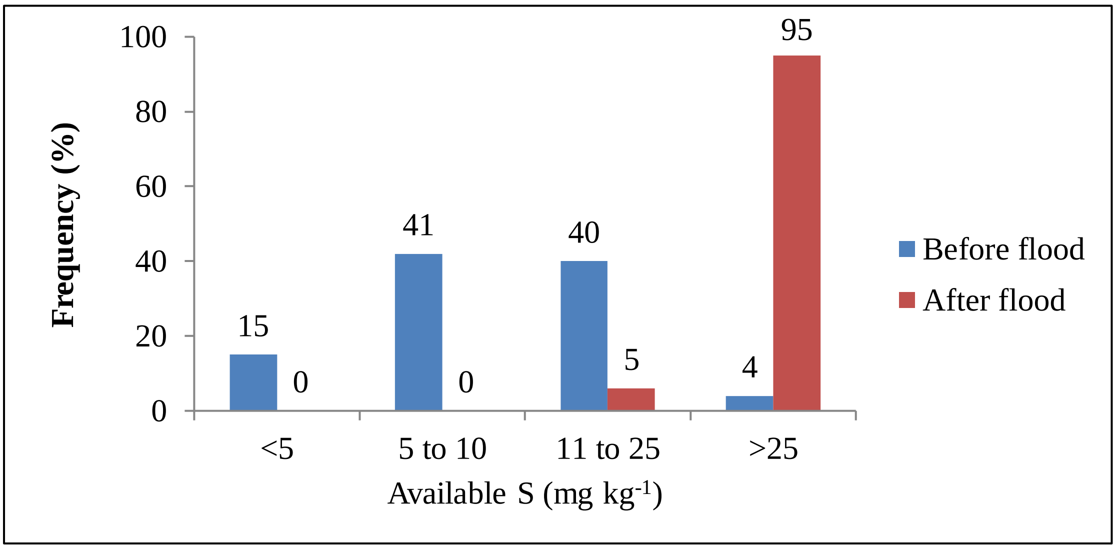


Fig 5.11 Frequency distribution of available S (mg kg^{-1}) before and after flood in the soils of AEU 13 in Palakkad district of Kerala.

5.1.2.7 Available iron

The frequency distribution of available Fe before and after flood in soils of the study area is given in figure 5.12. All the samples had adequate amount of iron before and after flood. Available Fe varied from 12.95 mg kg^{-1} to 146.98 mg kg^{-1}. However, average available iron in flood affected soil (58.91 mg kg^{-1}) and land slide affected soil (64.65 mg kg^{-1}) showed a variation. The main reason for reduction in aggregate stability of flooded soils was suggested to be the increased dissolution of cementing agents like iron oxide during water logging (De-Campos *et al*., 2009). Anaerobic condition also affects the complex formation which releases more available iron. Amarawansha *et al.* (2015) reported that flood affected alkaline soils show iron deficiency, because of the increase in concentration of bicarbonates, which interfere with iron availability. The soils of the present study area were acidic and were sufficient in available iron.

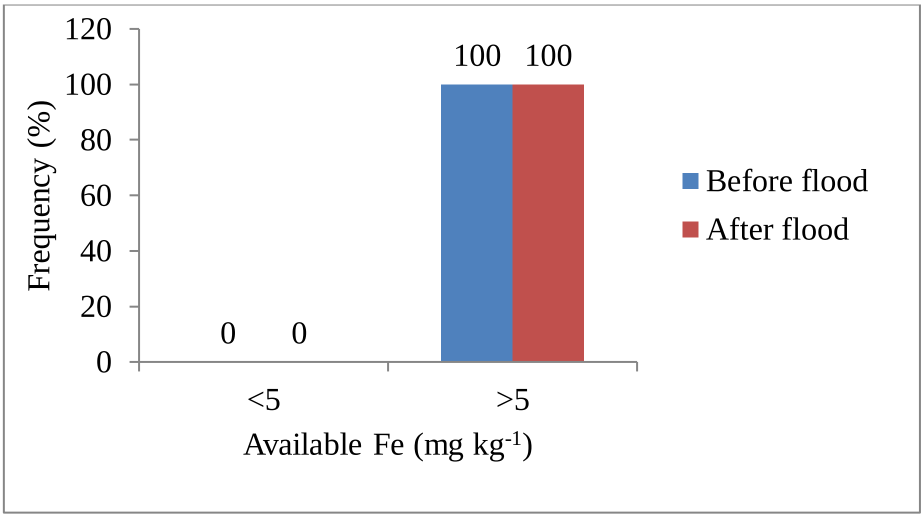


Fig 5.12 Frequency distribution of available Fe (mg kg^{-1}) before and after flood in flood soils of AEU 13 in Palakkad district of Kerala.

5.1.2.8 Available manganese

The frequency distribution of available Mn before and after flood in soils of the study area is given in figure 5.13. The entire soil samples collected from AEU 13 came under adequate class and the average of available Mn in samples affected by river overflow was 53.36 mg kg^{-1}, but for samples affected by land slide it was 87.81 mg kg^{-1}. The higher values obtained for samples from land slide affected areas might indicate the presence of Mn containing minerals in the soil brought by landslides. Soil wetness highly influence micronutrients. Sometimes soluble Mn concentration will burst out after flood. Kalshetty *et al*. (2012) reported an increased level of Mn in flood affected Indian soils.

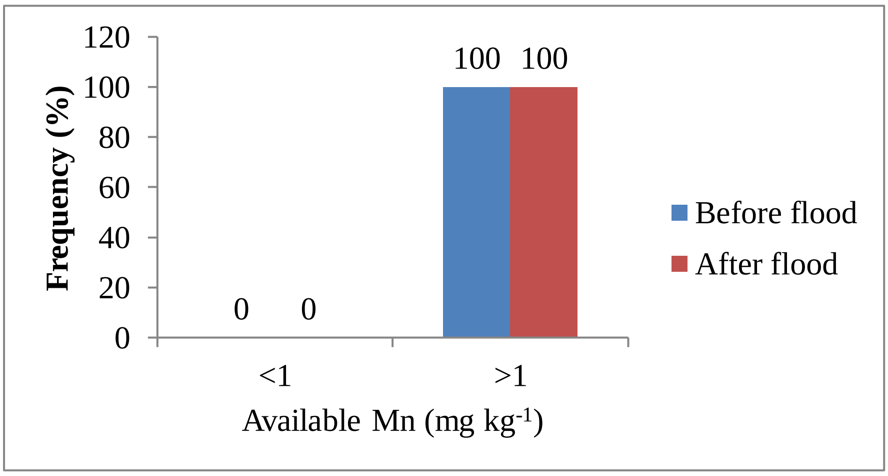


Fig 5.13 Frequency distribution of available Mn (mg kg^{-1}) before and after flood in soils of AEU 13 in Palakkad district of Kerala

5.1.2.9 Available copper

The available Cu content was adequate in all soil samples before and after flood (figure 5.14). The available Cu content ranged from 1.31 to 8.41 mg kg^{-1} with an average of 3.993 mg kg^{-1} in the selected area. Generally flood increases the concentration of metals like lead, cadmium and copper (Akpoveta *et al.*, 2014). This can be explained by two reasons, flood water carry the lithogenic contribution of these metals and their salts in to the soil, more over high moisture content in soil after flood assured favorable condition for the metals to exist in their highly available forms (Abeh *et al*., 2007).

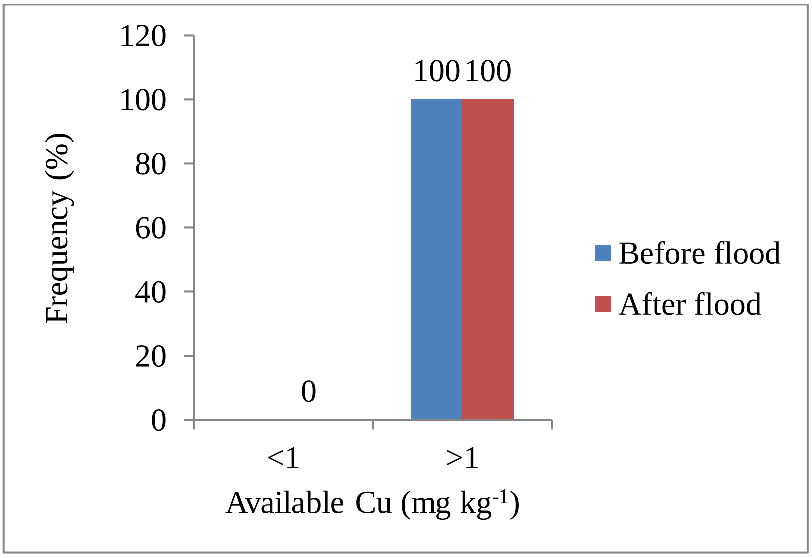


Fig 5.16 Frequency distribution of available Cu (mg kg^{-1}) before and after flood in soils of AEU 13 in Palakkad district of Kerala

5.1.2.10 Available Zinc

All the soil samples from the flood affected areas of AEU 13 in Palakkad district had adequate available Zn. But the data on soil analysis collected from DSTL, Pattambi showed deficiency of available Zn in 2% of samples (fig. 5.15) An average available Zn of 5.015 mg kg^{-1} was recorded from the study area with a range of 1.4 mg $kg^{-1}$to 38.1 mg kg^{-1}. There is no significant variation observed before and after flood.

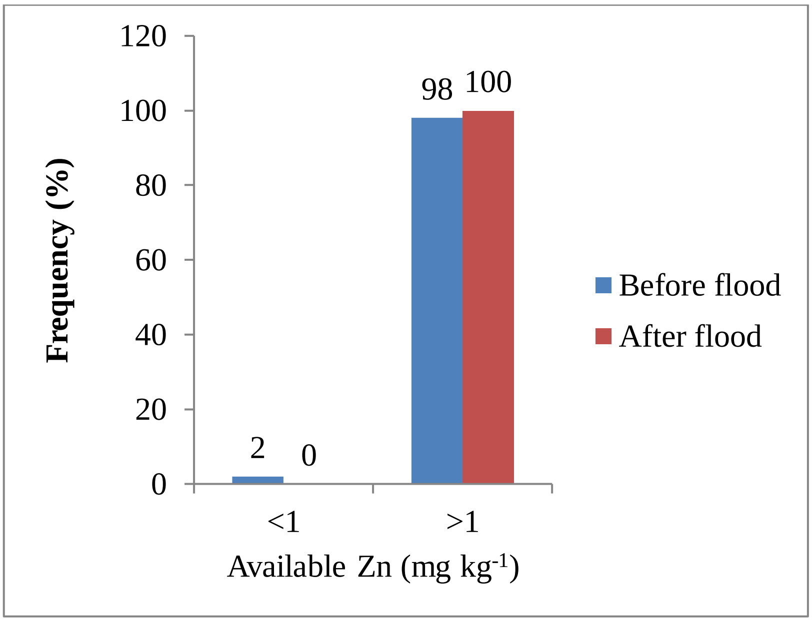


Fig 5.15 Frequency distribution of available Zn (mg kg^{-1}) in the post flood soils of AEU 13 in Palakkad district of Kerala.

5.1.2.11 Available Boron

The frequency distribution of available B before and after flood in soils of the study area is given in figure 5.16. Deficiency of available B was common in AEU 13 before and after flood. The data on soil analysis collected from DSTL, Pattambi, indicated that 79% samples were deficient in available B whereas after flood 99% of samples came under deficiency class (figure 5.16). The analytical results of a multi institutional project jointly implemented by Department of Agriculture, KAU, ICAR and IITMK also reported deficiency of boron in the AEU 13 (Rajasekharan *et al*., 2013). Behera *et al*. (2016) reported the same trend in all acidic soils of India (36-78% deficiency). Boron adsorption in soil increases with increase in soil pH up to 9. So low pH observed in study area was one of the reasons for low availability of boron. Moreover, B was completely water soluble and subjected to profound leaching on water logging. Borax is the key fertilizer used to treat B deficiency, which is very susceptible for leaching (Saleem *et al.*, 2011).

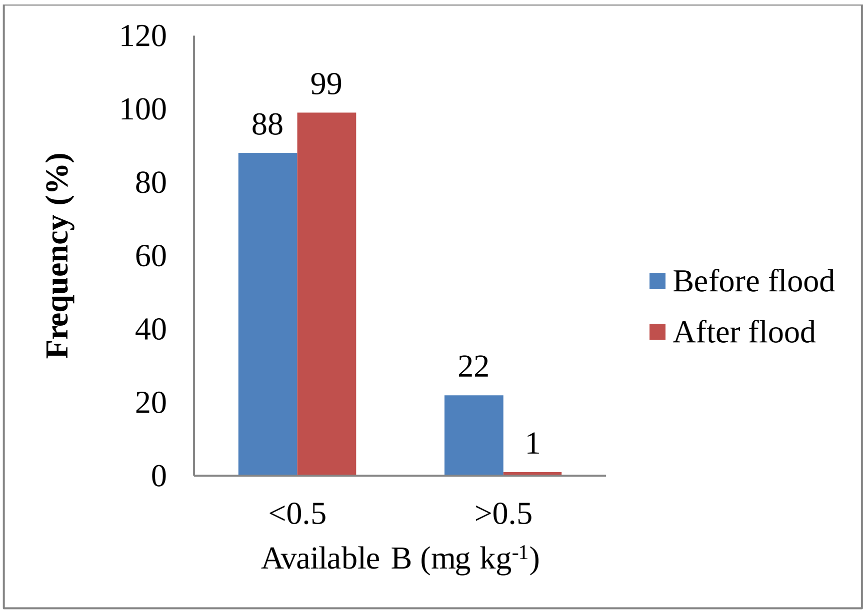


Fig 5.16 Frequency distribution of available B (mg kg^{-1}) before and after flood in soils of AEU 13 in Palakkad district of Kerala

5.1.2.12 Soil reaction (pH)

The frequency distribution of soil pH before and after flood in soils of the study area is given in figure 5.17. All the samples were acidic in nature and the pH range of the study area was 3.86 (Alanallur) to 6.77 (Mannarkkad). The average reported pH was 5.26. The secondary data collected from DSTL also indicated the acidic nature of the lateritic soils of the study area even before flood, which was also recorded in the study reports of the multi-institutional project implemented in Kerala (Rajasekharan *et al*., 2013) There was no significant change regarding the frequency distribution before and after flood except the twelve percentage of samples coming under extremely acidic category (fig.5.17). There were some reports on the increase of acidity on flooding because of water logging induced production of organic acid by fermentation (Akpoveta *et al.*, 2014). Soil pH is an important factor which determines the availability of other nutrients. Leaching of available Ca and Mg might be the major reason for the decrease in soil pH observed after flood. Many metallic cations like Cu, Zn, Pb and Ni were reported to be soluble and more available in low pH range (McBride, 1994).

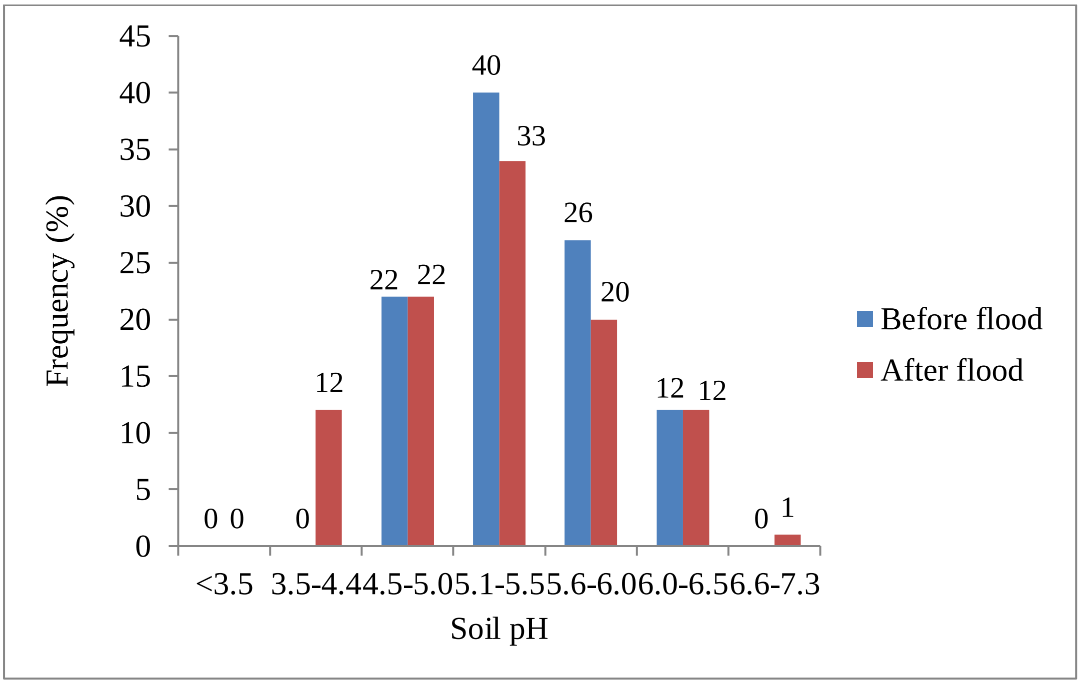


Fig 5.17 Frequency distribution of soil pH before and after flood in soils of AEU 13 in Palakkad district of Kerala

5.1.2.13 Electrical conductivity

All the samples (100%) showed very low EC. The mean average EC was 0.077 dS m^{-1}. Moreover, the comparison between the present analytical data and secondary data collected from DSTL, Pattambi indicated a slight decrease in EC after flood (figure 5.18). EC is the measure of concentration of ions in soil or the concentration of dissolved salts in soil or is a measure of soil salinity. Normally after flood a trend of increase in EC was noticed. Akpoveta *et al.* (2014) reported such an increase in EC in flood plains of Nygeria. Similarly Kalshetty *et al.* (2012) reported high EC values from the soils affected by flooding from Krishna river in Bagalkot district of Karnataka. The increase was explained by the addition of salts, ions and other dissolved solids by flood which cause salinity hazard. But in our area the flood water may be not much saline instead it washed out the salts from the soil and made the soil less saline with low EC as observed in the frequency distribution (Fig 5.20).

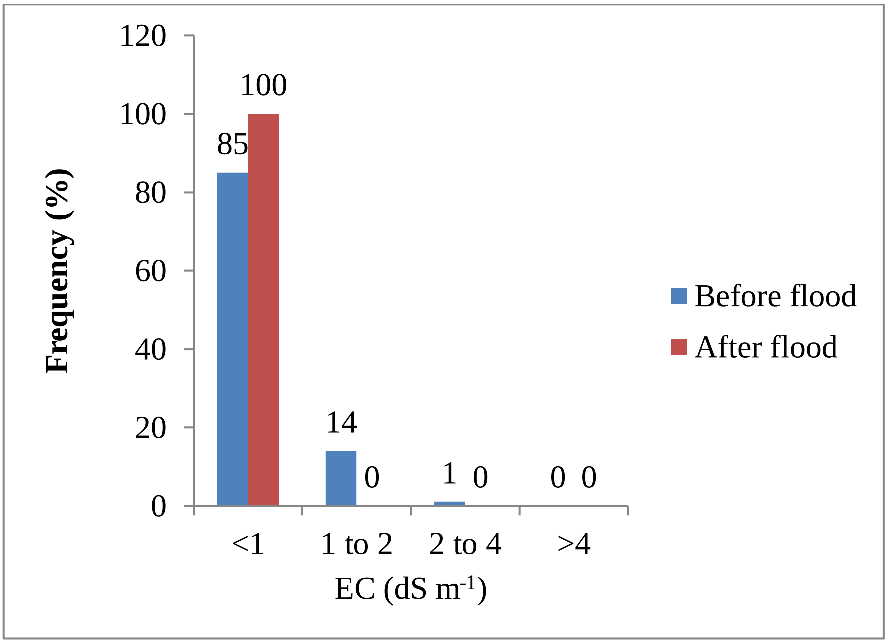


Fig 5.18 Frequency distribution of EC (dS m^{-1}) before and after flood in soils of AEU 13 in Palakkad district of Kerala

5.1.2.14 Exchangeable acidity

The exchangeable acidity of the soil samples varied from 0.16 cmol kg^{-1} to 0.66 cmol kg^{-1} with all the samples (100%) coming under low class (<1 cmol kg^{-1}) (figure 5.19). The average value was also very low (0.152 cmol kg^{-1}). Exchangeable acidity indicates the exchangeable H^+ and Al^{3+} ion concentration which was a measure of buffering capacity of the soil. Most of the studies reported that the exchangeable acidity constituted mostly by Al^{3+} and Abreu *et al.* (1983) after his research in acid soils opinioned that even in soils with high acidity, Al^{3+} may not be present and Al^{3+} is a function of parent material and of soil mineralogy. Even though all the samples were acidic, the exchangeable acidity was low which might be due to less Al containing minerals in the study area.

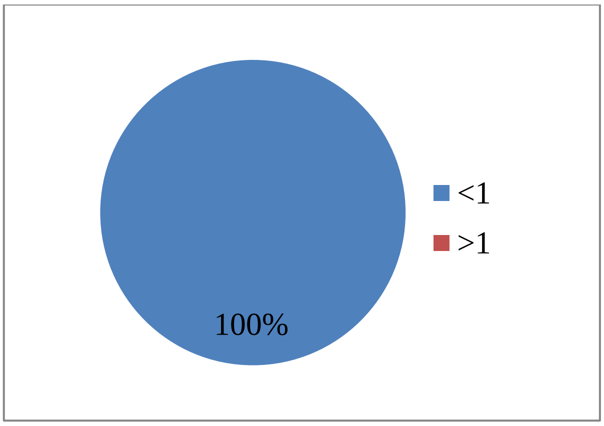


Fig 5.19 Frequency distribution of exchangeable acidity (cmol kg^{-1}) in the post flood soils of AEU 13 in Palakkad district of Kerala

5.1.2.15 Effective cation exchange capacity

The mean ECEC of the studied area was 8.365 cmolkg^{-1}. The recorded ECEC ranged from 5.655 to 14.09 cmol kg^{-1}in the study area. Among the total samples 84% had low ECEC (<10 cmol kg^{-1}) and remaining 16% came under medium category (10-16 cmol kg^{-1}) of ECEC (figure 5.20). According to Mendonca and Rowell (1996) ECEC was highly correlated with clay content and organic matter content of soil. The soils of the study area were dominated by low activity clay minerals such as Kaolinite with very low CEC. Low ECEC can also be due to the absence of enough ionization of functional groups of organic matter to provide more negative charges or due to the reduced negative charge owing to the strong interaction between organic and inorganic phases

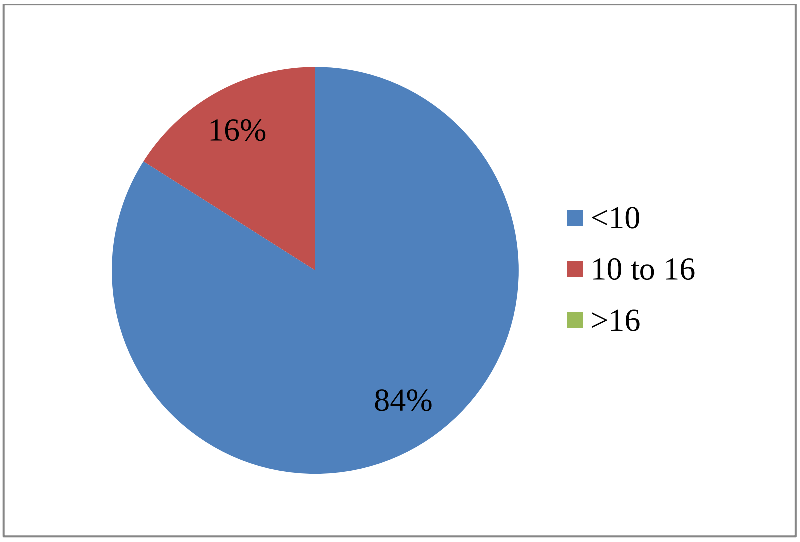


Fig 5.20 Frequency distribution of ECEC (cmol kg^{-1}) in the post flood soils of AEU 13 in Palakkad district of Kerala

Researchers reported both increase as well as reduction of cations in soil after flood. The concentration of available Ca, Mg, Na and K decreased after flood due to leaching and dilution (Day, 1982). During flood more nutrients get dissolved in soil water and lost through water infiltration and leaching. However, there may be an increase depending on the nature of the deposits retained in soil after flood. The anaerobic condition due to flood accelerate denitrification to a greater extend. The dissociation of NO_3^- from HNO_3 will hasten the leaching of cations (Barber, 1995). In the anaerobic condition due to lack of oxygen, decomposition of organic matter was in a slow rate, which decelerate the release of nutrients from organic matter (Gallardo, 2003). This also might be one of the reasons for reduced available nutrient contents recorded immediately after flood.

High available K, Mg, Na, and pH in flood affected areas was reported to be mainly due to the sediment deposition after flood (Tsheboeing *et al.*, 2014). Upsurge in lateral flow deposition, evapo-transpiration and organic matter decomposition rate instigate the increase of nutrients in post flood soils (Moorhead and Mc Author, 1996). When organic matter dried it mineralized into cationic nutrients such as Ca which cause an increase of the available cations in soil (Kalisz and Lachacz, 2009).

5.1.3 Biological attributes

5.1.3.1 Organic carbon

The average organic carbon content of the studied soil samples was 0.859%, which came under the medium category. Fifty eight percentage of the samples had medium organic carbon content, 28% low, 9% very low and 5% high amount of organic carbon (figure 5.21). Organic carbon content ranged from 0.315% to 1.83%. When compared with the pre-flood analytical data collected from District Soil Testing Laboratory, Pattambi, Department of Agriculture, the frequency of soil samples coming under medium and high category of organic carbon in soil increased after flood. Before flood in 2017, sixty percentage of the samples came under low class, 30% medium and 10% under high category. Flood cause deposition of organic matter in the affected area and lead to an increase in organic carbon in soil (Brady, 1984; Boyd, 1995). Increase in organic matter content increases the nutrient concentration and cause reduction in BD (Chaudhari *et al*., 2013). Organic carbon alters many soil characters like color, density, nutrient holding capacity, which in turn influence aeration and water relations (Pluske *et al*., 2003). The sediments brought about by river overflow in the present study might have increased the organic carbon status of the soils.

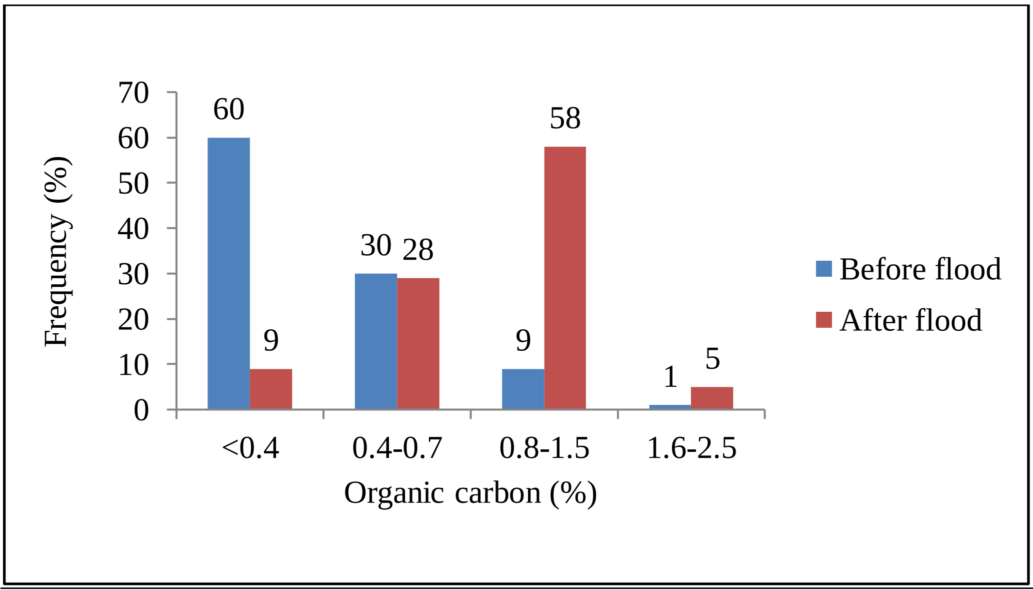


Fig 5.21 Frequency distribution of organic carbon (%) in before and after flood soils of AEU 13 in Palakkad district of Kerala

5.1.3.2 Dehydrogenase activity

Dehydrogenase activity of the surveyed area varied from 14.28 to 462.6 µg TPF g soil^{-1}day^{-1} with a mean activity of 129.0 µg TPF g soil^{-1}day^{-1}. Nearly seventy percentage of the samples had DHA more than 75 µg TPF g soil^{-1}day^{-1} (figure 5.22). Findings of Chendrayan *et al.*, 2014 denoted that soil water content and temperature influences the dehydrogenase activity in soil. The reports suggested that the flooded condition alters the oxidation-reduction status of soil which cause decrease in redox potential and oxygen diffusion rate indirectly causing an increase in dehydrogenase activity. Gu *et al.* (2009) also recorded higher DHA in flooded soils compared to non flooded soils. DHA showed a negative correlation with porosity.

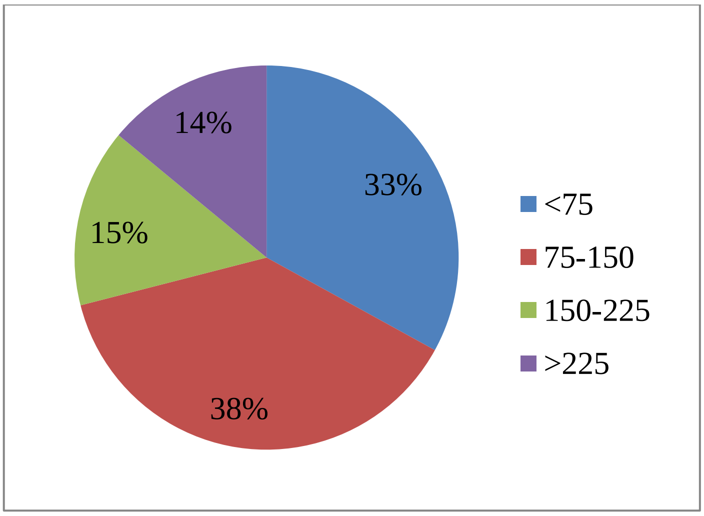


Fig. 5.22 Frequency distribution of dehydrogenase activity (µg TPF g soil^{-1}day^{-1}) in the post flood soils of AEU 13 in Palakkad district of Kerala

5.2 Comparison between the analytical data of the soil samples collected from flood and landslide affected areas

There were some appreciable differences observed in the average of soil attributes between flood affected and landslide affected soils. Regarding physical properties, bulk density (BD) and particle density (PD) were higher in landslide affected soils (Fig. 5.23) which may be due to the addition of heavier minerals to top soil during land slide.

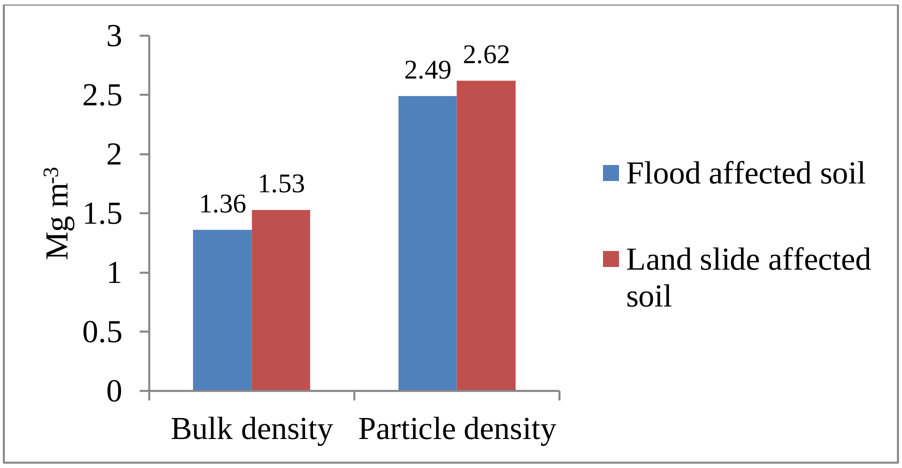


Fig 5.23 Average BD and PD of flood affected and land slide affected soils

Organic carbon percent and available N were higher in flood affected soils (0.91% and 251.2 kg ha^{-1}) than landslide affected soils (0.49% and 157.3 kg ha^{-1}).

During flooding organic matter will be deposited in the area which improves the organic carbon content and available N (fig 5.24 and 5.25). In landslide affected areas, massive deposition the materials from hills, majorly the subsoil of the inorganic composition on the surface will affect the organic C and available N in soil. There was no significant difference between soils collected from flood affected and landslide affected areas regarding available P and K.

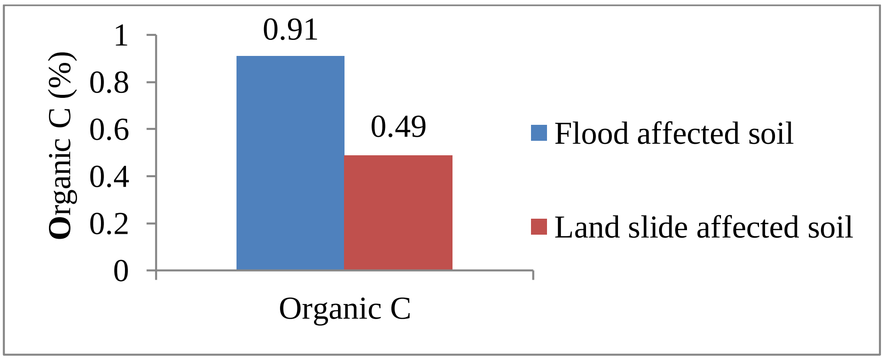


Fig 5.24 Average organic C (%) of flood affected and land slide affected soils

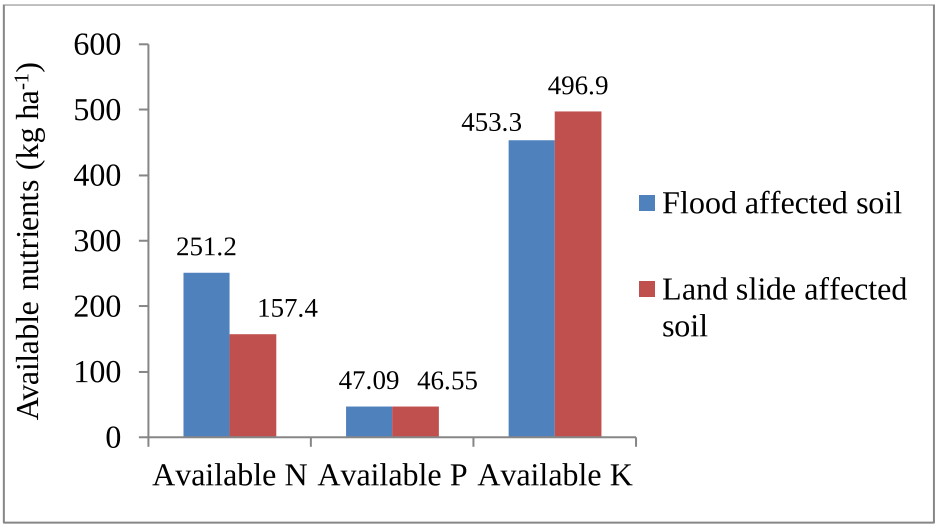


Fig 5.25 Average of available N, P and K of flood affected and land slide affected soils

Available S, Fe and Mn were higher in landslide affected soils than flood affected soils within which mean available Mn showed high variation. This may be due to incorporation of minerals containing these nutrients during landslide from subsoil areas of the hills subjected to landslide (fig 5.26)

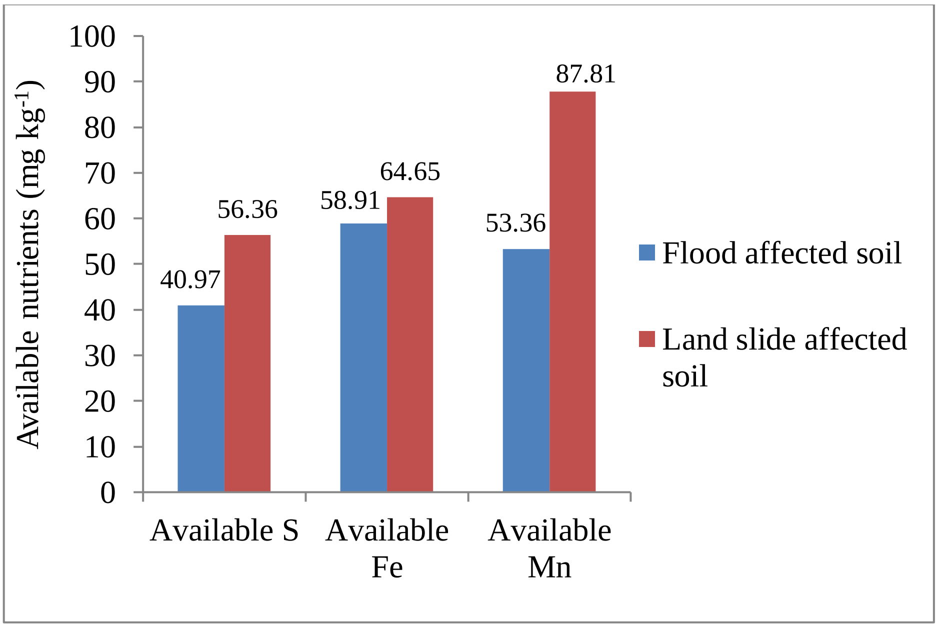
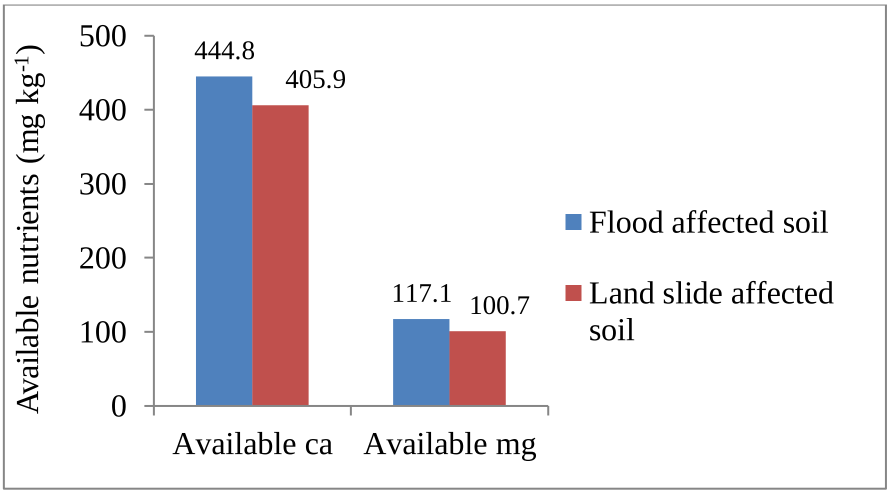
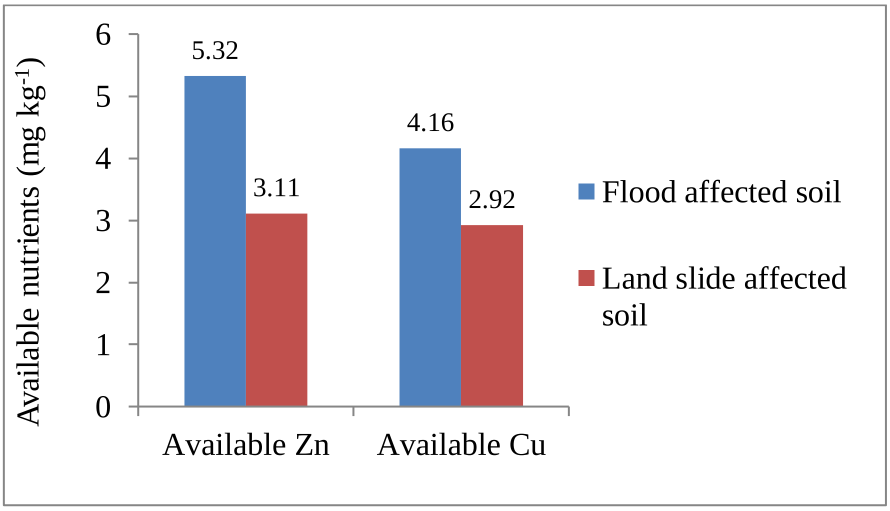


Fig 5.26 Average of available S, Fe and Mn of flood affected and land slide affected soils.

Secondary nutrients like available Ca and Mg and micronutrients like available Zn and Cu were high in flooded soils than landslide affected soils (fig 5.27 and 5.28). This may be due to the deposition of alluvium on flood affected soils. Singh *et al*. (2001) reported very low content of extractable nutrients like Ca, Mg and K in the land slide affected areas of Nepal Himalayas.



5.27 Average of available Ca and Mg of flood affected and land slide affected soils



5.28 Average of available Zn and Cu of flood affected and land slide affected soils

5.3 Soil quality index and Relative soil quality index

Computation of Soil quality index was well described in section 4. After correlation analysis of 22 soil attributes using principle component analysis (PCA), 8 attributes were selected as minimum data set (MDS). Soil quality index was calculated using the scores assigned for each attribute in the minimum data set depending on the recorded range of values for different parameters. The highest SQI computed in the selected location was 0.703 (Alanallur) and lowest was 0.314 (Karimba). Figure 5.29 gives information about the contribution of each attribute in MDS to the SQI.

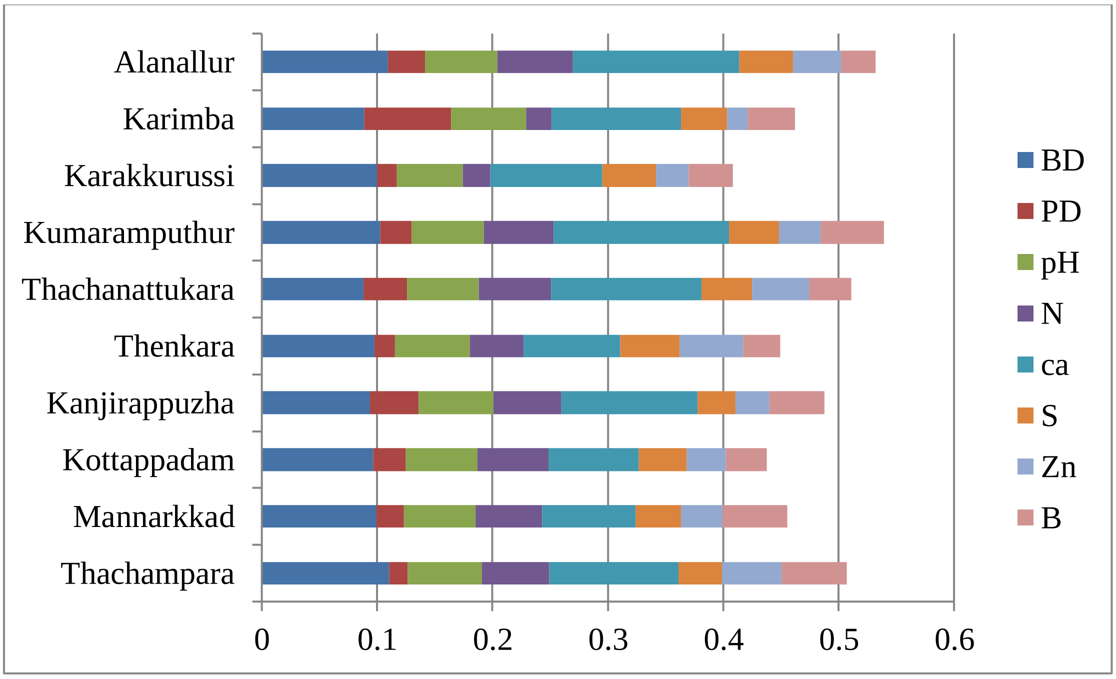


Fig. 29 Contribution of different MDS attributes to SQI of different panchayats in AEU13 in Palakkad district of Kerala

The computed SQI was compared with a theoretical maximum SQI to classify the samples to different categories (Karlen and stott, 1994) which was known as relative soil quality index (RSQI). RSQI ranged from 28.8 to 64.3%. Eighty percentage of samples had low relative soil quality and 20 % had medium RSQI (figure 5.30). When average RSQI was calculated all the 10 panchayats of AEU 13 in Palakkad came under low class of RSQI. Among the 8 MDS parameters, regarding available N and B high deficiency was reported in majority of the samples. Available Ca also was found to be deficient in few samples. High bulk density and particle density and low available N and B might be the reason for low soil quality observed throughout the area.

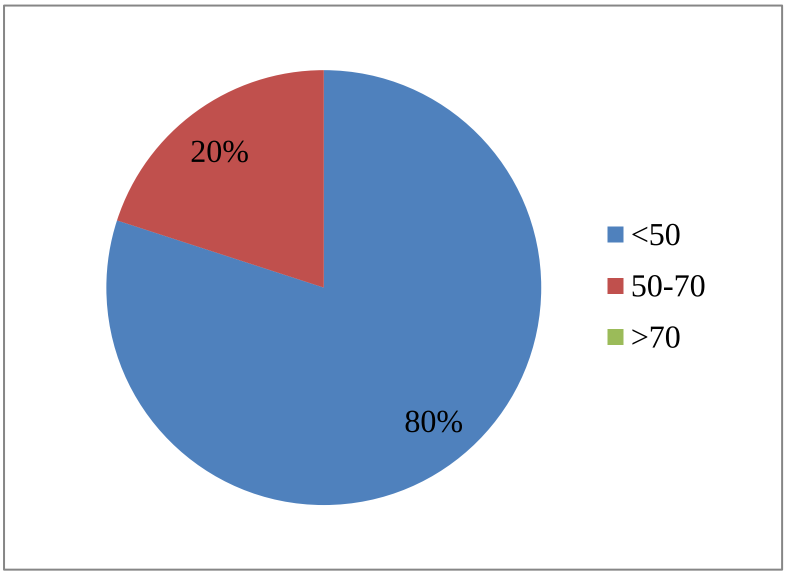


Fig 5.30 Frequency distribution of RSQI (%) in the post flood soils of AEU 13 in Palakkad district of Kerala

5.4 Nutrient indexing

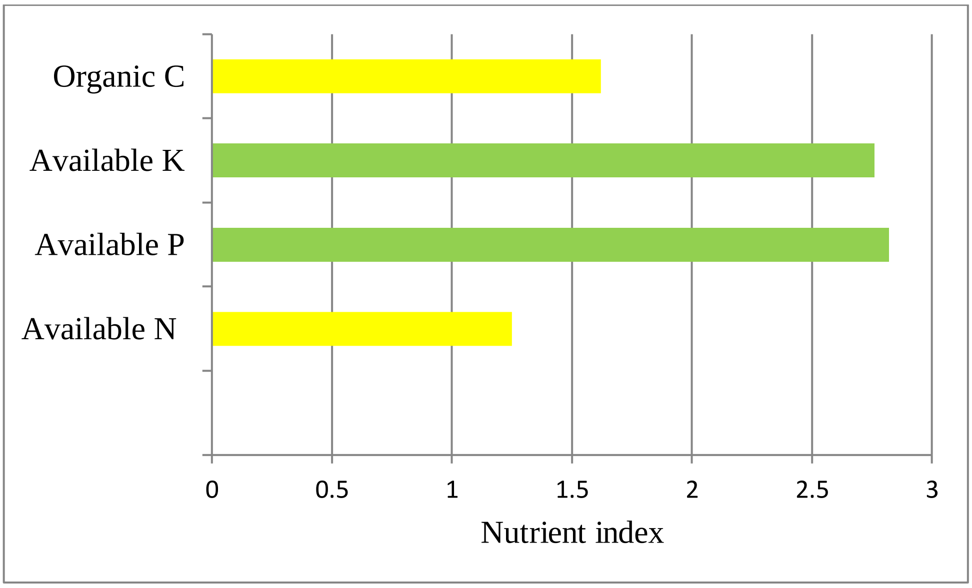


Fig. 5.31 Nutrient index of organic carbon, available N, P and K for the study area

To evaluate the soil fertility status of the surveyed area, nutrient indices of organic carbon, available N, P and K were calculated. Based on the ranges proposed by Ramamoorthy and Bajaj (1969), index computed over the range of values recorded for the survey area were classified as low, medium and high with poor, medium and good fertility status. The index depends upon the number of samples coming under each category. In our study, nutrient index of OC and available N came under low category indicating poor fertility of the area where as NI of available P and K came under high category indicating highly fertile soils with respect to P and K good fertility (figure 5.25). Ravikumar and Somashekar (2013) computed the NI of OC available N, P and K and made commends on soil fertility of Varahi river basins of Karnataka, where flooding was a common phenomena. Similarly based on the results of the present study, further amendments can be suggested to improve the fertility of flood affected areas of AEU 13 in Palakkad district of Kerala.

6. Summary

6. SUMMARY

The most devastating flood of Kerala occurred during 2018 resulted in a lot of sudden and evident damage to the human population. Assessment of these social, economical and ecological impacts of flood was very relevant as a part of rebuilding of the state. Assuming an imperceptible change taken place in soil quality, the investigation entitled "Assessment of soil quality in the post flood scenario of AEU 13 in Palakkad District of Kerala and mapping using GIS techniques" was carried out. In the beginning of the study, a survey was performed in association with Krishibhavans and 101 composite soil samples were taken from the flood and land slide affected areas of AEU 13 in Palakkad district of Kerala.

Twenty two soil attributes were analyzed and recorded. Bulk density, particle density, porosity, soil moisture content and water holding capacity were the physical attributes analysed. Soil chemical attributes like soil pH, EC, exchangeable acidity, ECEC, available N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, and B and biological characteristics such as organic carbon and dehydrogenase activity were also measured. The whole results were subjected to correlation analysis in PCA and minimum data set (MDS) with 8 attributes were developed. Available N, Ca, S, Zn, B, pH, BD and PD were the attributes which came in MDS. Nonlinear scoring function was used to score each attribute and SQI was calculated using simple additive method. RSQI was computed from SQI to categorize the area according to soil quality. Later, a comparison was made between the after flood soil test results and soil health card reports of 2017-18 (before flood) collected from DSTL, Pattambi. The results of the study are summarized below:

- The bulk density ranged from 1.1 Mg m^{-3} to 1.69 Mg m^{-3} with an average of 1.38 Mg m^{-3}. When averaged over the ten panchayats Thachampara (1.26 Mg m^{-3}) had lowest and Thachanattukara (1.52 Mg m^{-3}) had highest BD
- Average particle density of the area was 2.51 Mg m^{-3} and it ranged from 1.95 Mg m^{-3} to 2.76 Mg m^{-3}.when averaged over panchayats, Thachampara (2.38 Mg m^{-3}) had lowest and Karimba (2.63 Mg m^{-3}) had highest PD

- Mean porosity of the study area was 44.7% and it ranged from 32% to 59%. When averaged over different panchayats, the highest mean was observed in Thachanattukara (42%) and lowest in both Thachampara and Alanallur (47%)
- Mean maximum water holding capacity varied from 31% (Karimba) to 47.09% (Alanallur) with an overall mean of 38.02%
- Moisture content showed high variation (2.48%-43.72%) with an average of 19.79%. when averaged over different panchayats, Thachampara (13.5%) had lowest and Thachanattukara (27.34%) had highest MC
- The available N ranged from 94.08 kg ha^{-1} to 273.5 kg ha^{-1} with an average of 238.2 kg ha^{-1}. When averaged over the ten panchayats, Karimba (131.1 kg ha^{-1}) had lowest and Alanallur (273.5 kg ha^{-1}) had highest available N
- Average available P of the area was 47.02 kg ha^{-1} and it ranged from 12.06 kg ha^{-1} to 108.9 kg ha^{-1}. When averaged over different panchayats, Kottopadam (59.8 kg ha^{-1}) had lowest and Kumaramputhur (34.62 kg ha^{-1}) had highest available P
- Mean available K of the study area was 459.3 kg ha^{-1} and it ranged from 134.1 kg ha^{-1} to 1079 kg ha^{-1}. Highest mean was observed in Thachanattukara (532.8 kg ha^{-1}) and lowest in Thenkara (411 kg ha^{-1})
- Available Ca showed high variation (106.1 mg kg^{-1}-957.4 mg kg^{-1}) with an average of 439.5 mg kg^{-1}. When averaged over different panchayats Mannarkkad (340.7 mg kg^{-1}) had lowest and Kumaramputhur (600.1 mg kg^{-1}) had highest available Ca
- Mean Available Mg varied from 87.25 mg kg^{-1} (Thenkara) to 188.8 mg kg^{-1} (Thachanattukara) with an overall mean of 114.9 mg kg^{-1}. Sixty percent of samples exhibited Mg deficiency
- Available S ranged from 11.53 mg $kg^{-1}$to 82.1 mg kg^{-1} with an average of 43.09 mg kg^{-1}. When averaged over the ten panchayats, Mannarkkad (36.12 mg kg^{-1}) had the lowest and Karakurissi (62.62 mg kg^{-1}) had the highest mean available S

- All the cationic micronutrients were sufficient in the area with a mean content of 59.71 mg kg^{-1} for available Fe, 58.14 mg kg^{-1} for available Mn, 3.99 mg kg^{-1} for available Cu and 5.02 mg kg^{-1} for available Zn
- Mean available B of the study area was 0.227 mg kg^{-1} and its range was from 0.09 mg kg^{-1} to 0.92 mg kg^{-1}. Highest mean available B was observed in Mannarkkad (0.31 mg kg^{-1}) and lowest in Alanallur (0.17 mg kg^{-1})
- All the samples were acidic with an average pH of 5.36 and range of 3.86 to 6.77. highest mean value was observed in Kanjirappuzha (5.48) and lowest in Karakurissi (4.99)
- Electrical conductivity of the samples were low with an average of 0.074 dS m^{-1}. When averaged over ten panchayats, Kottapadam (0.014 dS m^{-1}) had the lowest and Thenkara (0.168 dS m^{-1}) had the highest mean EC
- Very low exchangeable acidity was recorded from the study area and it ranged from 0.016 cmol kg^{-1}-0.666 cmol kg^{-1}. Highest mean was observed in Mannarkkad (0.221) and lowest in Thachampara (0.016 cmol kg^{-1})
- Mean ECEC varied from 6.97 cmol kg^{-1} (Thenkara) to 9.78 cmol kg^{-1} (Alanallur) with an overall mean of 8.365 cmol kg^{-1}. Eighty four percentage of the samples had an ECEC <10 cmol kg^{-1}.
- Organic carbon varied from 0.325% to 1.78% with a mean of 0.859%. Highest mean of OC was recorded in Kottappadam (1.12%) and lowest in Karimba (0.51%)
- Dehydrogenase activity ranged from 14.28 µg TPF g $soil^{-1}day^{-1}$ to 462.6 µg TPF g $soil^{-1}day^{-1}$ with an average of 129.0 µg TPF g $soil^{-1}day^{-1}$. When averaged over the ten panchayats, Thenkara (91.81 µg TPF g $soil^{-1}day^{-1}$) had lowest and Thachanattukara (238.9 µg TPF g $soil^{-1}day^{-1}$) had highest DHA

Comparison between pre flood and post flood analytical data of the soil samples

- Compared to the pre flood data from DSTL, Pattambi, Organic C, available P and S increased after flood
- Cationic micronutrients were sufficient before and after flood, where as available B decreased after flood

- Compared to the pre flood data of 2013 (Rajashekaran *et al., 2013)* available Ca and Mg were more deficient after flood
- Soil pH and EC showed slight reduction after flood

Comparison of the present status of the soil samples collected from flood and land slide affected areas

- Land slide affected soils had high BD, PD, available S, Fe and Mn compared to flood affected soils
- Flood affected soils had high organic C, available N, Ca, Mg, Zn and Cu compared to land slide affected soils
- Other attributes did not show significant variation

Soil quality and nutrient indices

- SQI of the area varied from 0.314 to 0.703
- The average RSQI was 43.92% rated as low and all the 10 panchayats had poor soil quality, when averaged over panchayats Kumaramputhur had highest (49.36%) and Karakkurussi had lowest (37.36%) average RSQI
- Eighty percentage of the samples had low RSQI and the remaining 20% had medium RSQI
- Nutrient index of organic carbon and available N came under low class where as that of available P and K came under high class

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Appendices

APPENDICES

Appendix I. Soil test results of 22 soil attributes of 101 soil samples of flood affected areas of AEU 13 in Palakkad district of Kerala

The soil attributes were bulk density (BD) (Mg m^{-3}), particle density PD (Mg m^{-3}), Porosity (%), Maximum water holding capacity (MWHC) (%), Moisture content (%), Organic carbon (OC)(%), Dehydrogenase activity (DHA)(µg TPF g $soil^{-1}day^{-1}$), Soil pH, EC (dS m^{-1}), available N (kg ha^{-1}), P(kg ha^{-1}), K(kg ha^{-1}), Ca (mg kg^{-1}), Mg (mg kg^{-1}), S (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}), Zn (mg kg^{-1}), Cu (mg kg^{-1})and B (mg kg^{-1}), effective cation exchange capacity (ECEC) (cmol kg^{-1}) and exchangeable acidity (EA) (cmol kg^{-1}).

Sample No.	Bulk density	Particle density	Porosity	Moisture content	MWHC	OC	DHA	PH
1	1.362	2.252	0.395	13.9	32.76	0.69	336.8	5.22
2	1.232	2.392	0.484	14.33	34.54	0.57	96.53	5.39
3	1.457	2.577	0.434	17.49	40.35	0.72	130.1	5.73
4	1.494	2.5	0.402	17.08	37.09	0.825	437.1	5.67
5	1.104	2.225	0.503	14.97	36.59	0.69	327.3	4.68
6	1.216	2.617	0.535	11.53	43.34	0.65	68.65	4.97
7	1.201	2.293	0.476	9.235	43.41	0.75	304.2	5.38
8	1.172	2.27	0.484	13.22	48.05	0.42	63.90	5.47
9	1.143	2.293	0.501	9.725	44.40	0.56	59.48	6.5
10	1.292	2.358	0.452	15.05	41.45	0.72	53.02	6.1
11	1.077	2.24	0.519	21.36	43.15	0.85	14.27	5.16
12	1.391	2.590	0.462	14.92	37.34	0.78	113.8	5.27
13	1.604	2.369	0.322	12.17	31.88	0.705	152.6	5.45
14	1.291	2.673	0.516	17.43	46.31	1.1	62.54	6.15
15	1.322	2.5	0.471	15.42	38.52	1.24	80.89	4.94
16	1.509	2.617	0.42	13.05	36.06	0.87	107.0	4.92
17	1.480	2.427	0.38	12.68	38.74	0.765	462.5	6.77
18	1.305	2.325	0.438	9.292	37.49	0.6	80.21	4.5
19	1.413	2.538	0.442	22.53	40.99	0.93	183.2	6.18

20	1.478	2.56	0.423	20.91	40.52	0.71	114.5	5.22
21	1.260	2.26	0.443	24.86	42.00	0.38	164.8	4.59
22	1.334	2.43	0.45	26.45	41.32	0.42	125.4	5.22
23	1.51	2.60	0.420	17.14	36.41	0.315	92.72	4.21
24	1.48	2.59	0.42	15.88	38.88	0.575	91.43	5.21
25	1.376	2.336	0.410	15.67	37.75	1.71	166.20	5.48
26	1.42	2.538	0.440	20.02	39.09	0.51	66.61	5.24
27	1.25	2.232	0.44	18.69	33.09	1.125	64.24	5.17
28	1.509	2.55	0.408	23.08	35.57	1.2	39.08	5.11
29	1.41	2.631	0.464	12.01	33.10	1.365	70.69	4.71
30	1.405	2.604	0.46	21.72	41.92	1.74	133.5	5.14
31	1.255	2.46	0.49	26.2	41.73	1.29	95.17	4.98
32	1.421	2.68	0.469	26.11	36.44	1.32	69.67	5.05
33	1.19	2.42	0.509	23.67	46.00	1.53	133.5	4.62
34	1.279	2.41	0.470	14.76	36.30	1.41	15.63	5.22
35	1.438	2.59	0.444	17.13	36.95	1.83	48.94	4.75
36	1.627	2.759	0.410	15.96	36.78	1.38	31.61	5.86
37	1.614	2.64	0.389	16.05	30.53	1.305	161.7	5.99
38	1.425	2.59	0.449	20.77	40.58	1.785	75.45	4.81
39	1.451	2.551	0.430	14.63	39.90	1.155	279.7	6.08
40	1.42	2.625	0.459	21.96	41.72	0.53	35.68	5.6
41	1.48	2.551	0.419	23.04	35.97	0.525	283.6	5.41
42	1.501	2.702	0.444	23.44	34.79	0.39	213.0	5.45
43	1.458	2.64	0.448	14.56	39.26	0.45	259.5	5.8
44	1.520	2.736	0.444	17.10	32.57	0.36	28.91	5.75
45	1.580	2.525	0.374	17.43	34.18	0.35	114.9	5.95
46	1.200	2.43	0.506	24.61	39.85	0.975	297.0	5.21
47	1.659	2.68	0.382	17.87	37.45	0.35	96.37	5.16
48	1.47	2.61	0.436	14.50	33.26	1.45	53.75	6.48
49	1.365	2.504	0.454	22.00	45.54	0.97	65.05	5.9
50	1.536	2.56	0.402	19.63	36.88	0.53	78.81	4.78
51	1.541	2.57	0.40	21.29	31.90	0.81	107.73	5.47
52	1.408	2.46	0.427	25.4	39.53	0.75	32.69	4.76
53	1.311	2.55	0.485	24.68	43.3	0.68	78.81	4.9
54	1.348	2.59	0.479	21.26	29.25	0.615	70.55	5.32
55	1.450	2.732	0.469	25.31	39.94	0.57	213.3	6.18
56	1.097	2.245	0.511	12.06	47.85	0.81	59.88	6.36
57	1.505	2.61	0.423	18.26	22.31	0.54	148.00	4.89
58	1.589	2.65	0.400	20.07	18.1	0.7	21.33	5.27

59	1.45	2.59	0.440	21.15	35.21	0.81	138.0	5.3
60	1.566	2.475	0.367	28.24	36.47	1.18	54.72	4.91
61	1.637	2.72	0.397	13.32	11.55	0.865	332.1	6.34
62	1.419	2.631	0.460	31.91	44.7	1.12	356.9	5.2
63	1.29	2.617	0.507	26.52	43.47	1.23	149.0	5.7
64	1.69	2.604	0.351	36.74	12.53	1.08	301.8	4.31
65	1.47	2.52	0.416	17.40	35.11	0.81	67.11	4.86
66	1.240	2.564	0.516	13.53	38.50	0.84	77.44	5.91
67	1.196	2.477	0.516	29.95	49.40	0.95	104.9	6.2
68	1.444	2.551	0.433	25.49	42.32	1.05	80.53	4.73
69	1.196	2.252	0.468	34.87	22.77	1.215	217.5	5.89
70	1.319	2.503	0.472	26.78	44.35	1.305	187.2	6.17
71	1.280	2.38	0.461	31.37	40.96	1.08	233.0	5.17
72	1.502	2.675	0.438	25.13	39.04	1.25	81.91	3.98
73	1.445	2.581	0.44	17.73	9.477	1.005	261.5	4.61
74	1.356	2.39	0.432	9.451	37.23	1.02	157.6	6.25
75	1.23	2.392	0.485	7.90	39.15	0.615	73.65	4.73
76	1.47	2.604	0.435	18.92	38.00	0.57	175.1	4.08
77	1.501	2.358	0.363	25.84	39.94	0.645	203.4	5.68
78	1.313	2.551	0.48	20.44	26.00	0.67	53.69	5.4
79	1.45	2.645	0.451	25.17	39.01	0.81	88.45	6.24
80	1.34	2.381	0.437	30.02	32.94	0.405	140.4	5.73
81	1.35	2.688	0.497	20.07	34.11	0.48	75.37	4.62
82	1.403	2.74	0.487	27.67	37.43	0.51	45.77	5.37
83	1.622	2.55102	0.364	24.03	32.88	0.41	72.04	5.24
84	1.63	2.475	0.341	21.66	25.57	0.35	130.7	5.39
85	1.67	2.722	0.386	14.89	14.61	0.325	103.9	6.07
86	1.481	2.66	0.443	31.76	32.00	0.945	83.29	5.35
87	1.625	2.72	0.402	26.32	33.24	0.36	163.8	5.39
88	1.52	2.717	0.44	33.06	28.22	0.52	66.42	5.16
89	1.412	2.347	0.398	26.08	36.47	0.95	83.29	4.82
90	1.281	2.5	0.487	34.16	48.36	1.05	156.9	5.67
91	1.36	2.631	0.483	8.437	46.57	0.91	137.6	4.29
92	1.25	2.538	0.507	6.369	44.69	0.93	161.7	4.53
93	1.447	1.75	0.173	20.55	15.94	0.88	140.4	6.14
94	1.260	2.564	0.508	8.601	49.12	1.65	28.22	5.94
95	1.117	2.325	0.519	38.92	50.42	0.825	56.79	5.72
96	1.131	2.6	0.565	2.917	50.02	1.17	59.96	5.34
97	1.442	2.69	0.463	28.78	44.24	1.095	93.9	5.66

98	1.281	2.42	0.470	11.31	40.30	1.17	120.1	4.18
99	1.191	2.314	0.485	2.481	45.55	0.57	90.17	6.36
100	1.28	2.5	0.488	6.873	44.4	0.65	53.0	5.43
101	1.122	2.369	0.526	34.71	50.12	0.6	135.9	5.71

Sample No.	**EC**	**Available N**	**Available P**	**Available K**	**Available Ca**	**Available Mg**	**Available S**
1	0.058	256.1	18.46	134.8	309.3	30.39	46.5
2	0.143	155.1	23.61	212.7	456.1	84.21	33.92
3	0.056	363.7	53.46	366.1	513.5	125.9	58.12
4	0.075	457.8	114.7	848.0	530.1	105.9	26.43
5	0.043	194.4	38	179.5	456.1	194.3	35.17
6	0.057	181.8	19.25	134.1	293.7	74.78	16.52
7	0.036	232.0	95.34	688.2	383.1	106.1	43.51
8	0.047	181.8	17.1	338.2	351.4	59.16	64.95
9	0.097	250.5	40.4	568.3	520.4	119.7	58.1
10	0.048	200.7	32.65	324.8	349.7	98.15	23.69
11	0.034	287.8	59.72	365.4	392.7	124.3	15.46
12	0.043	219.5	64.35	346.7	335.8	50.49	41.25
13	0.034	263.4	17.65	198.6	380.9	79.62	28.7
14	0.049	455.7	46.91	851.1	493.9	140.8	36.91
15	0.026	472.4	77.82	412.6	188.4	90.96	17.84
16	0.039	401.4	53.49	223.1	197.4	46.14	25.66
17	0.120	263.7	86.54	294.6	538.2	145.0	46.35
18	0.082	169.3	51.23	151.4	106.1	56.34	41.38
19	0.073	257.1	45.6	587.1	659.4	117.6	39.68
20	0.039	206.9	12.06	426.8	295.2	122.8	45.26
21	0.043	150.1	87.19	598.3	213.4	48.36	41.96
22	0.067	175.6	34.65	911.0	471.8	88.89	41.37
23	0.056	94.08	40.82	401.3	237.0	51.77	42.68
24	0.042	194.4	108.91	313.0	250.5	77.67	53.61
25	0.065	369.6	95.46	731.1	408.2	115.0	35.66
26	0.074	175.6	73.24	211.0	210.8	49.39	26.1
27	0.059	263.4	78.36	301.1	392.3	101.6	34.72
28	0.058	225.7	46.25	724.5	356.2	90.93	31.06

29	0.078	275.9	53.62	163.0	196.7	42.13	58.75
30	0.043	438.6	49.12	376.9	299.9	132.0	76.42
31	0.046	263.4	43.62	414.3	275.6	194.6	27.11
32	0.051	257.1	75.81	140.1	314.4	79.14	58.46
33	0.042	244.6	65.42	358.8	202.3	52.59	59.2
34	0.046	317.1	95.24	705.1	215.4	68.79	65.4
35	0.056	369.6	23.59	794.9	204.1	85.51	43.51
36	0.050	281.8	35.18	669.8	212.4	244.5	29.88
37	0.055	238.3	76.15	211.5	628.1	195.5	37.44
38	0.036	319.8	24.59	610.5	278.2	109.2	39.62
39	0.061	232.0	38.64	513.4	883.4	297.4	28.67
40	0.021	250.8	71.58	575.9	563.6	107.8	54.39
41	0.010	131.7	59.84	236.5	517.8	161.3	82.1
42	0.043	95.37	63.46	695.1	243.0	68.45	62.45
43	0.016	156.8	67.11	353.4	187.5	22.51	42.55
44	0.137	100.3	73.89	464.2	539.7	128.1	46.32
45	0.091	131.7	43.61	410.5	292.5	52.5	53.16
46	0.188	338.6	19.06	458.7	398.4	100.9	59.81
47	0.06	213.2	27.65	554.6	442.7	120.8	41.62
48	0.053	432.0	28.13	726.0	931.8	88.89	11.53
49	0.051	389.5	49.16	708.2	524.1	69.96	58.41
50	0.124	181.8	15.86	175.1	339.3	156.4	46.52
51	0.099	263.4	29.89	347.9	473.1	124.1	49.28
52	0.126	238.3	34.75	321.0	327.3	127.6	26.94
53	0.126	269.6	56.94	222.1	342.3	94.62	38.49
54	0.074	257.1	81.46	685.0	404.8	225.1	75.14
55	0.105	225.7	26.53	527.1	472.1	208.7	62.41
56	0.085	263.4	18.75	868.7	651.0	113.3	33.57
57	0.129	156.8	23.57	193.8	172.6	16.62	31.45
58	0.124	169.3	38.91	126.7	272.3	74.35	42.6
59	0.117	225.7	63.45	154.5	338.9	144.6	38.16
60	0.090	344.9	52.84	578.3	295.4	126.2	35.67
61	0.045	206.9	55.36	309.2	809.6	360.1	42.98
62	0.08	257.1	42.59	494.8	626.1	155.1	47.11
63	0.050	282.2	21.56	735.5	681.5	224.3	34.61
64	0.080	200.7	68.43	546.4	226.4	78.12	53.48
65	0.100	143.9	57.62	548.2	372.4	86.97	37.45
66	0.045	156.8	43.59	447.0	705.0	130.5	26.55
67	0.037	275.9	41.68	194.8	719.8	92.65	31.58

68	0.087	232.0	37.95	426.9	364.4	42.85	34.96
69	0.074	344.6	12.68	879.6	623.2	124.6	58.42
70	0.086	301	18.17	510.0	825.2	227.9	47.18
71	0.040	250.8	29.35	629.5	560.7	120.5	56.83
72	0.056	269.6	34.81	284.1	572.4	168.5	47.11
73	0.046	257.1	26.74	171.7	299.7	72.15	35.66
74	0.135	263.4	43.59	466.2	957.4	125.5	64.72
75	0.195	181.8	81.46	399.3	329.2	49.25	38.14
76	0.123	104.0	91.05	245.0	196.2	74.4	32.46
77	0.110	125.4	51.23	558.8	528.2	278.6	45.71
78	0.116	137.9	16.49	878.7	479.1	93.6	43.95
79	0.158	169.3	62.41	342.4	744	193.9	43.08
80	0.140	131.7	36.57	612.5	528.7	102.7	24.15
81	0.059	106.6	41.24	530.3	285.3	84.82	35.61
82	0.039	119.1	55.13	210.6	303.6	33.81	33.55
83	0.067	100.3	58.91	549.8	520.7	163.5	27.64
84	0.068	87.80	28.99	448.3	557.2	85.65	68.51
85	0.062	81.75	39.61	1265.	415.0	118.9	61.72
86	0.064	250.8	26.81	344.0	307.0	85.65	67.09
87	0.089	119.1	51.2	348.6	467	139.8	58.44
88	0.073	144.2	19.96	251.8	230.9	53.43	63.25
89	0.066	282.2	23.46	338.5	267.7	75.32	55.83
90	0.113	326.1	25.34	755.5	901.4	163.5	34.45
91	0.037	213.2	39.61	171.8	428.2	135.0	28.95
92	0.080	257.1	34.87	666.2	371.7	164.5	36.7
93	0.131	238.3	42.59	648.0	904.0	129.5	45.18
94	0.103	381.8	51.62	905.5	593.9	255.6	46.09
95	0.103	225.7	78.61	784.2	717.6	175.4	40.01
96	0.043	382.5	44.86	167.0	486.7	103.9	47.26
97	0.095	363.7	44.01	603.5	652.4	136.5	32.54
98	0.043	344.9	16.88	299.9	234.0	89.57	38.64
99	0.077	169.3	25.94	422.8	801.8	94.89	36.13
100	0.068	194.4	36.54	384.8	496.5	34.1	40.28
101	0.075	175.6	29.17	426.5	557.2	42.35	39.43

Sample No.	Available Fe	Available Mn	Available Zn	Available Cu	Available B	ECEC	Exchangeable acidity
1	44.11	8.35	4.89	6.35	0.278	5.704	0.333
2	33.55	11.98	4.02	5.43	0.239	5.946	0.166
3	95.76	25.08	6.09	5.04	0.234	8.188	0.033
4	94.8	27.48	9.73	4.01	0.298	8.55	0.016
5	110.3	76.03	4.4	5.31	0.274	9.026	0.666
6	92.96	51.43	5.17	5.96	0.220	7.104	0.166
7	39.27	20.51	8.33	7.28	0.376	7.720	0.2
8	146.5	64.73	6.55	5.15	0.327	6.608	0.066
9	51.65	19.05	2.78	2.47	0.210	7.193	0.033
10	60.61	50.54	2.75	1.31	0.288	7.996	0.133
11	112.8	21.09	5.14	3.88	0.259	8.374	0.4
12	28.93	19.86	3.57	3.8	0.234	6.589	0.033
13	39.08	37.33	4.61	2.96	0.293	7.569	0.016
14	61.3	17.08	2.76	4.85	0.215	7.452	0.033
15	40.63	14.9	2.65	1.74	0.440	6.924	0.2
16	51.03	43.9	4.77	1.98	0.244	7.437	0.433
17	101.0	12.85	8.15	8.41	0.249	7.472	0.033
18	145.6	17.09	4	2.83	0.264	5.767	0.366
19	29.55	39.31	2.8	1.94	0.215	7.049	0.166
20	125.6	29.62	3.38	3.57	0.401	7.05	0.1
21	50.56	52.24	10.5	4.05	0.176	9.513	0.666
22	36.66	25.37	7.1	3.7	0.249	8.045	0.066
23	24.5	50.33	4.92	2.93	0.166	8.871	0.6
24	17.2	20.13	5.18	3.61	0.924	6.459	0.066
25	18	80.97	5	3.18	0.181	7.755	0.033
26	32.02	48.08	3.45	3.49	0.166	6.488	0.1
27	71.58	10.49	4.41	3.97	0.107	7.259	0.05
28	84.76	12.62	3.08	4.3	0.171	6.754	0.1
29	60.98	43.83	8.41	3.2	0.200	7.501	0.3
30	20.69	92.61	3.43	2.21	0.195	7.177	0.166
31	37.86	32.42	2.44	3.93	0.092	7.724	0.133
32	91.13	51.08	5.85	3.57	0.249	8.379	0.133
33	15.62	62.41	4.71	2.28	0.137	7.570	0.466
34	52.97	147.8	5.55	3.2	0.146	7.489	0.166

35	18.69	120.1	2.95	3.07	0.254	8.555	0.333
36	79.3	26.06	3.32	3.02	0.097	8.001	0.033
37	82.21	18.48	1.8	3.4	0.161	7.782	0.033
38	15.52	121.4	2.44	2.3	0.308	7.884	0.500
39	26.58	82.33	9.19	2.61	0.146	10.70	0.201
40	43.2	50.43	3.02	2.78	0.411	9.995	0.366
41	105.2	72.59	1.84	1.52	0.220	10.29	0.100
42	71.58	41.31	4.96	3.46	0.195	5.934	0.016
43	96.51	103.4	2.57	2.19	0.185	6.300	0.066
44	47.44	36.28	3.26	1.59	0.327	9.289	0.066
45	37.77	41.43	2.97	1.50	0.200	6.549	0.033
46	40.25	44.31	5.79	4.40	0.254	9.157	0.050
47	17.61	96.35	5.00	5.10	0.137	8.915	0.166
48	14.65	84.95	12.21	1.68	0.239	11.318	0.066
49	57.5	18.09	2.86	1.58	0.215	10.006	0.300
50	26.13	23.98	2.23	3.36	0.288	8.0647	0.133
51	34.85	50.55	4.78	5.52	0.298	8.007	0.033
52	39.75	18.96	3.05	2.87	0.205	7.259	0.016
53	18.55	38.08	3.49	2.43	0.171	6.580	0.066
54	19.89	20.75	4.01	2.69	0.259	8.175	0.033
55	70.12	35.52	4.17	2.66	0.195	8.316	0.100
56	48.44	46.29	7.23	3.63	0.141	9.433	0.033
57	116.6	33.99	7.57	2.51	0.166	6.359	0.366
58	134.6	15.67	5.35	3.91	0.112	5.655	0.2
59	94.37	16.22	3.78	3.16	0.293	6.432	0.066
60	116.4	52.47	7.79	7.86	0.288	9.986	0.233
61	105.8	46.31	3.33	4.19	0.254	10.27	0.033
62	86.39	84.15	8.76	5.05	0.122	9.594	0.2
63	39.81	115.8	2.75	7.18	0.137	9.966	0.166
64	129.0	55.25	5.78	5.37	0.166	10.45	0.3
65	81.57	109.9	14.99	5.24	0.141	10.32	0.233
66	66.58	86.9	3.08	3.23	0.215	7.760	0.066
67	48.33	65.65	2.74	4.00	0.318	6.978	0.066
68	80.21	70.01	7.36	4.85	0.244	9.792	0.333
69	27.08	109.2	3.3	5.75	0.308	8.608	0.183
70	23.12	48.41	6.17	4.82	0.362	10.79	0.05
71	33.98	120.4	6.99	6.39	0.303	9.598	0.133
72	48.88	65.67	9.01	5.72	0.293	10.00	0.333
73	12.95	18.93	2.72	6.55	0.239	6.818	0.166

74	35.93	70.84	38.98	2.28	0.2447	10.39	0.035
75	37.2	73.21	5.00	4.8	0.205	10.32	0.15
76	32.6	19.72	2.19	4.6	0.244	10.35	0.3
77	30	17.47	1.88	5.31	0.112	7.913	0.066
78	38.6	60.55	4.95	4.84	0.220	9.508	0.05
79	102.2	106.7	3.38	3.74	0.161	9.463	0.033
80	61.21	127.1	3.98	2.79	0.117	8.356	0.066
81	40.27	156.6	3.37	2.44	0.088	8.625	0.166
82	66.29	36.26	1.77	2.38	0.254	5.867	0.1
83	83.44	140.7	1.89	2.85	0.293	9.563	0.083
84	76.16	187.7	1.40	2.23	0.200	8.482	0.2
85	33.12	136.9	3.60	2.89	0.220	8.559	0.016
86	104.9	122.0	2.48	2.64	0.239	6.531	0.1
87	85.13	90.02	3.19	4.71	0.215	8.112	0.133
88	62.8	65.7	1.60	2.98	0.298	7.002	0.066
89	110.2	84.74	5.43	6.72	0.117	11.85	0.166
90	95.85	23.07	5.89	6.19	0.097	14.09	0.1
91	32.1	45.59	2.22	4.23	0.137	8.778	0.183
92	21.84	102.7	5.28	4.48	0.122	9.819	0.2
93	70.24	42.62	5.73	7.73	0.166	10.41	0.033
94	20.19	19.08	1.79	4.36	0.137	9.521	0.033
95	44.63	26.57	3.93	4.99	0.092	10.63	0.066
96	94.26	50.01	3.89	8.15	0.137	7.954	0.033
97	47.28	95.66	9.00	4.77	0.166	9.063	0.016
98	30.26	65.49	2.45	3.45	0.220	8.651	0.2
99	72.74	122.4	6.14	6.48	0.298	9.965	0.25
100	43.85	60.37	3.34	4.85	0.249	8.264	0.100
101	80.08	76.43	6.55	4.36	0.254	8.104	0.066

Appendix II. SQI and RSQI of the soil samples

Sample No.	SQI	RSQI
1	0.455	41.65
2	0.489	44.77
3	0.546	50.03
4	0.630	57.67

5	0.514	47.03
6	0.397	36.40
7	0.541	49.56
8	0.478	43.81
9	0.511	46.76
10	0.424	38.81
11	0.489	44.80
12	0.436	39.94
13	0.494	45.19
14	0.645	59.05
15	0.409	37.44
16	0.449	41.09
17	0.570	52.18
18	0.348	31.87
19	0.539	49.37
20	0.426	39.04
21	0.327	30.00
22	0.514	47.09
23	0.324	29.69
24	0.435	39.84
25	0.511	46.83
26	0.369	33.77
27	0.461	42.25
28	0.422	38.69
29	0.409	37.45
30	0.421	38.6
31	0.396	36.27
32	0.543	49.71
33	0.36	33.67
34	0.399	36.57
35	0.402	36.83
36	0.372	34.06
37	0.487	44.57
38	0.432	39.56
39	0.611	55.90
40	0.530	48.53
41	0.406	37.22
42	0.433	39.66
43	0.332	30.41
44	0.563	51.59
45	0.350	32.03
46	0.519	47.51

47	0.537	49.14
48	0.557	50.97
49	0.517	47.32
50	0.392	35.94
51	0.510	46.70
52	0.432	39.58
53	0.439	40.21
54	0.463	42.41
55	0.567	51.93
56	0.604	55.31
57	0.374	34.25
58	0.363	33.27
59	0.454	41.62
60	0.492	45.02
61	0.637	58.35
62	0.542	49.59
63	0.539	49.33
64	0.342	31.35
65	0.365	33.40
66	0.548	50.18
67	0.606	55.51
68	0.489	44.77
69	0.572	52.37
70	0.641	58.72
71	0.562	51.43
72	0.648	59.35
73	0.415	38.02
74	0.544	49.85
75	0.439	40.20
76	0.314	28.76
77	0.400	36.66
78	0.470	43.82
79	0.510	46.68
80	0.475	43.49
81	0.429	39.32
82	0.470	43.64
83	0.451	41.28
84	0.388	35.54
85	0.482	44.12
86	0.487	44.60
87	0.499	45.68
88	0.420	38.46

89	0.388	35.58
90	0.602	55.14
91	0.428	39.18
92	0.458	41.92
93	0.672	61.51
94	0.520	47.67
95	0.538	49.27
96	0.523	47.85
97	0.703	64.34
98	0.402	36.82
99	0.615	56.28
100	0.497	45.56
101	0.560	51.69

Appendix III. Fertility ratings of soils

Soil attribute	**Range**	**Rating**
Soil pH	<3.5	Ultra acid
	3.5-4.5	Ex. Acid
	4.5-5.0	V, Strongly acid
	5.0-5.5	Strongly acid
	5.5-6.0	Moderately acid
	6.0-6.5	Slightly acid
	6.5-7.3	Neutral
	7.3-7.8	Slightly alkaline
	7.8-8.4	Moderately alkaline
	8.4-9.0	Strongly alkaline
	>9.0	V, Strongly alkaline
Organic carbon (%)	<0.4	Very low
	0.4-0.7	Low
	0.7-1.5	Medium
	1.5-2.5	High
	2.5-5.0	V. high
	>5.0	Ex. High
Available N (Kg ha^{-1})	<280	Low
	280-560	Medium
	>560	High
Available P (Kg ha^{-1})	<5	Very low
	5-10	Low
	10-25	Medium
	25-35	High

	35-100	V. high
	>100	Ex. High
Available K (Kg ha^{-1})	<75	Very low
	75-115	Low
	115-275	Medium
	275-400	High
	400-1000	V. high
	>1000	Ex. High
Available Ca (mg kg^{-1})	<150	Very low
	150-300	Low
	>300	Adequate
Available Mg (mg kg^{-1})	60	Very low
	60-120	Low
	>120	Adequate
Available S (mg kg^{-1})	<5	Low
	5-10	Medium
	11-25	Adequate
	>25	High
Available Fe (mg kg^{-1})	<5	Deficient
	>5	Adequate
Available Mn, Zn and Cu (mg kg^{-1})	<1	Deficient
	>1	Adequate
Available B (mg kg^{-1})	<0.5	Deficient
	0.5-2	Adequate
	>2	High

ASSESSMENT OF SOIL QUALITY IN THE POST FLOOD SCENARIO OF AEU 13 IN PALAKKAD DISTRICT OF KERALA AND MAPPING USING GIS TECHNIQUES

By

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(2018-11-107)

ABSTRACT OF THE THESIS

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Assessment of soil quality in the post flood scenario of AEU 13 in Palakkad district of Kerala and mapping using GIS techniques

Abstract

Soil quality is the capacity of the soil to function within its ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health. It primarily depends on its dynamic properties which significantly change under environmental disturbances. The flood of August 2018 witnessed by Kerala not only caused havoc to life and properties but also triggered alarming changes in soil quality. Two types of flood damages were noticed throughout the state either due to river overflow and water logging or by caustic landslides. The parts of AEU 13 (Northern foothills) in Palakkad district consisting of low hills with undulating topography was affected both by river overflow and landslides. The study area in AEU 13 comprises of ten panchayats belonging to Mannarkkad and Sreekrishnapuram block panchayats. Heavy overflow of Nellippuzha, Kunthippuzha and Kanjirappuzha rivers in the area caused destruction of field crops and sand and silt deposition on their banks. Landslides from Kalladikkodan and Anangan hills resulted in complete demolishment of the nearby areas in Karimba, Kottopadam and Kanjirappuzha panchayats.

The present study was undertaken to assess the soil quality in the flood affected areas of AEU 13 in Palakkad district and to develop maps on soil characters and quality using GIS techniques. The soils of AEU 13 are poor in organic matter, strongly acidic, dominated by low activity clays and sesqui-oxides and suffer from multi-nutrient deficiencies. One hundred and one georeferenced soil samples were collected from the flooded and landslide affected areas, processed and analyzed for different chemical, physical and biological properties.

The results showed variation in all soil attributes except in available B, exchangeable acidity and electrical conductivity. The bulk density ranged from 1.11 Mgm^{-3} to 1.69Mgm^{-3} with 54 percentage of samples coming above 1.4 Mgm^{-3}. Regarding

particle density, seventy five percentage of the samples had values greater than 2.4 Mgm^{-3}, whereas porosity and water holding capacity were in an optimum range.

All the samples were acidic with pH ranging from 3.9 (Alanallur) to 6.8 (Mannarkkad), but with low exchangeable acidity. Soil organic carbon varied from 0.38 (Mannarkkad) to 1.78 percent (Kottopadam) with40percentage of samples coming under low category. Seventy five percentage of the samples were low in available N with an average value of 238.2 kg ha^{-1} for the area. The available P and K were high in the area with 67 and 74 percentage of samples coming under high category for available P and K respectively. Available Ca was sufficient (>300 mg kg^{-1}) in 70 percentage of samples while available Mg was deficient (<120 mg kg -1) in 60 percentage of the soil samples. All the soils were sufficient in available Fe, Mn, Cu and Zn whereas 99 percentage of samples were deficient in available B. Effective cation exchange capacity of the selected area was also low with an average of 8.4cmol kg^{-1}. Thirty three percentage of the soil samples had dehydrogenase activity less than 75 µg TPF g $soil^{-1}day^{-1}$. The nutrient index of the AEU 13 in Palakkad district was low (<1.67) with respect to organic C and available N and high (>2.33) with respect to available P and K. Pearsons correlation matrix showed a strong positive correlation between organic C and available N and negative correlation between OC and bulk density. Soil pH is negatively correlated with exchangeable acidity and positively correlated with available Ca, Mg and K.

When compared with the pre-flood analytical data collected from District Soil Testing Laboratory (DSTL), Pattambi, proportion of soil samples coming under medium and high category of soil organic carbon increased after flood, which may be due to organic matter deposition. There was a reduction in available Ca and Mg after flood which might be due to leaching and infiltration loss. The pre-flood data collected as well as the analytical results of the present study indicated deficiency of B and sufficiency of cationic micronutrients like Fe, Cu, Mn and Zn in AEU 13.

Assessment of the present status of the land slide affected soils indicated higher bulk density and particle density than that of flood affected soils of the study area which may be due to the addition of heavier minerals during land slide from subsurface areas to topsoil. Available S, Fe and Mn were also higher in soil samples collected from landslide affected areas.

For developing minimum data set (MDS), principal component analysis (PCA) was performed for 22 attributes and resulted in seven principle component groups. Soil quality index (SQI) was worked out using non linear scoring method. The MDS comprised of eight attributes with available Ca and bulk density having highest contribution to SQI. Soil quality index ranged from 0.408 (Karimba) to 0.539 (Kumaramputhur). The average relative soil quality index (RSQI) of flood affected soils of AEU 13 in Palakkad district was 43.92 percent which is rated as low. Only 20 % of the soil samples collected from the area had medium RSQI values. When averaged over different panchayats, Alanallur (48.67 percent) had highest and Karimba had lowest RSQI (37.36 percent). High bulk density and particle density and low available N and B might be the reason for low soil quality observed throughout the area. The soil quality of the post flooded soils in the AEU 13 can be improved by adopting appropriate soil health management strategies with major thrust on site specific and integrated nutrient management practices.