# ASSESSMENT OF SOIL QUALITY IN THE POST-FLOOD SCENARIO OF AEU 4 IN PATHANAMTHITTA DISTRICT OF KERALA AND GENERATION OF GIS MAPS.

*By*

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**THESIS**

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**COLLEGE OF AGRICULTURE, VELLAYANI.**

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## DECLARATION

I, hereby declare that this thesis entitled **"ASSESSMENT OF SOIL QUALITY IN THE POST-FLOOD SCENARIO OF AEU 4 IN PATHANAMTHITTA DISTRICT OF KERALA AND GENERATION OF GIS MAPS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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## CERTIFICATE

Certified that this thesis entitled **"ASSESSMENT OF SOIL QUALITY IN THE POST-FLOOD SCENARIO OF AEU 4 IN PATHANAMTHITTA DISTRICT OF KERALA AND GENERATION OF GIS MAPS"** is a record of research work done independently by Ms. Sumeena K J, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, or fellowship to her.

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Date: 24.08.2020

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We, the undersigned members of the advisory committee of Ms. Sumeena K J, a candidate for the degree of **Master of Science in Agriculture** with major in Soil Science and Agricultural Chemistry, agree that the thesis entitled **“ASSESSMENT OF SOIL QUALITY IN THE POST-FLOOD SCENARIO OF AEU 4 IN PATHANAMTHITTA DISTRICT OF KERALA AND GENERATION OF GIS MAPS”** may be submitted by Ms. Sumeena K J, in partial fulfillment of the requirement for the degree.

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# CONTENTS

LIST OF TABLES

LIST OF FIGURES

# LIST OF PLATES

LIST OF APPENDICES

## LIST OF ABBREVIATIONS AND SYMBOLS USED

| | |
|---|---|
| % | Per cent |
| @ | At the rate of |
| AP | Acid phosphatase |
| BD | Bulk Density |
| Ca | Calcium |
| Cu | Copper |
| Fe | Iron |
| g | Gram |
| GIS | Geographic information system |
| h | Hour |
| ha | Hectare |
| INM | Integrated nutrient management |
| K | Potassium |
| kg | Kilogram |
| KSPB | Kerala state planning board |
| LQI | Land quality index |
| MC | Moisture content |
| MDS | Minimum data set |
| Mg | Magnesium |
| mg | Milligram |
| Mg | Mega gram |
| Mn | Manganese |
| MWD | Mean weight diameter |
| MWHC | Maximum water holding capacity |
| N | Nitrogen |
| n | Number of samples |
| NI | Nutrient index |
| $^{o}C$ | degree Celsius |
| P | Phosphorus |
| PCA | Principle component analysis |
| PD | Particle density |
| PNP | Para-nitrophenol |
| S | Sulphur |
| SQI | Soil quality index |
| WSA | Water stable aggregates |
| Zn | Zinc |
| µg | Microgram |

# INTRODUCTION

# 1. INTRODUCTION

World health organization (1989) defined flood as "the most frequent type of natural disaster and occur when an overflow of water submerges land that is usually dry. Floods are often caused by heavy rainfall, rapid snowmelt or a storm surge from a tropical cyclone or Tsunami in coastal areas". India is the most flood affected country in the world after Bangladesh. Flood cause havoc in many regions of India every year during the monsoon season. Flood results in large scale loss to life and damage to properties. Bhattacharya *et al*. (2015) reported that in India soil degradation in 14 M ha area was from flood.

Kerala State is one among the Indian states that receives very high rainfall during the monsoon season. In 2018, Kerala faced the worst flood since 1924. It was declared as level 3 calamity or calamity of severe nature by Government of India. Kerala faced high rainfall from 1$^{st}$ June 2018 to 19$^{th}$ August 2018. This resulted in intense flooding in 13 out of 14 districts within the State. CRIS- IMD, (2018) reported that Kerala received 2346.6 mm of rainfall from 1$^{st}$ June 2018 to 19$^{th}$ August 2018 whereas the expected rainfall was 1649.5 mm. This rainfall becomes approximately 42% above the normal. Further, the rainfall over Kerala for the duration of June, July and 1$^{st}$ to 19$^{th}$ of August changed into 15%, 18% and 164% respectively, above normal. The unprecedented rainfall leads to massive flood causing damage to land area and crops. The devastating flood caused decline in soil quality and loss of nutrients from the soil.

Agro-Ecological Unit (AEU) 4 in Pathanamthitta received 621.33 mm rainfall during August 2018 which is 115.34% more than the average of 324.42 mm (RRS, Mancompu). AEU 4 is Kuttanad special agro- ecological unit delineated to represent the waterlogged lands which spreads mainly across 3 districts of Kerala such as Alappuzha (55% area), Kottayam (35%) and Pathanamthitta (10%). In Pathanamthitta district, it spreads over Pulikeezhu block with 5 grama Panchayats (Kadapra, Kuttoor, Nedumpuram, Niranam and Peringara.) and Thiruvalla Municipality which covers an area of 8,999 ha. This area comes under upper Kuttanad region. The soils of AUE 4 in Pathanamthiita district is coastal alluvial with acidic reaction. Major crops grown in this area were paddy, sugarcane, banana, coconut, cassava, nutmeg and vegetables etc.

Almost all the panachayats were severely affected by flood havoc and submergence. With the opening of the Anathodu, Pampa and Kochupampa dams which pushed up the water level in the pampa, several places in Thiruvalla Taluk have been submerged due to this. The type of flood which affects these areas was flash flooding. According to World health organization, (1989) Flash floods are caused by rapid and excessive rainfall that raises water heights quickly, and rivers, streams, channels or roads may be overtaken. Flooding and water logging resulted in washing off of the top soil and loss in soil fertility of this area. Water stagnation in this area continued for 5 to 6 days. The level of flood varied a lot from a few inches to a level that goes up to meters like a house's roof level. Among the major crops, Paddy and banana were the worst hit by flood.

Flooding may lead to increase or decrease in the nutrient content of the soil. The contribution of essential nutrients that might be lacking in the soil is a positive contribution of flood to the soil properties (O'Connor, 2004). Whereas flood results in soil degradation and harvest failure which directly or indirectly affect the farmers. Deposition of organic matter, minerals, and nutrients from rivers into land due to flood makes the soil fertile and productive in nature (Visser *et al*., 2003). Njoku et al. (2011) showed that soil properties such as total porosity, moisture content, pH, and organic carbon were higher in a soil after flooding than before flooding. Flooded soils have greater challenges for agriculture; it includes sand deposition on productive lands, erosion of top soil, flooded soil syndrome (loss of soil biology which makes the nutrients available to plants).

Flood influences changes in many soil properties. The evaluation of these attributes to know about the impact of flood is done through the assessment of soil quality. According to Karlen *et al*. (1997) "soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation". Soil quality assessment identifies the soil properties which are most affected by flood and the capability of soil to function within the limit. It helps to restore and manage the soil to increase productivity.

Farming after flood is a major constraint. The changes taken place due to flood should be analyzed as flood might have caused nutrient losses and land degradation.

So it is important to know the fertility and productivity status of soil. Overall soil health, including soil texture, structure, water holding capacity, and nutrient availability, must be restored to allow for agricultural productivity after flooding.

A detailed study involving soil analysis for physical, chemical and biological attributes on AEU will help in the formulation of sustainable crop management strategies for the flood affected areas. Site specific management practices are necessary to overcome the changes in soil due to flood. This will make the farmers aware about the changes in soil brought about by the flood and for adopting effective management of post flood soils. Alteration in nutrients application according to the current status of soil will help to achieve productivity.

In the light of above background, the present investigation was carried out with the following objectives

- The assessment of soil quality of post-flood soils of AEU 4 in Pathanamthitta district.
- To develop maps on soil characters and quality using GIS techniques.
- To work out the Soil Quality Index (SQI).

# REVIEW OF LITERATURE

# 2. REVIEW OF LITERATURE

The present study is an attempt to investigate the effect of flooding on the soil quality in the post-flood soils of AEU 4 in Pathanamthitta district of Kerala. The relevant literature pertaining to the present study entitled “Assessment of soil quality in the post-flood scenario of AEU 4 in Pathanamthitta district of Kerala and generation of GIS maps” is reviewed in this chapter.

## 2.1 SOIL PROPERTIES OF AEU 4 OF PATHANAMTHITTA

Agro-ecological unit 4 is Kuttanadu special agro-ecological unit delineated to represent the waterlogged lands which spreads mainly across 3 districts of Kerala such as Alappuzha (55% area), Kottayam (35%) and Pathanamthitta (10%). It is classified into 3 regions based on elevation and geography viz. Upper Kuttanadu, Lower Kuttanadu and Kayal lands (Pillai *et al*., 1983). The types of soil comes under this AEU are Kayal, Karappadam and Kari. In Pathanamthitta district, it spreads over Pulikeezhu block with 5 grama panchayats (Nedumpuram, Kadapra, Kuttoor, Niranam and Peringara) and Thiruvalla Municipality which covers an area of 8,999 ha. This area comes under Upper- Kuttanadu region and Karappadam soil is mostly found here (Mathew, 2002).

The area consists of poorly drained, deep and riverine alluvial soil with silty loam to silty clay loam surface texture. These soils have less soil acidity than Kayal and Kari soil. Soil color varies from dark grey to deep brown or black. This soil exhibits medium organic matter content and poor nutrient status (KSPB, 2013). The climate is tropical humid monsoon type with mean annual temperature of $27.6^0$C and rainfall 2,746.1 mm.

## 2.2 IMPACT OF FLOOD ON SOIL

A series of changes occurs in physical, chemical and biological processes that influence soil quality due to flooding on soil. The nature, pattern and magnitude of these changes depend on different soil properties and the submergence period (Ponnamperuma, 1984).

A post flood study of soil by Kalshetty *et al* in 2012 in the Bagalkot district of Karnataka, India, revealed that there is not much changes in bulk density, texture and water holding capacity of the soil. But pH decreased and became acidic and electrical conductivity had an elevation due to the deposition of total dissolved solids. There was a lowering of nitrogen content in the flood affected soils. It was due to the leaching of nitrate nitrogen with flooded water and denitrification due to anaerobic condition. Available potassium increased after flood. It was due to the swelling of clay minerals due to water saturation and thus released the fixed potassium. Phosphorus, sulphur, calcium and magnesium contents were increased. There was a slight elevation in iron, zinc and copper content and reduction in manganese and boron content after flood.

Another post flood study by Akpoveta *et al* in 2014 in Asaba and Onitsha of Nigeria showed that there exists considerable decrease in the values of organic carbon, pH, total nitrogen, total phosphorus and cation exchange capacity but elevation in electrical conductivity. There was a major reduction in potassium and essential micronutrients like manganese and nickel. They concluded that there was a major negative effect of flooding in that particular area.

### 2.2.1 Impact of flood on soil physical properties.

During flooding, rapture of large soil aggregates takes place. Due to this, pores become filled with dispersed clay so the permeability of soil decreases. (Kirk *et al*., 2014). Flooding induces changes in pore volume or soil texture, thus results in variation of bulk density. In flooded soil pH value move towards neutrality (Unger *et al*., 2008). De Campos *et al*. (2009) reported that flooding had impact on soil aggregation. Disintegration of soil structure and clogging of soil pores occurs due to the poorly formed aggregates. Negative impact of flooding on soil aggregation affects soil quality and productivity.

### 2.2.2 Impact of flood on soil chemical properties.

The important chemical changes occur due to flood on soil are reduction of oxygen, carbon dioxide accumulation, anaerobic decomposition of organic matter, nitrogen transformations and reduction of iron and manganese (Ponnamperuma, 1972). If rainfall last for a very longer time, flooding of water on the surface of soil occurs due to poor drainage capacity which prevents the exchange of carbon dioxide and oxygen between soil and atmosphere. A condition of anoxia (absence of oxygen) occurs in soil and thereby reduces the availability of nutrients to plants. It affects chemical and biological properties of soil. (Ravichandran, 2002). As submergence persists, available oxygen in the soil is utilized by aerobic organisms for their respiration which in turn forms an aerobic condition (Kozlowski, 1984).

Nitrogen transformations under anaerobic condition are ammonification, nitrate reduction, and denitrification. Due to ammonification and nitrate reduction, ammoniacal nitrogen ($NH_4$–N) was produced and due to nitrate reduction and denitrification, nitrate nitrogen $NO_3$–N is lost. Nitrate nitrogen already present in the soil gets leached. (Unger *et al*., 2009).

The rate of decomposition of organic matter in submerged soils is slower than in aerobic soils which results in the net accumulation of organic matter in the soils that remain flooded for long time (Sahrawat, 2003). Reduced or incomplete decomposition of organic matter, decreased humification results in increased accumulation of organic matter in wetland soils (Olk *et al*., 2000; Mahieu *et al*., 2002).

### 2.2.3 Impact of flood on soil biological properties.

Enzymes in flooded soil show temporal peak activity during the first week after flood. It indicates that available carbon was utilized rapidly by the microorganisms. Later on there is a decline in enzyme activity rate due to the limitation of substrates in the flooded soil **(**Burns and Ryder, 2001).

Mace *et al.* (2016) says that flooding have impact on nutrient availability oxygen availability and soil biology. It will directly affect the soil enzyme activity. Activity of cellulose and lignin degrading enzymes enhances with flooding.

## 2.3 SOIL QUALITY – CONCEPT

The quality of soil determines the productivity and health of soil and its ecosystem. The evolution of soil quality was started by the introduction of the term by Warkentin and Fletcher in 1977. Scientists have different version of definitions for soil quality. According to Wilson and Kordybach (2000), it is the inherent features of soil which are procured from soil characters like fertility, erodibility, compactibility etc. The capacity of soil such as humus contents, water holding capacity, pH, nutrients supply, aggregation etc. which support crop production is termed as soil quality (Power and Meyer, 1989). Soil quality is the productive nature of soil by maintaining the resources (Larson & Pierce, 1991).

Various physical, chemical, and biological attributes of soil have complex interaction with each other. This interaction determines the capability of soil to function efficiently and produce healthy crops. The integration of these attributes and the level of productivity is known as soil quality (Parr, 1992).

Soil quality depends on the people, as decisions and management practices done by the humans determine the sustainability of an agricultural production system on a particular soil (Arshad and Coen, 1992). Haberern (1992) opined that soil quality determines the sustainability of agriculture, environmental status, plant, animal and human health.

According to Doran and Parkin, (1994) productivity, environmental quality and animal health were the major components of soil quality and considered several factors such as soil management practices, ecosystem functions, land use, environmental interactions, socio economic factors etc. for the development of the definition. They defined soil quality as “The capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health".

Karlen *et al*. (1997) says that soil quality is the potential of a of soil to function, within natural or managed environment boundaries, to maintain plant and animal productivity, preserve or enhance water and air quality, and hold up human health .

Organic farming is known to be better than conventional farming as organic farming conserves soil health, improves soil biology, and nurtures crops without the use of synthetic fertilizers and pesticides. Studies show that the shift from conventional farming to organic farming increased soil quality (Hansen *et al*., 2001). The significance of soil quality lies in achieving sustainable land use and control system to balance productiveness and environmental protection (De la Rosa, 2005).

### 2.3.1 Factors affecting Soil quality

Soil quality comprises mainly two distinct but related inherent and dynamic qualities. Inherent soil quality results from natural and soil forming processes such as parent material, climate, topography, time and living organisms. Dynamic soil quality results from changes due to human use and management which includes cropping history and crop rotation, drainage, soil amendments, cover crops, tillage and land use type (Schwilch *et al*., 2016).

### 2.3.2 Soil quality indicators

Those physical, chemical and biological parameters, characteristics and processes which can be determined to assess the changes in soil were termed as soil quality indicators (USDA, 2006). The status of soil quality of a particular site can be determined by changes in the soil quality indicators. It helps to identify whether soil quality is enhancing, steady or declining. (Brejda *et al*., 2001). It is important to adopt different natured indicators such as physical, chemical and biological to develop soil quality .Soil organic carbon and pH were the widely used indicators. Integration of all indicators helps to develop soil quality index (SQI) which provides knowledge about soil processes and information (Zornoza *et al*., 2015).

For selecting soil quality indicators for specific goals, it is necessary to observe some critical soil functions like nutrient cycling, drainage, infiltration, water holding, saturation and how well the plants were growing etc. Best indicators form minimum data set. It can be used to assess the quality and functions of soil (Andrews *et al*., 2002).

Soil indicators are interdependent as they interact with each other. The value of one parameter is affected by others. The attributes which are sensitive to management practices are suitable for selecting as a parameter. The quantifiable soil properties that have an impact on the ability of soil to perform crop production or environmental functions were referred to as soil quality indicators. The selection of indicators changes according to the goal. Some indicators selected for crop production as objective were pH, EC, organic carbon, depth, infiltration, aggregation etc. For developing soil quality index it necessary to identify a minimum data set (Arshad and Martin, 2002).

The integration of different soil chemical, physical and biological properties attributes and the level of productivity is known as soil quality. Earlier biological properties were not given much importance as chemical or physical properties. It is due to the difficulty in measuring and interpreting biological behavior (Parr *et al*., 1992). It is much hard to separate soil functions into chemical, physical, and biological processes since they have dynamic and interactive nature. This interaction is stronger in chemical and biological indicators (Doran and Parkin, 1994).

According to Cardoso *et al.* (2013), instead of choosing one kind of indicators, selection of different kind of indicators such as physical chemical and biological indicators were safe. Physical indicators include bulk density, particle density, porosity, soil texture, soil moisture, aggregation and among chemical indicators organic carbon, available macro and micronutrients, organic matter, cation exchange capacity were well established. Microbial activity was selected as biological indicator

Soil quality changes according to the alterations occurring in indicators. Granatstein, (1990) reported that increased level of infiltration, macro pores, aggregate size and stability, soil organic matter content and aeration indicates better soil quality. Decline in soil quality can be due to water logging, alkalinity, salinity, deforestation and degradation of land (Sharma and Mandal, 2009).

#### *2.3.2.1 Physical indicators*

Physical indicators gives information about status of air and water in the soil such as water holding capacity and infiltration rate and capacity of soil to withstand physical forces like raindrop splashing, flooding and erosion. Physical indicators are directly related to the functions of soil. Indicators such as soil texture and soil depth were useful for evaluating soil quality before and after soil management practices. Soil texture is the important soil physical indicator which controls aeration, nutrients and moisture uptake and retention in soil (Schoenholtz *et al.*, 2000).

Commonly used physical indicators of soil were soil tilth (Papendick, 1991), bulk density, particle density, water holding capacity, porosity, soil strength (Powers *et al.*, 1998), aggregate stability (Doran and Parkin, 1994), soil depth (Larson and Pierce, 1991), soil texture etc.

#### 2.3.2.2 Chemical indicators

Reactions and processes taking place in the soil were affected by chemical components of soil. pH can control mobility and suitability of micro and macro nutrients and heavy metals. It affects soil biological properties. Chemical indicators were affected by management and natural disturbances. Irrigation water, crops cultivated, fertilizer application also affect chemical components of soil. Due to the association of organic carbon to mineral fraction it is considered as a chemical indicator.

Soil chemical attributes have impact on soil microbiological processes and chemical properties. Physical and chemical properties decide the ability of soils to hold, supply, and cycle plant nutrients and the movement of water in soil (Schoenholtz *et al.*, 2000). Doran and Parkin, (1994) identified some chemical attributes like pH, EC, organic carbon, mineralizable nitrogen, mineral phosphorus, exchangeable potassium and micro nutrients as best for soil quality assessment.

#### *2.3.2.3 Biological indicators*

Biological attributes provides information about the living components of soil. It encompass various soil components and process of organic matter cycling in soil, which include total and mineralizable organic carbon and nitrogen, microbial biomass, enzyme activities and soil fauna and flora. These attributes were important indicators of soil quality, since they respond to both herbal and human initiated changes (Gregorich *et al*., 1997).

Gil-Sotres *et al.* (2005) reported that the biological properties used to evaluate soil quality include microbial biomass carbon, activity of enzymes like dehydrogenase, phosphatase, urease and β-glucosidase etc. Soil enzyme activities have important potential as a biological indicator of soil health. Soil enzyme activities are the better indicator of changes in soil biology which occurs due to management practices or environmental factors (Alkotra *et al*., 2003). Soil enzymes were important soil quality indicators because of their relationship to soil biology, sensitiveness ease to measure. They were portrayed as biological fingerprints of past soil management (Utobo and Tewari, 2015).

Soil enzymes are continuously playing crucial roles for the upkeep of soil ecology and soil health. They are the important indicators of soil health as changes in enzyme activity arise earlier than other parameters (Das and Varma, 2010). Enzymes are catalyst which mediates reactions and release nutrients available to plants. Acid phosphatase is interrelated to phosphorus in soil. Acid phosphatase catalyzes the breakdown of phosphate bond and releases phosphate through hydrolysis (Kumar *et al*, 2011).

Farming system and fertilization affects microbial activity indicator such as acid phosphatase, dehydrogenase etc. Generally biological parameters were enhanced in organic farming when comparing with integrated farming system as application of manures affect soil quality positively (Fließbach *et al*., 2007).

### 2.3.3. Minimum Data Set (MDS) for SQI

Minimum data set provides a small subset of parameters that will allow a more realistic soil quality assessment (Gregorich *et al*., 1997). The set of physical, chemical and biological indicators which shows at least 70% of variability in the total data set at each sampling site is termed as Minimum Data Set (MDS) for determining soil quality (Rezaei *et al*., 2006). MDS is chosen on the basis of capacity soil properties to predict soil stability and productivity (Lima *et al*., 2013).

The first step in the development of an MDS is the selection of suitable soil quality indicators that monitor soil functions effectively and efficiently based on the objectives for which the soil quality assessment is conducted. This group of indicators chosen forms an MDS. MDS are selected using principal component analysis (PCA). Researchers changes MDS according to their objectives of soil quality assessment (Sharma and Mandal, 2009).

For selecting the minimum data set (MDS), Principal component analysis (PCA) and expert opinion (EO) methods were used. PCA was the widely used method. It is important to consider the characteristics of study area such as climate, rainfall, and pedogenic processes etc. while selecting indicators (Vasu *et al*, 2016). It is necessary that the indicators which are selected for MDS should represent the functions and intricacy of the soil related to soil quality (Moncada *et al*., 2014). PCA is the statistical tool of data reduction. It identifies a better indicator which shows variability within the large set of data. When this method is done with comprehensive collection of data, it offers less chance of disciplinary bias (Bhattacharyya *et al*., 2017).

The expert who knows about the study area can decide the MDS. This method is known as expert opinion. For that the expert should know about the soil, crop cultivation, fertilization, and management practices done in that particular area. It leads to the development of authentic and significant soil quality index (Budak *et al*., 2018).

### 2.3.4. Soil Quality Index

The indicators selected for soil quality analysis changes according to the objectives. Parr *et al.* (1992) proposed a soil quality index as the function of soil properties, potential productivity, environmental factors, health (human/animal) erodibility, biological diversity, and food quality/safety and management inputs.

Doran and Parkin, (1994) developed a performance based soil quality index by assessing soil functions in terms of sustainable production, environmental quality and human and animal health. This index was calculated as the function of food and fibre production, erosivity, ground water quality, surface water quality, air quality, and food quality. Later, development of various SQI models was done using various sets of soil indicators. Andrews *et al.* (2004) developed Soil Management Assessment Framework (SMAF) which is a score based indicator set. It is done in two steps such as indicator selection and interpretation and aggregation. The selection and interpretation of indicators involves transforming soil attributes into unitless indicator scores, and combining these individual scores into a single index value (Karlen *et al.*, 2008).

### 2.3.5. Calculation of SQI

Estimation of soil quality index involves four steps – (i) Selection of objectives, (ii) Selection of minimum data set from different soil properties (iii) Scoring of the selected indicators and (iv) Calculation of SQI (Vasu *et al.*, 2016).

Method of estimation of SQI used by (Doran et al., 1994; Doran and Parkin, 1994; Karlen *et al.*, 1994) were simple additive method, weighted additive method and statistical method using Principal component analysis (PCA)

#### ***2.3.5.1. Simple additive Soil Quality Index (SQI-1)***

This method was given by Amacher *et al.* (2007). The additive index was calculated by adding the PCA selected indicators from sampling site.

$$\Sigma \text{ SQI} = \Sigma \text{ Individual soil parameter index values}$$

### *2.3.5.2. Weighted additive Soil Quality Index (SQI-2)*

The equation for a weighted SQI was proposed by Wymore, (1993)

$$SQI = \Sigma\ W_i\ S_i$$

Where, $W_i$ is the weighted factor and $S_i$ is the weighted score.
The weighted factor is derived using correlation coefficient (Nakajima *et al*., 2015) or PCA methods (Armenie *et al*., 2013).

### *2.3.5.3. Evaluation of soil quality indexing methods*

Masto *et al.* (2008) evaluated soil quality indexing methods using sensitivity analysis. He calculated sensitivity as the ratio of maximum and minimum soil quality index according to scoring procedure. The soil quality indexing approach with a higher sensitivity value is preferred because this was sensitive to pedoturbation and management practices (Burger *et al*., 1998)

## 2.4. NUTRIENT INDEX

Nutrient index (NI) value is the measure of nutrient supplying capacity of soil to plants (Singh *et al*., 2016). Nutrient index was used for the recommendation of area wise fertilizer and the comparison of soil fertility rates of various panchayats (Parker *et al.*, 1951). The nutrient index is determined giving weightage to the number of samples falling in low (NI), medium (Nm) and high (Nh) fertility classes.

## 2.5. LAND QUALITY INDEX

The potential of land to make human valuable goods and services is referred to as land quality. This ability is obtained from natural characteristics like fertility, climate, water, vegetation, topography and produced characteristics like infrastructure, irrigation, fertilization, management (Wiebe, 2003).

According to Beinroth *et al*. (2001), land quality is the capacity of land to carry out some specific functions without deteriorating itself. The specific functions to be done by soil include food and fiber production, sustain water quality, support human and animal inhabitancy, carbon sequestration etc. The principal factors of land quality were performance and resilience of soil. Desertification and degradation of land were the indicators of land quality decline. Land quality analysis, description, mapping, and monitoring quality is necessary for care and management of land (Eswaran *et al*., 2005).

Natarajan *et al* in 2010 worked on assessment of land degradation and its impacts on land resources of Sivagangai block of Tamil Nadu state, India. They concluded that bulk density, organic carbon and yield obtained from particular land can be considered as indicators of land quality. Soil organic matter was considered as an indicator of land quality as it act as the store house of nutrients, reduces soil compaction through increasing aeration. It influence soil structure and water stable aggregate formation. It increases the water holding capacity and infiltration rate of water in the soil (Rusco *et al*, 2001)

Kumar and Jhariya, (2015) classified land quality for agriculture into 4 categories high quality, moderate quality, marginal quality and low quality. In this study land quality was determined by using Analytic Hierarchy Process (AHP) technique by using GIS (Geographic Information System). It is a method of measurement using pair wise comparison and priority scales which were obtained by expert opinion. They selected different thematic layers like soil organic matter content, soil texture, soil depth, pH, EC, available phosphorus and potassium, geomorphology, slope and vegetative cover for determining LQI.

## 2.6. USE OF GPS AND GIS TECHNOLOGIES

A map designed to visualize about a particular data or information effectively is known as thematic map. For representation of laboratory analyzed data of soil quality Arc GIs tool can be used. Representative soil samples are to be collected using Global Positioning System (GPS). Principal component analysis or Expert opinion method can be used to determine the specific soil quality indicators. Then soil quality indicators can be calculated. SQI is plotted in a map according to the GPS coordinates. It shows the soil quality spatial variations. The map helps to provide scientific knowledge about the quality of the soil in that particular area (Hui Li *et al.*, 2005).

Generation of soil quality map involves various steps like GPS based soil sample collection, laboratory analysis of soil, soil quality index calculation and Arc GIS mapping. A case study was done by AbdelRehman *et al.* (2018) in Chamrajanagar District in Karnataka. They considered the soil quality indicators like BD, Organic Carbon, pH, EC, macro and micro nutrients for soil quality determination. From the investigation, it was found that the soil vary from low to very high soil quality. Generation of GIS map helps to monitor the soil properties for efficient use of resources. GIS also helps to assess the environmental impacts. They studied the rainfall and soil erosion impacts in that particular area. They concluded from the generated map that soil erosion, rainfall and salinity were the major problems in that area which reduces the soil quality.

Geographic information system (GIS) is an effective tool for flood management and preparing flood map. It can give visualization of flood affected area and it helps to estimate probable flood hazards (Clark, 1998). GPS helps to evaluate and record the correct position on earth surface continuously. It provides unique latitude and longitude data for each position (Shrestha, 2006). Mishra, *et al.* (2014) opined that soil sample collection with proper record of latitude and longitude using GPS is necessary for making thematic soil maps. It has greater importance in agriculture for monitoring nutrient status of soil and interpreting suitable soil management of different locations.

GIS helps in efficient and effective manipulation of spatial and non-spatial data for preparing scientific maps and characterizing and identifying soil status for the use of local people (Star *et al.*, 1997). According to Binita *et al.* (2009), GIS is the primary requisite of preparing site specific soil fertility map. It conveys the idea for preparing fertilizer recommendation from nutrient status of soil and also helps to identify the quality of soil for agriculture purposes.

To determine effective management strategies, information gathered from different satellite data can be integrated and referenced with the help of GPS. The development and implementation of site specific agriculture was made possible through the combination of GPS and GIS (Liaghat and Balasundram, 2010).

GPS and GIS technologies have the capability to increase soil surveying efficiency. Primary objective of GIS is to take raw data and turn it into new information through overlay and other analytical operations that can help in decision making processes (Sahu *et al*., 2015). GIS has been defined as a powerful set of tools to collect, store, retrieve, transform and display real world spatial data for a given set of purposes (Burrough, 1986).

Dickinson and Calkins (1988) stated that the use of GIS tool will help to reduce problems of data integration caused by various geographic units related to different data sets. GIS comprises of manual and computer-based information system and integrates the spatially referenced data sets for modeling and decision making purposes. It is an innovative tool for soil quality assessment (Jafari and Narges, 2010).

GIS is very much useful for mapping and projecting current and future fluctuations in precipitation, crop yield, soil fertility etc. GIS can analyze soil data to determine the suitable crops and management of soil fertility status. In agriculture, GIS helps local people to achieve higher productivity with lower inputs by allowing better management of land resources (Holland *et al*., 2013).

# MATERIALS AND METHODS

# 3. MATERIALS AND METHODS

The present investigation entitled “Assessment of soil quality in the post-flood scenario of AEU 4 in Pathanamthitta district of Kerala and generation of GIS maps” was carried out to determine the changes in the soil after flood during 2018.

The study includes

3.1. Survey, collection and characterization of soil

3.2. Development of minimum data set (MDS)

3.3. Formulation of SQI, LQI and NI

3.4. Generation of GIS maps

3.5. Statistical analysis of data

## 3.1. SURVEY, COLLECTION AND CHARACTERIZATION OF SOIL

### 3.1.1. Details of the location

Agro Ecological Unit 4 in Pathanamthitta district spreads over 5 Grama panchayats and one municipality which cover an area of 8,999 ha. It lies within the coordinates 9º20’0” N to 9º24’0” N and 76º28’0” E to 76º36’0” E. Almost all the panachayats were severely affected by flood havoc and submergence during August 2018. The type of flood which affects this area is flash flooding. Flooding and water logging resulted in washing off of the top soil and deposition. These areas come under Upper Kuttanad region and were mainly drained by Manimalayar and Pamba River. The study was carried out in,

1. Nedumpuram panchayat
2. Peringara panchayat
3. Kuttoor panchayat
4. Niranam panchayat
5. Kadapra panchayat
6. Thiruvalla municipality

The soils of AUE 4 in Pathanamthita district is coastal alluvial with acidic reaction. Major crops grown in this area were paddy, sugarcane, banana, coconut, cassava, nutmeg and vegetables etc. The climate is tropical humid monsoon type with mean annual rainfall of 2746 mm and mean annual temperature of 27.6 °C (KSPB, 2013) Continuous heavy rain for 10-15 days results in flash flood during monsoon.

### 3.1.3. Soil sample collection

Soil samples were collected from the selected major flood affected areas of AEU 4 of Pathanamthitta district during 2019. The sites of soil sample collection were decided with the help of Krishibhavan. From each panchayat more than 10 soil samples were collected. At each sampling site V notch method of 0-15 cm depth was used to collect composite soil samples of one kg. Soil samples were collected at random from the selected field. The collected samples were spread on a polythene sheet and quartering method was used to get one kg of representative sample. One core sample was also collected from each site. Altogether, 75 representative samples were collected. It was packed in polythene covers with proper labelling. With the help of GPS, Geographical coordinates of each site of soil sample collection was recorded.

Table.1. Details of soil sample collection site.

| Sl. No. | Panchayat | No. of samples | Sampling point | N latitude | E longitude |
|---|---|---|---|---|---|
| 1 | Nedumpuram | 13 | 1 | 9.368147 | 76.550183 |
| | | | 2 | 9.361997 | 76.554772 |
| | | | 3 | 9.353587 | 76.556853 |
| | | | 4 | 9.358073 | 76.558051 |
| | | | 5 | 9.363471 | 76.548867 |
| | | | 6 | 9.373109 | 76.548872 |
| | | | 7 | 9.369605 | 76.534869 |
| | | | 8 | 9.376161 | 76.516398 |
| | | | 9 | 9.371266 | 76.525446 |
| | | | 10 | 9.374063 | 76.534936 |
| | | | 11 | 9.355071 | 76.553041 |
| | | | 12 | 9.370156 | 76.543939 |
| | | | 13 | 9.365699 | 76.538723 |

Table.1. Details of soil sample collection site (continued).

| Sl. No. | Panchayat | No. of samples | Sampling point | N latitude | E longitude |
|---|---|---|---|---|---|
| 2 | Peringara | 12 | 14 | 9.385005 | 76.52585 |
| | | | 15 | 9.383315 | 76.555113 |
| | | | 16 | 9.398445 | 76.586846 |
| | | | 17 | 9.400086 | 76.531516 |
| | | | 18 | 9.387513 | 76.540894 |
| | | | 19 | 9.413578 | 76.549115 |
| | | | 20 | 9.408052 | 76.573676 |
| | | | 21 | 9.375566 | 76.59138 |
| | | | 22 | 9.385322 | 76.590654 |
| | | | 23 | 9.402663 | 76.551641 |
| | | | 24 | 9.392267 | 76.555261 |
| | | | 25 | 9.372553 | 76.559183 |
| 3 | Kuttoor | 12 | 26 | 9.357727 | 76.571566 |
| | | | 27 | 9.35556 | 76.577879 |
| | | | 28 | 9.352214 | 76.585495 |
| | | | 29 | 9.354433 | 76.592331 |
| | | | 30 | 9.35666 | 76.566508 |
| | | | 31 | 9.358136 | 76.584 |
| | | | 32 | 9.355195 | 76.600632 |
| | | | 33 | 9.361449 | 76.59409 |
| | | | 34 | 9.36693 | 76.59564 |
| | | | 35 | 9.36316 | 76.59933 |
| | | | 36 | 9.357069 | 76.609144 |
| | | | 37 | 9.350002 | 76.605434 |
| 4 | Niranam | 12 | 38 | 9.331926 | 76.481504 |
| | | | 39 | 9.33702 | 76.486793 |
| | | | 40 | 9.334874 | 76.504731 |
| | | | 41 | 9.33623 | 76.518288 |
| | | | 42 | 9.342996 | 76.518642 |
| | | | 43 | 9.341004 | 76.510123 |
| | | | 44 | 9.343473 | 76.502181 |
| | | | 45 | 9.348907 | 76.515033 |
| | | | 46 | 9.338131 | 76.49564 |
| | | | 47 | 9.346856 | 76.510263 |
| | | | 48 | 9.346617 | 76.5239 |
| | | | 49 | 9.338786 | 76.524399 |

Table.1. Details of soil sample collection site (continued)

| Sl. No. | Panchayat | No. of samples | Sampling point | N latitude | E longitude |
|---|---|---|---|---|---|
| 5 | Kadapra | 13 | 50 | 9.338351 | 76.550253 |
| | | | 51 | 9.346255 | 76.546249 |
| | | | 52 | 9.344401 | 76.5375 |
| | | | 53 | 9.35769 | 76.536688 |
| | | | 54 | 9.359067 | 76.528481 |
| | | | 55 | 9.35029 | 76.5334 |
| | | | 56 | 9.358077 | 76.520545 |
| | | | 57 | 9.329919 | 76.494887 |
| | | | 58 | 9.328242 | 76.515662 |
| | | | 59 | 9.325958 | 76.502099 |
| | | | 60 | 9.328234 | 76.525236 |
| | | | 61 | 9.334554 | 76.535643 |
| | | | 62 | 9.328871 | 76.540591 |
| 6 | Thiruvalla Municipality | 13 | 63 | 9.3714 | 76.56962 |
| | | | 64 | 9.366353 | 76.57202 |
| | | | 65 | 9.364015 | 76.566133 |
| | | | 66 | 9.388707 | 76.571192 |
| | | | 67 | 9.382614 | 76.568064 |
| | | | 68 | 9.39923 | 76.56685 |
| | | | 69 | 9.393387 | 76.570831 |
| | | | 70 | 9.386069 | 76.574744 |
| | | | 71 | 9.380194 | 76.575298 |
| | | | 72 | 9.376537 | 76.569418 |
| | | | 73 | 9.371663 | 76.576254 |
| | | | 74 | 9.36729 | 76.58009 |
| | | | 75 | 9.365008 | 76.584921 |

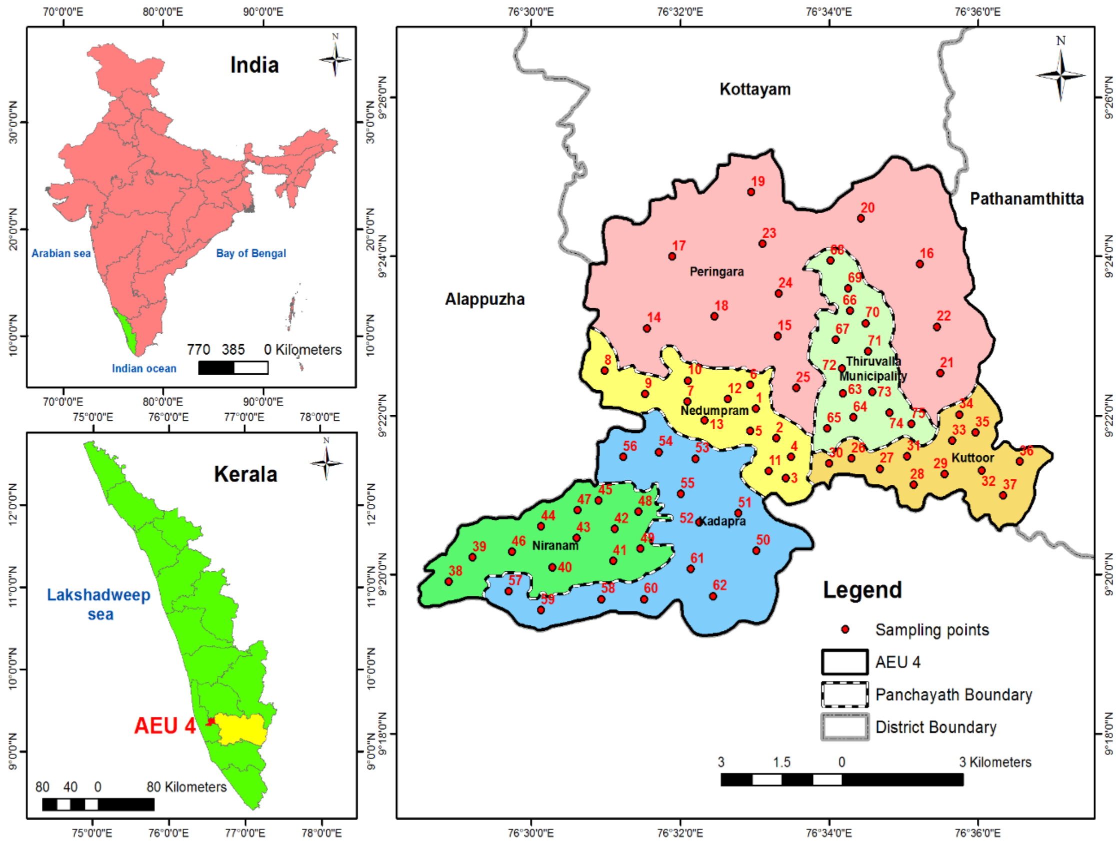



Fig.1. Location map of samples in AEU 4 of Pathanamthitta district.

Plate. 1. Surface soil sample collection.

Plate. 2. Soil sample collection using core.

Plate. 3. Surveying at the time of soil sample collection.

### 3.1.4. Weather data of the area

The weather data was collected from Rice Research Station, Moncompu, Alappuzha. The average monthly rainfall, rainy days, minimum and maximum temperature and relative humidity during May 2018 to May 2019 are represented in fig.2. The rainfall data from 2008 to 2017 were analyzed to find the deviation of rainfall in 2018 from the average value of 2008 – 2017. The result is represented in table.2.

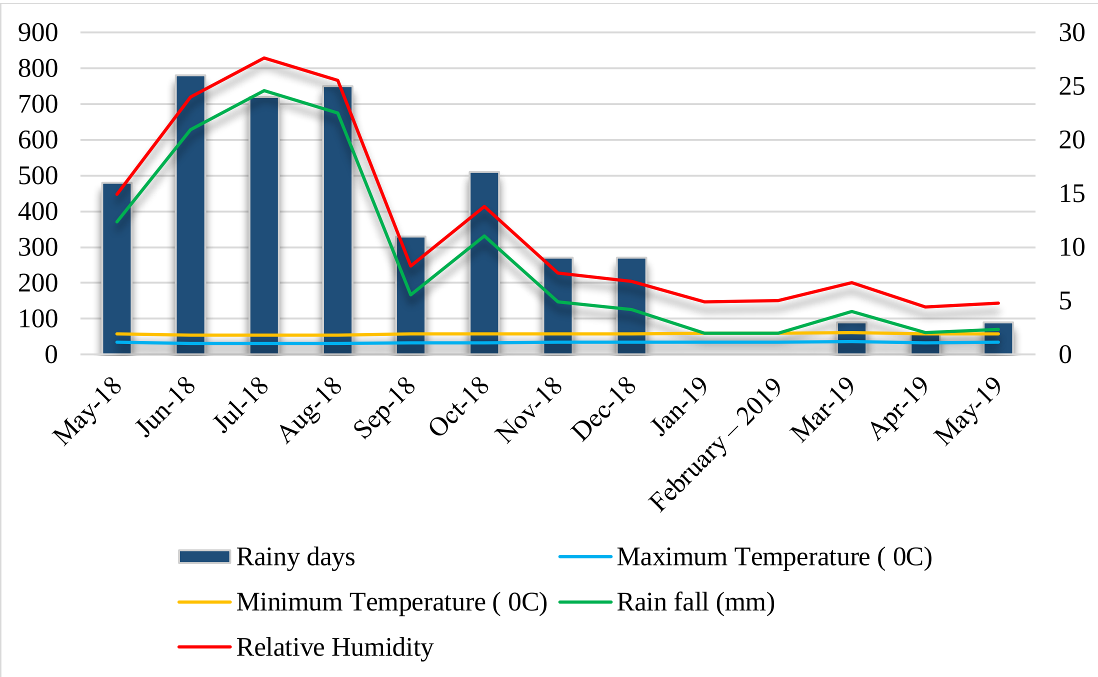



Fig.2. Monthly mean of weather parameters in AEU 4 in Pathanamthitta (May 2018 to May 2019).

Table.2. Deviation in rainfall during 2018 from the average monthly rainfall over previous years.

| Month | Average rainfall (2008-17) (mm) | Rainfall during 2018 (mm) | Deviation in rainfall | Rainy days average (2008-2017) | Rainy days (2018) | Deviation in no of rainy days |
|---|---|---|---|---|---|---|
| January | 12.39 | 0 | -12.39 | 0.8 | 0 | -0.8 |
| February | 39.68 | 1 | -38.68 | 1.2 | 1 | -0.2 |
| March | 49.2 | 29.8 | -19.4 | 5.5 | 3 | -2.5 |
| April | 136.55 | 71.6 | -64.9 | 8.7 | 4 | -4.7 |
| May | 234.36 | 312.8 | +78.44 | 12.2 | 17 | + 4.8 |
| June | 497.64 | 573.2 | +75.56 | 23.4 | 26 | +2.6 |
| July | 382.65 | 683.3 | +300.65 | 22.8 | 24 | +1.2 |
| August | 296.88 | 621.3 | +324.42 | 18.3 | 25 | +6.7 |
| September | 241.35 | 108.8 | -133.35 | 17.5 | 11 | -6.5 |
| October | 255.12 | 273.9 | +18.78 | 13.7 | 17 | +3.3 |
| November | 128.55 | 88.2 | -40.35 | 10.6 | 9 | -1.6 |
| December | 63.52 | 67.2 | +3.68 | 3.7 | 9 | +5.3 |

### 3.1.5. Processing of collected soil samples

The soil samples were brought to the laboratory. The collected moist soil samples were kept for air/shade drying. It was ground to powder form with wooden mortar and pestle and stored in labelled plastic bags.

## 3.2. CHARACTERIZATION OF COLLECTED SOIL SAMPLES

The collected soil samples were analyzed for determining different physical, chemical and biological attributes.

Table.3. Analytical methods for physical, chemical and biological analysis of soil.

| Sl. no. | Parameter | Method | Reference |
|---|---|---|---|
| 1. | Bulk density | Core method | Al-Shammary *et al* (2018). |
| 2. | Particle density | Pycnometer method | Vadyunina and Korchagina (1986) |
| 3. | Porosity | From bulk density and particle density | Biswas and Mukherjee (2014) |
| 4. | Texture | Hydrometer method | Bouyoucos (1962) |
| 5. | Water holding capacity | Core method | Gupta and Dhanalekshmi (1980) |
| 6. | Aggregate stability | Yoder's wet sieving method | Yoder (1936) |
| 7. | Soil pH | pH meter (1:2.5 soil water ratio) | Jackson (1973) |
| 8. | Electrical conductivity | Conductivity meter(1:2.5 soil water ratio) | Jackson (1973) |
| 9. | Organic Carbon | Walkley and Black method | Walkley and Black (1934) |
| 10. | Available N | Alkaline permanganate method | Subbaiah and Asija (1956) |
| 11. | Available P | Bray extraction and colorimetric estimation | Watanabe and Olsen (1965) |
| 12. | Available K | Neutral normal ammonium acetate extraction and Flame photometry | Jackson (1973) |
| 14. | Available Ca | Neutral normal ammonium acetate extraction and Atomic absorption spectroscopy | Hesse (1971) |
| 15. | Available Mg | Neutral normal ammonium acetate extraction and Atomic absorption spectroscopy | Hesse (1971) |
| 16. | Available S | $CaCl_2$ extraction and spectrophotometry | Massouni and Cornfield (1963) |
| 17. | Available Fe | 0.1 N HCl extraction and Atomic absorption spectroscopy | Sims and Johnson (1991) |
| 18. | Available Mn | 0.1 N HCl extraction and Atomic absorption spectroscopy Atomic absorption spectroscopy | Sims and Johnson (1991) |
| 19. | Available Zn | 0.1 N HCl extraction and Atomic absorption spectroscopy Atomic absorption spectroscopy | Sims and Johnson (1991) |
| 20. | Available Cu | 0.1 N HCl extraction and Atomic absorption spectroscopy Atomic absorption spectroscopy | Sims and Johnson (1991) |
| 21. | Available B | Hot water extraction and spectrophotometry | Gupta (1972) |
| 22. | Acid phosphatase | Calorimetric estimation of PNP released $g^{-1}$ of soil $h^{-1}$ | Tabatabai and Bremner (1969) |

3.3. DEVELOPMENT OF MINIMUM DATA SET (MDS)

The best soil properties were selected using Principal Component Analysis (PCA) method for developing MDS. The indicators having high degree of variability in the total data set were selected. PCA was based on the premise that Principal Components (PCs) with higher values were selected for MDS. Only the PCs having Eigen values greater than one was examined. The one with the highest sum of correlation coefficients was selected for MDS among each PC. The MDS attributes were transformed into unit less data by assigning scores.

3.4. FORMULATION OF SOIL QUALITY INDEX

**3.4.1. Formulation of soil quality index (SQI)**

By scoring method, particular scores were assigned to MDS indicators. Weightage to each parameter was given on the basis of percentage of variance. The scores were compiled to form an overall weighted soil quality index. It was obtained by the formula (Wymore, 1993)

$$SQI = \Sigma\ Wi\ Si$$

Where, Wi is the weighted factor and Si is the weighted score.

**3.4.2. Relative soil quality index**

Relative soil quality index was used to measure the changes in the soil quality (Karlen and Stott, 1994)

$$\text{RSQI} = \left(\frac{\text{SQI}}{\text{SQImax}}\right) 100$$

Where SQI was the determined soil quality index and SQImax was the maximum soil quality index that can be obtained theoretically. Each panchayat in the study area were rated based on RSQI ratings.

Table.4. Relative soil quality index ratings (Kundu *et al.*, 2012)

| **RSQI** | **Value (%)** |
|---|---|
| Poor | <50 |
| Medium | 50 – 70 |
| Good | >70 |

3.5. LAND QUALITY INDEX

Land quality index is estimated from Soil organic carbon stock (Shalima Devi, 2006). It is expressed in kg $ha^{-1}$.

Soil organic carbon stock in the soil is calculated by the formula given by Batjes, (1996). It is expressed in Mg $ha^{-1}$.

Soil organic carbon stock = Soil organic carbon (%) X Bulk density (Mg $m^{-3}$) X Soil depth (m) X 100.

Table.5. Land quality index ratings (Shalima Devi, 2006).

| **SOC stock (kg $m^{-2}$)** | **Land quality index** |
|---|---|
| <3 | Very low |
| 3 - 6 | Low |
| 6 - 9 | Medium |
| 9 - 12 | Moderate |
| 12 - 15 | High |
| >15 | Very high |

## 3.6. SOIL NUTRIENT INDEX

Nutrient index of each panchayat was estimated by the formula given by Parker *et al*. (1951). Nutrient index was calculated for nitrogen, phosphorus, potassium and organic carbon.

$$\text{Nutrient index} = \frac{(\text{Nl x 1 + Nm x 2 + Nh x 3})}{\text{Nt}}$$

Where, Nl - Number of samples falling in low category

Nm - Number of samples falling in medium category

Nh - Number of samples falling in high category

Nt - Total number of samples analyzed

Table.6. Nutrient index ratings (Parker *et al*., 1951).

| Nutrient index | Value | Class |
|---|---|---|
| Low | <1.67 | Low fertility |
| Medium | 1.67-2.33 | Medium fertility |
| High | >2.33 | High fertility |

## 3.7. GENERATION OF GIS MAPS

ArcGIS software version 10.3 was used to make GIS maps. Inverse Distance Weighted Interpolation (IDW) method was used in mapping. Principle underlying IDW interpolation is the First law of Geography formulated by Tobler (1970) which states that everything is related to everything else, but near things are more related than distant things. It assumes that the nearer a sample point is to the cell whose value is to be estimated, the more closely the cell's value will resemble the sample point's value. The visualization of nutrient status data in spatial environment is done by the below mentioned procedure.

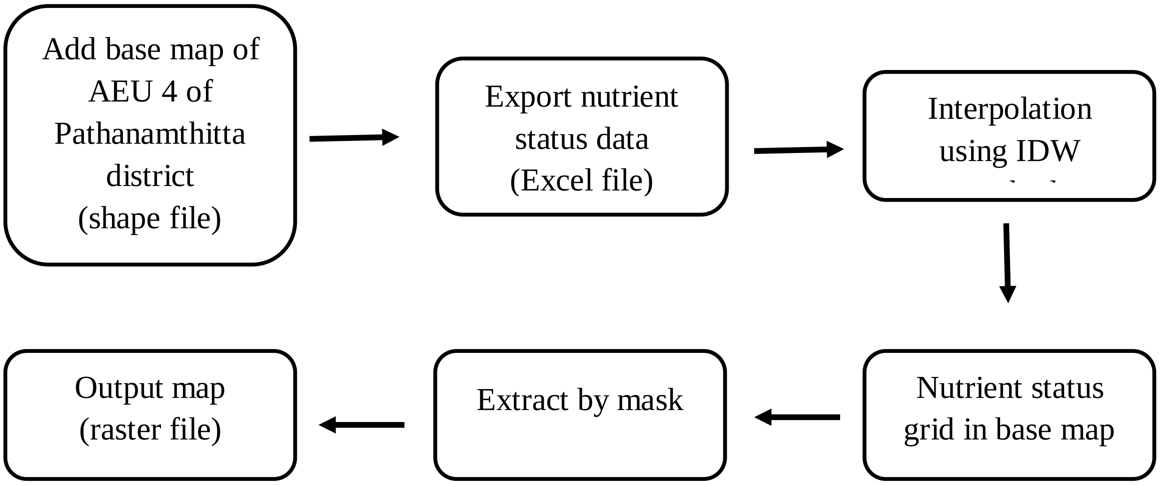



Fig.3. Flow chart of ArcGIS mapping using IDW method.

Various thematic soil maps were prepared for sampling location, soil texture, pH, organic carbon, available nitrogen, phosphorus, potassium, calcium, sulphur, soil quality index, land quality index and nutrient indices of organic carbon, nitrogen, phosphorus and potassium.

3.8. STATISTICAL ANALYSIS OF THE DATA

Correlations between physical, chemical and biological properties were done using Pearson’s correlation coefficient in OPSTAT software (Panse and Sukhatme, 1978)

# RESULTS

# 4. RESULTS

The quality of the soil in AEU 4 of Pathanamthitta district after 2018 flood was evaluated through the present investigation entitled “Assessment of soil quality in the post-flood scenario of AEU 4 in Pathanamthitta district of Kerala and generation of GIS maps”. The data generated from the investigation to realize the objectives of the study are presented in this chapter.

## 4.1. DETAILS OF SURVEY

A survey based on predesigned questionnaire was conducted at the time of soil sample collection at AEU 4 in Pathanamthitta district. It includes the basic details of crops cultivated, nutrient management and land holdings of the farmers. The high rainfall and rise in water level in Pampa and Manimala rivers caused widespread crop damage in this area. Water stagnation in this area continued for 5 to 6 days. Among the major crops, paddy and banana were the worst hit by flood. In Kuttoor panchayat, crop damage was reported over 20 ha of area. Nutmeg and banana showed withering. Nendran variety of banana was most affected. Farmers reported rotting of tuber crops, drying up of nutmeg, rubber, and coconut in this area. Large quantity of silt and clay deposition was observed at Perinagara, Niranam, Kadapra, Nedumpuram, Kuttoor and Thiruvalla Municipality. The thickness of deposits varies from 1 to 25 cm. Farmers reported increased weed growth, yellowing and wilting of plants immediately after the flood.

Most of the paddy growers in this area rely on integrated nutrient management and conventional system of farming. It was observed that majority of the farmers in the area belong to marginal and small group. The farmers cultivating vegetables and banana flowed organic nutrient sources like composts, biogas slurry, fresh and dried cow dung, ash, green manuring crops etc.

Table.7. Details of field survey conducted in AEU 4 of Pathanamthitta district

| Particulars | No. of farmers | Per cent (%) |
|---|---|---|
| Crops | | |
| 1. Paddy | 17 | 22.7 |
| 2. Coconut | 08 | 10.7 |
| 3. Banana | 16 | 21.3 |
| 4. Cassava | 06 | 8.00 |
| 5. Nutmeg | 12 | 16.0 |
| 6. Vegetables | 11 | 14.7 |
| 7. Sugarcane | 03 | 4.00 |
| 8. Rubber | 02 | 2.67 |
| Nutrient management | | |
| 1. INM | 18 | 24.0 |
| 2. Organic | 33 | 44.0 |
| 3. Conventional | 24 | 32.0 |
| Size of holdings | | |
| 1. Marginal | 64 | 85.3 |
| 2. Small | 9 | 12.0 |
| 3. Medium | 2 | 2.67 |

## 4. 2. CHARACTERIZATION OF SOIL SAMPLES

### 4.2.1. Physical attributes

The effect of flood on different soil physical properties such as bulk density, particle density, porosity, texture, soil moisture, maximum water holding capacity, water stable aggregates and mean weight diameter were studied and the results are furnished below.

#### *4.2.1.1. Bulk Density, Particle density and Porosity*

The results of bulk density, particle density and porosity of the soil samples in the post-flood area of AEU 4 in Pathanamthitta district are presented in Table.8.

Bulk density varied between 0.89 to 1.64 Mg $m^{-3}$ with a mean of 1.36 Mg $m^{-3}$. The lowest and highest mean at panchayat level were observed for Nedumpuram (1.28 $Mgm^{-3}$) and Kadapra (1.49 Mg $m^{-3}$) respectively.

Particle density ranged between 1.73 to 2.62 Mg $m^{-3}$. The mean of particle density for the AEU was 2.01 Mg $m^{-3}$. The lowest mean at panchayat level were observed for Nedumpuram (1.94 Mg $m^{-3}$) and Peringara (1.94 Mg $m^{-3}$) and highest at Kadapra (2.13 Mg $m^{-3}$) respectively.

Porosity varied between 15.7 to 51.1% with a mean of 32.5% .The lowest and highest mean at panchayat level were observed for Kuttoor (29.7%) and Niranam (35.2%) respectively.

Table.8: Bulk density, particle density and porosity in the post-flood soils of AEU 4 of Pathanamthita district.

| **Panchayat/ Municipality** | **Bulk density (Mg $m^{-3}$)** | | **Particle Density (Mg $m^{-3}$)** | | **Porosity (%)** | |
|---|---|---|---|---|---|---|
| | **Mean ±SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| Nedumpuram | 1.28 ± 0.20 | 0.89-1.56 | 1.94 ± 0.11 | 1.77-2.14 | 34.2 ± 8.99 | 15.7-49.7 |
| Peringara | 1.29 ± 0.17 | 0.98-1.59 | 1.94 ± 0.19 | 1.79-2.35 | 33.4 ± 9.13 | 20.9-51.1 |
| Kuttoor | 1.38 ± 0.10 | 1.16-1.55 | 1.98 ± 0.17 | 1.73-2.29 | 29.7 ± 7.14 | 20.2-47.5 |
| Niranam | 1.33 ± 0.16 | 1.11-1.59 | 2.04 ± 0.09 | 1.90-2.16 | 35.2 ± 6.08 | 25.0-46.2 |
| Kadapra | 1.49 ± 0.22 | 0.95-1.62 | 2.13 ± 0.14 | 1.79-2.37 | 30.1 ± 8.41 | 20.9-48.1 |
| Thiruvalla Municipality | 1.39 ± 0.27 | 0.96-1.64 | 2.04 ± 0.25 | 1.77-2.62 | 32.3 ± 9.46 | 19.1-46.4 |
| **AEU 4 - Pathanamthitta** | 1.36 ± 0.20 | 0.89-1.64 | 2.01 ± 0.18 | 1.73-2.62 | 32.5±8.29 | 15.7-51.1 |

#### *4.2.1.2 Depth of sand/silt/clay deposition*

Sediment deposition of silt and clay were observed in this area with varied depth (Table.9). Kadapra panchayat was observed with highest silt deposition ranges between 15 -25 cm. followed by Niranam (5-15 cm), Nedumpuram (7-12 cm), Perinagara (1-10cm) and Thiruvalla Municipality (1-2 cm).

Table.9. Depth of silt/sand/clay deposition in the post-flood soils of AEU 4 in Pathanamthitta district

| Panchayat/Municipality | Depth of deposition (cm) | Nature of deposits |
|---|---|---|
| Nedumpuram | 7-12 | Clay, Silt |
| Peringara | 1-10 | Clay, Silt |
| Kuttoor | 5-15 | Clay, Silt |
| Niranam | 5-15 | Clay, Silt |
| Kadapra | 15-25 | Clay, Silt |
| Thiruvalla Municipality | 1-2 | Clay, Silt |

#### *4.2.1.3. Soil texture*

The results of the percentage of sand, silt and clay in the post-flood area of AEU 4 in Pathanamthitta district are presented in Table.10.

Percentage of sand ranged from 12 to 65% in the unit. The mean of percentage of sand for the AEU was 36.0%. The lowest and highest mean at panchayat level were observed for Niranam (23.7%) and Kadapra (41.5%) respectively.

Percentage of silt in the unit varied between 13 to 66% with a mean of 40.1%. The lowest mean at panchayat level was observed for Nedumpuram (36.9%) and highest for Niranam (48.9%).

Percentage of clay varied from 12% to 35% with a mean of 23.9%. The lowest mean at panchayat level were observed for Kadapra (21.2%) and highest for Niranam

(27.4%). The predominant soil texture in this area is silt loam. Other samples have textural classes such as clay loam, silty clay loam, sandy clay loam and sandy loam.

Table.10: Percentage of sand, silt and clay in the post-flood soils of AEU 4 of Pathanamthita district.

| Panchayat/ Municipality | % Sand | | % Silt | | % Clay | |
|---|---|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| Nedumpuram | 37.1 ± 13.8 | 16.0-57.0 | 36.9 ± 18.2 | 13.0-66.0 | 26.0 ± 7.3 | 15.0-35.0 |
| Peringara | 32.3 ± 19.6 | 12.0-65.0 | 42.8 ± 19.7 | 14.0-66.0 | 24.9 ± 05.4 | 17.0-31.0 |
| Kuttoor | 39.8 ± 19.2 | 16.0-65.0 | 38.2 ± 20.5 | 14.0-59.0 | 22.1 ± 05.9 | 14.0-30.0 |
| Niranam | 23.7 ± 14.4 | 12.0-61.0 | 48.9 ± 13.2 | 16.0-59.0 | 27.4 ± 04.3 | 17.0-32.0 |
| Kadapra | 41.5 ± 16.6 | 22.0-62.0 | 37.4 ± 18.6 | 14.0-60.0 | 21.2 ± 04.3 | 16.0-29.0 |
| Thiruvalla Municipality | 41.0 ± 13.1 | 24.0-64.0 | 37.0 ± 13.3 | 15.0-58.0 | 22.0 ± 05.8 | 12.0-29.0 |
| **AEU 4 - Pathanamthitta** | 36.0 ± 16.9 | 12.0-65.0 | 40.1 ± 17.4 | 13.0-66.0 | 23.9 ± 05.9 | 12.0-35.0 |

### *4.2.1.4. Soil moisture and maximum water holding capacity*

Available soil moisture in the post-flood area of AEU 4 in Pathanamthitta district varied between 0.15 to 62.1% with a mean of 21.0%. The lowest and highest mean at panchayat level were observed for Nedumpuram (16.0%) and Kadapra (32.0%) respectively (Table.11).

Maximum water holding capacity ranged between 24.2% and 89.8%. The mean of maximum water holding capacity for the AEU was 49.7%. The lowest and highest mean at panchayat level were observed for Kadapra (44.1%) and Peringara (60.3%) respectively.

Table.11: Soil moisture and water holding capacity in the post-flood soils of AEU 4 of Pathanamthita district.

| **Panchayat/ Municipality** | **Soil moisture (%)** | | **Maximum water holding capacity (%)** | |
|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| Nedumpuram | 16.0 ± 13.7 | 4.05-55.7 | 48.7 ± 8.51 | 30.9-62.1 |
| Peringara | 16.4 ± 10.6 | 2.99-37.2 | 60.3 ± 15.0 | 29.2-77.3 |
| Kuttoor | 21.2 ± 10.9 | 0.15-34.8 | 53.5 ± 18.9 | 33.8-89.8 |
| Niranam | 17.4 ± 9.30 | 8.40-30.5 | 45.3 ± 12.2 | 34.2-72.9 |
| Kadapra | 32.0 ± 17.8 | 10.6-62.1 | 44.1 ± 10.1 | 24.2-58.1 |
| Thiruvalla Municipality | 22.3 ± 16.6 | 4.66-62.1 | 47.4 ± 10.3 | 33.6-70.1 |
| **AEU 4 - Pathanamthitta** | 21.0 ± 14.3 | 0.15-62.1 | 49.7 ± 13.6 | 24.2-89.8 |

#### *4.2.1.5. Water stable aggregate and mean weight diameter*

Data on water stable aggregate and mean weight diameter in the post-flood area of AEU 4 in Pathanamthitta district are presented in Table.12.

Percentage of water stable aggregate in the AEU 4 varied between 4.38 and 81.7% with a mean of 46.2%. The lowest and highest mean at panchayat level were observed for Peringara (30.1%) and Niranam (59.3%) respectively.

Mean weight diameter varied between 0.06 and 3.10 mm with a mean of 0.66 mm. The lowest mean at panchayat level was observed for Peringara (0.33 mm) and highest for Niranam (1.19 mm).

Table.12: Water stable aggregates and mean weight diameter in the post-flood soils of AEU 4 of Pathanamthita district.

| **Panchayat/ Municipality** | **Water stable aggregates (%)** | | **Mean weight diameter (mm)** | |
|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| Nedumpuram | 45.2 ± 11.1 | 21.0-57.7 | 0.73 ± 0.31 | 0.19-1.23 |
| Peringara | 30.1 ± 17.1 | 8.20-63.9 | 0.33 ± 0.20 | 0.10-0.67 |
| Kuttoor | 41.2 ± 17.0 | 4.82-67.0 | 0.58 ± 0.33 | 0.06-1.29 |
| Niranam | 59.3 ± 14.8 | 41.0-81.7 | 1.19 ± 0.94 | 0.43-3.10 |
| Kadapra | 52.9 ± 14.8 | 25.9-70.4 | 0.54 ± 0.47 | 0.20-2.04 |
| Thiruvalla Municipality | 47.6 ± 22.9 | 4.38-74.6 | 0.63 ± 0.49 | 0.20-2.04 |
| **AEU 4 - Pathanamthitta** | 46.2 ± 18.5 | 4.38-81.7 | 0.66 ± 0.56 | 0.06-3.10 |

### 4.2.2. Chemical attributes

The different soil chemical properties such as pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and available micronutrients like iron, copper, zinc, manganese and boron were studied and the results are furnished below.

#### *4.2.2.1. pH, electrical conductivity and organic carbon*

The data on pH, electrical conductivity and organic carbon in the post-flood area of AEU 4 in Pathanamthitta district are given in Table.13. pH of the AEU ranged between 4.02 and 6.56. The mean of pH for the AEU was 5.35. The lowest and highest mean at panchayat level were observed for Peringara (4.72) and Kadapra (5.70) respectively.

Electrical conductivity in AEU 4 in Pathanamthitta district varied between 0.04 and 1.99 $dSm^{-1}$ with a mean of 0.41 $dSm^{-1}$. The lowest and highest mean at panchayat level were observed for Kadapra (0.10 $dSm^{-1}$) and Peringara (1.10 $dSm^{-1}$) respectively.

Organic carbon varied between 0.75 and 4.53% in the AEU 4 in Pathanamthitta district with a mean of 2.5% .The lowest mean at panchayat level were observed for Kadapra (2.18%) and highest for Peringara (3.17%). Generally organic carbon content was high in this AEU.

Table.13: pH, electrical conductivity and organic carbon in the post-flood soils of AEU 4 of Pathanamthita district

| **Panchayat/ Municipality** | **pH** | | **Electrical conductivity ($dSm^{-1}$)** | | **Organic carbon (%)** | |
|---|---|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| Nedumpuram | 5.32±0.77 | 4.4-6.09 | 0.24±0.35 | 0.05-1.38 | 2.32±0.70 | 1.44-3.90 |
| Peringara | 4.72±0.62 | 4.02-6.08 | 1.10±0.61 | 0.04-1.99 | 3.17±1.09 | 0.75-4.17 |
| Kuttoor | 5.56±0.88 | 4.08-6.52 | 0.47±0.58 | 0.04-1.58 | 2.35±0.75 | 1.44-3.96 |
| Niranam | 5.57±0.81 | 4.50-6.56 | 0.35±0.31 | 0.06-1.10 | 2.62±0.96 | 1.53-3.84 |
| Kadapra | 5.70±0.52 | 5.00-6.41 | 0.10±0.04 | 0.05-0.18 | 2.18±1.11 | 1.32-4.53 |
| Thiruvalla Municipality | 5.23±0.50 | 4.37-6.16 | 0.25±0.21 | 0.07-0.86 | 2.43±1.27 | 0.93-4.35 |
| **AEU 4- Pathanamthitta** | 5.35±0.74 | 4.02-6.56 | 0.41±0.50 | 0.04-1.99 | 2.50±1.02 | 0.75-4.53 |

### *4.2.2.2. Available nitrogen, phosphorus and potassium*

Table.14. presents the status of available nitrogen, phosphorus and potassium in the post-flood area of AEU 4 in Pathanamthitta district .Available nitrogen ranged from 75.3 to 452 kg ha$^{-1}$ with a mean of 224 kg ha$^{-1}$.The lowest and highest mean at panchayat level were observed for Nedumpuram (178 kg ha$^{-1}$) and Kuttoor (283 kg ha$^{-1}$) respectively.

Available phosphorus ranged between 3.55 and 328 kg ha$^{-1}$ in the AEU 4 in Pathanamthitta district. The mean of available phosphorus for the AEU was 84.9 kg ha$^{-1}$. The lowest and highest mean at panchayat level were observed for Peringara (43.1kgha$^{-1}$) and Kadapra (134 kg ha$^{-1}$) respectively.

Available potassium ranged from 26.1 to 367 kg ha$^{-1}$ in the AEU 4 with a mean of 131 kg ha$^{-1}$ .The lowest and highest mean at panchayat level were observed for Kadapra (75.4 kg ha$^{-1}$) and Niranam (164 kg ha$^{-1}$) respectively.

Table.14: Available nitrogen, phosphorus and potassium in the post-flood soils of AEU 4 of Pathanamthita district

| **Panchayat/ Municipality** | **Available nitrogen (kg ha$^{-1}$)** | | **Available phosphorus (kg ha$^{-1}$)** | | **Available potassium (kg ha$^{-1}$)** | |
|---|---|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| Nedumpuram | 178±87.8 | 75.3-326 | 97.6±95.5 | 11.9-289 | 147±95.6 | 26.1-367 |
| Peringara | 232±125 | 87.8-452 | 43.1±80.5 | 3.55-236 | 128±67.4 | 47.5-226 |
| Kuttoor | 283±64.1 | 125-389 | 72.2±63.6 | 6.55-227 | 118±73.8 | 45.0-258 |
| Niranam | 213±63.0 | 113-314 | 102±92.5 | 5.73-251 | 164±66.0 | 34.7-292 |
| Kadapra | 232±30.6 | 188-289 | 134±100 | 7.36-328 | 75.4±47.2 | 32.5-201 |
| Thiruvalla Municipality | 208±47.6 | 113-289 | 57.9±88.3 | 4.09-223 | 153±65.1 | 53.0-249 |
| **AEU 4 - Pathanamthitta** | 224±79.4 | 75.3-452 | 84.9±90.2 | 3.55-328 | 131±74.4 | 26.1-367 |

#### *4.2.2.3. Available calcium, magnesium and sulphur*

The status of available secondary nutrients *viz*. calcium, magnesium and sulphur in the post flood soils of AEU 4 in Pathanamthitta district are presented in Table.15. Available calcium ranged from 0.99 to 742 mg kg$^{-1}$ with a mean of 234 mg kg$^{-1}$. The lowest mean was observed for Thiruvalla municipality (123 mg kg$^{-1}$) and the highest for Niranam panchayat (336 mg kg$^{-1}$).

Available magnesium status in the AEU 4 varied between 5.90 to 19.9 mg kg$^{-1}$. The lowest and highest mean at panchayat level were observed for Nedumpuram (10.2 mg kg$^{-1}$) and highest for Thiruvalla municipality (16.7 mg kg$^{-1}$) respectively.

Available sulphur ranged between 0.09 and 13.2 mg kg$^{-1}$ in the unit. The mean available sulphur for the AEU was 2.63 mg kg$^{-1}$. The lowest and highest mean at panchayat level were observed for Nedumpuram (0.32 mg kg$^{-1}$) and Peringara (5.25 mg kg$^{-1}$) respectively.

Table.15: Available calcium, magnesium and sulphur in the post-flood soils of AEU 4 of Pathanamthita district

| **Panchayat/ Municipality** | **Calcium (mg kg$^{-1}$)** | | **Magnesium (mg kg$^{-1}$)** | | **Sulphur (mg kg$^{-1}$)** | |
|---|---|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| Nedumpuram | 325±216 | 45.5-683 | 10.2±1.48 | 5.90-11.4 | 0.32±0.21 | 0.11-0.85 |
| Peringara | 141±56.3 | 79.1-287 | 10.9±0.93 | 9.21-12.4 | 5.25±3.19 | 0.15-9.10 |
| Kuttoor | 334±221 | 83.0-678 | 11.8±1.34 | 10.1-15.4 | 2.18±3.76 | 0.09-11.3 |
| Niranam | 336±284 | 7.38-742 | 15.2±3.28 | 10.8-19.9 | 2.44±4.19 | 0.17-13.2 |
| Kadapra | 153±136 | 10.8-378 | 12.2±2.93 | 9.37-16.9 | 1.70±3.20 | 0.18-11.3 |
| Thiruvalla Municipality | 123±152 | 0.99-448 | 16.7±1.45 | 13.5-18.6 | 4.07±3.68 | 0.24-9.79 |
| **AEU 4 - Pathanamthitta** | 234±209 | 0.99-742 | 12.9±3.12 | 5.90-19.9 | 2.63±3.56 | 0.09-13.2 |

*4.2.2.4. Available iron, zinc, manganese, copper and boron*

Critical appraisal of the data presented in Table.16, revealed that the availability of iron in the post flood soils of AEU 4 ranged from 0.82 to 358 mg $kg^{-1}$ with a mean of 116 mg $kg^{-1}$. The lowest mean was observed for Thiruvalla municipality (81.9 mg $kg^{-1}$) and the highest for Peringara panchayat (209 mg $kg^{-1}$).

Available zinc varied between 0.44 to 15.5 mg $kg^{-1}$. The lowest and highest mean at panchayat level were observed for Thiruvalla municipality (3.87 mg $kg^{-1}$) and highest for Nedumpuram (8.25 mg $kg^{-1}$) respectively.

Available manganese ranged between 1.51 and 37.3 mg $kg^{-1}$ with a mean value of 17.8 mg $kg^{-1}$. Kadapra panchayat showed the lowest mean value (13.6 mg $kg^{-1}$) whereas Peringara panchayat showed the highest mean value (24.2 mg $kg^{-1}$).

Available copper in the AEU varied between 0.01 and 5.49 mg $kg^{-1}$ with a mean of 0.37 mg $kg^{-1}$. The lowest and highest mean at panchayat level were observed for Niranam (0.17 mg $kg^{-1}$) and Nedumpuram (0.93 mg $kg^{-1}$) respectively.

Available boron varied between 1.05 mg $kg^{-1}$ and 1.69 mg $kg^{-1}$ with a mean of 1.39 mg $kg^{-1}$. The lowest mean at panchayat level was observed for Nedumpuram (1.29 mg $kg^{-1}$) and highest for Niranam (1.45mg $kg^{-1}$).

Table.16: Available iron, zinc, manganese, copper and boron in the post-flood area of AEU 4 of Pathanamthita district

| **Panchayat/ Municipality** | **Iron (mg kg$^{-1}$)** | | **Zinc (mg kg$^{-1}$)** | | **Manganese (mg kg$^{-1}$)** | | **Copper (mg kg$^{-1}$)** | | **Boron (mg kg$^{-1}$)** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| Nedumpuram | 128±76.3 | 57.2-358 | 8.25±3.87 | 4.60-15.5 | 14.7±7.20 | 6.58-27.1 | 0.93±1.58 | 0.01-5.49 | 1.29±0.09 | 1.13-1.47 |
| Peringara | 209±86.3 | 57.0-348 | 7.78±1.76 | 4.81-9.89 | 24.2 ±10.0 | 1.62-37.3 | 0.19 ±0.15 | 0.02-0.55 | 1.33±0.10 | 1.05-1.45 |
| Kuttoor | 91.1±108 | 12.8-336 | 7.85 ±2.69 | 5.33-15.5 | 16.7±7.17 | 1.51-29.1 | 0.29 ±0.10 | 0.15-0.44 | 1.42±0.14 | 1.20-1.64 |
| Niranam | 105±56.0 | 27.2-206 | 6.58±2.76 | 1.90-11.2 | 19.8±8.61 | 6.75-32.5 | 0.17±0.10 | 0.06-0.35 | 1.45±0.11 | 1.27-1.59 |
| Kadapra | 88.1±61.1 | 0.82-176 | 5.06±1.61 | 0.62-7.06 | 13.6±8.49 | 3.48-33.3 | 0.35±0.21 | 0.01-0.63 | 1.39±0.10 | 1.24-1.56 |
| Thiruvalla Municipality | 81.9±55.3 | 1.11-169 | 3.87±1.93 | 0.44-7.63 | 18.1±7.12 | 5.55-27.5 | 0.29±0.16 | 0.04-0.63 | 1.43±0.12 | 1.23-1.67 |
| **AEU 4 - Pathanamthitta** | 116±85.1 | 0.82-358 | 6.53±2.97 | 0.44-15.5 | 17.8±8.61 | 1.51-37.3 | 0.37±0.68 | 0.01-5.49 | 1.39±0.12 | 1.05-1.67 |

### 4.2.3. Biological attributes

The effect of flood on different soil biological property (Acid phosphatase activity) was studied and the results are furnished below.

#### *4.2.3.1. Acid phosphatase activity*

Perusal of the data on acid phosphatase activity in the post-flood area of AEU 4 in Pathanamthitta district revealed that the acid phosphatase activity ranged between 0.02 to 26.0 µg PNP produced $g^{-1}$soil $h^{-1}$ with a mean of 6.42 µg PNP produced $g^{-1}$soil $h^{-1}$. The highest mean at panchayat level was observed for Kadapra (11 µg PNP produced $g^{-1}$soil $h^{-1}$) and the lowest for Perngara (2.13 µg PNP produced $g^{-1}$soil $h^{-1}$) (Table.17).

Table.17: Acid phosphatase activityin the post-flood soils of AEU 4 of Pathanamthita district

| **Panchayat/ Municipality** | **Acid phosphatase (µg PNP produced $g^{-1}$soil $h^{-1}$)** | |
|---|---|---|
| | **Mean ± SD** | **Range** |
| Nedumpuram | 8.27 ± 6.39 | 0.02 - 20.2 |
| Peringara | 2.13 ± 4.72 | 0.02 - 13.3 |
| Kuttoor | 5.59 ± 5.17 | 0.64 - 17.2 |
| Niranam | 7.03 ± 7.02 | 0.05 - 19.2 |
| Kadapra | 11.0 ± 7.50 | 0.91 - 26.0 |
| ThiruvallaMunicipality | 4.16 ± 5.55 | 0.04 - 15.8 |
| **AEU 4-Pathanamthitta** | 6.42 ± 6.61 | 0.02 – 26.0 |

4.3. FORMULATION OF MINIMUM DATA SET (MDS)

The best indicators that effectively and efficiently influence soil quality are selected to form a Minimum Data Set (MDS) through Principal Component Analysis (PCA). The soil quality indicators (21 attributes) were considered for doing PCA method were bulk density, particle density, percentage of sand, silt, clay, maximum water holding capacity, water stable aggregates, pH, electrical conductivity, organic carbon, available nitrogen, phosphorus ,potassium, calcium, magnesium, sulphur, iron, zinc, manganese, copper and boron.

Six principle components (PCs) which have Eigen value greater than one were selected from PCA analysis. It indicated that the 6 PCs have variance of 41.23 per cent, 22.21 per cent, 12.66 per cent, 9.01 per cent, 7.69 per cent and 7.01 per cent respectively (Table.18). The overall changes in soil quality were expressed effectively by these six components and they were considered for MDS. According to Wander and Bollero (1999), only the variables which have high weightage within each PC were selected for MDS. When there is more than one indicator in single PC, correlation is worked out among them. If they have significant correlation ($r \geq 0.6$) between each other, then the one with highest loading factor was selected for MDS and the remaining were excluded. Thus, means that the non-correlated parameters were retained and elected for MDS (Andrews *et al.*, 2001).

Table.18. Result of principal component analysis (PCA)

| Particulars | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 |
|---|---|---|---|---|---|---|
| Eigenvalues | **6.577** | **3.526** | **2.009** | **1.429** | **1.222** | **1.112** |
| Proportion | 0.313 | 0.168 | 0.096 | 0.068 | 0.058 | 0.053 |
| Cumulative Proportion | 0.313 | 0.481 | 0.577 | 0.645 | 0.703 | 0.756 |

Table.18. continued

| Eigen vectors | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 |
|---|---|---|---|---|---|---|
| Bulk density | **0.2** | **0.354** | -0.025 | -0.066 | 0.123 | 0.103 |
| Particle density | **0.282** | -0.183 | 0.06 | 0.046 | -0.155 | -0.143 |
| MWHC | -0.065 | **0.32** | -0.117 | 0.229 | 0.152 | **0.357** |
| WSA | -0.087 | -0.02 | **0.645** | 0.225 | 0.109 | -0.079 |
| % sand | 0 | 0.062 | **-0.664** | -0.212 | 0.055 | -0.126 |
| % silt | 0.005 | -0.186 | 0.01 | 0.011 | **-0.469** | **0.543** |
| % clay | **-0.37** | -0.047 | -0.051 | 0.057 | 0.01 | -0.107 |
| pH | **-0.354** | -0.146 | -0.067 | 0.023 | 0.021 | -0.104 |
| EC | **0.228** | **-0.295** | -0.125 | 0.058 | 0.002 | 0.132 |
| OC | **0.242** | -0.031 | 0.028 | 0.124 | -0.22 | 0.074 |
| N | -0.142 | **0.258** | -0.051 | 0.269 | -0.179 | -0.187 |
| P | 0.097 | -0.122 | -0.137 | **0.582** | 0.044 | **-0.277** |
| K | 0.027 | 0.217 | -0.193 | **0.524** | -0.254 | -0.02 |
| Ca | **-0.3** | -0.058 | -0.041 | 0.033 | 0.114 | -0.084 |
| Mg | -0.099 | **-0.449** | -0.051 | -0.042 | 0.222 | -0.038 |
| S | 0.168 | **-0.337** | -0.016 | 0.076 | -0.019 | -0.016 |
| Fe | **-0.352** | -0.117 | -0.061 | 0.128 | -0.043 | -0.034 |
| Zn | 0.155 | **-0.335** | -0.18 | 0.241 | 0.131 | 0.069 |
| Mn | **-0.357** | -0.097 | -0.029 | 0.008 | -0.104 | 0.152 |
| Cu | **-0.248** | -0.076 | -0.038 | 0.061 | -0.193 | **0.394** |
| B | 0.031 | 0.014 | -0.026 | 0.227 | **0.652** | **0.418** |

In PC1, Percentage of clay, pH, available iron and manganese had high loading factor and they were not correlated to each other. So they were selected for MDS. Available magnesium was selected from PC2. Third PC consists of percentage of water stable aggregates, percentage of sand. In PC4 available phosphorus and potassium were considered. PC5 and PC6 consisted of available boron and percentage of silt respectively. The final MDS consists of 11 parameters (Table.19)

Table.19. Minimum data set (MDS)

<table>
<tr><th>PC1</th><th>PC2</th><th>PC3</th><th>PC4</th><th>PC5</th><th>PC6</th></tr>
<tr><td>% Clay</td><td rowspan="4">Available Mg</td><td rowspan="2">Water stable aggregate</td><td rowspan="2">Available phosphorus</td><td rowspan="4">Available boron</td><td rowspan="4">% Silt</td></tr>
<tr><td>pH</td></tr>
<tr><td>Available Fe</td><td rowspan="2">% Sand</td><td rowspan="2">Available potassium</td></tr>
<tr><td>Available Mn</td></tr>
</table>

## 4.4 FORMULATION OF SOIL QUALITY INDEX

### 4.4.1. Assigning scores to Minimum data set (MDS)

To formulate the soil quality index, proper weights were assigned to the selected parameters in the MDS and proper score was given to each class (Larson and Pierce, 1994). Scoring of the parameters was achieved using the method suggested by Kundu *et al.* (2012); Lal and Mukharjee (2012) with slight modification based on the soil fertility ratings for secondary and micronutrients for soils of Kerala (Table.20). For SQI calculation, it is necessary to convert the parameter values into unit less data. It was achieved by assigning scores.

Table.20. Scoring of MDS parameters

| **Soil quality indicators** | **Weights** | **Class I with score 4** | **Class II with score 3** | **Class III with score 2** | **Class IV with score 1** |
|---|---|---|---|---|---|
| Texture (Clay %) | 13 | Loam | Clay loam/ Sandy loam | Sand/Clay | Grit |
| Soil pH | 13 | 6.5 - 7.5 | 6 - 6.5 | 6 - 5.5 | <5.5 |
| Available Fe | 13 | >20 | 11-20 | 5-11 | <5 |
| Available Mn | 13 | >5.0 | 2.0 - 5.0 | 1.0 - 2.0 | <1.0 |
| Available Mg | 12 | >120 | 90-120 | 60-90 | <60 |
| WSA (%) | 8 | > 90 | 70 - 90 | 50 - 70 | < 50 |
| Texture (Sand %) | 8 | Loam | Clay loam/ Sandy loam | Sand/Clay | Grit |
| Available P | 6 | >25 | 15 - 25 | 15 - 10 | <10 |
| Available K | 6 | >280 | 200 - 280 | 120 - 200 | <120 |
| Available B | 5 | >1.5 | 0.7-1.5 | 0.5-0.7 | <0.5 |
| Texture (Silt %) | 3 | Loam | Clay loam/ Sandy loam | Sand/Clay | Grit |

### 4.4.2. Computation of Soil quality index and relative soil quality index

Relative soil quality index ranged between 55.8 and 81.8% in the post-flood area of AEU 4 in Pathanamthitta district. The mean of relative soil quality for the AEU was 65.5%. The highest soil quality was observed at Niranam panchayat (69.0%) and the lowest was at Peringara panchayt (62.0%). Majority of the soil samples were having medium range of soil quality and remaining fall in good soil quality. There were no samples which lied in poor soil quality (Table.21).

Table 21. Soil quality index and relative soil quality index of post-flood soils of AEU 4 of Pathanamthitta district.

| **Panchayat/ Municipality** | **SQI** | | **RSQI (%)** | |
|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| Nedumpuram | 267 ± 18.6 | 242 - 299 | 66.8 ± 4.65 | 60.5 - 74.8 |
| Peringara | 248 ± 11.8 | 236 - 280 | 62.0 ± 2.94 | 59.0 - 70.0 |
| Kuttoor | 267 ± 22.3 | 228 - 294 | 66.6 ± 5.56 | 57.0 - 73.5 |
| Niranam | 276 ± 29.7 | 236 - 327 | 69.0 ± 7.42 | 59.0 - 81.8 |
| Kadapra | 266 ± 23.9 | 228 - 296 | 66.4 ± 5.97 | 57.0 - 74.0 |
| Thiruvalla Municipality | 249 ± 16.0 | 223 - 282 | 62.2 ± 3.99 | 55.8 - 70.5 |
| **AEU 4 - Pathanamthitta** | 262 ± 22.8 | 223 - 327 | 65.5 ± 5.70 | 55.8 - 81.8 |

4.5. NUTRIENT INDEX (NI)

The measure of nutrient supplying capacity of soil to plants were calculated though Nutrient Index (NI). The results of nutrient indices of organic carbon, nitrogen, phosphorus and potassium are given below.

### 4.5.1. Nutrient indices of organic carbon

It is inferred from the Table.22, that the Nutrient index value of organic carbon in the post flood soils of AEU 4 of Pathanamthitta was high in Niranam panchayat (3.00) and low in Kadapra panchayat (2.62). All the samples analyzed showed high fertility in organic carbon.

Table.22. Nutrient indices of organic carbon in the flood affected areas of AEU 4 of Pathanamthitta district.

| Panchayat/Municipality | Nutrient index value | Rating |
|---|---|---|
| Nedumpuram | 2.92 | High fertility |
| Peringara | 2.92 | High fertility |
| Kuttoor | 2.92 | High fertility |
| Niranam | 3.00 | High fertility |
| Kadapra | 2.62 | High fertility |
| Thiruvalla Municipality | 2.70 | High fertility |

### 4.5.2. Nutrient indices of nitrogen

Table.23. revealed that Nutrient index value of nitrogen in the post flood soils of AEU 4 of Pathanamthitta falls in low fertility status for nitrogen. The values ranged from 1.08 – 1.17. All the samples analyzed showed low fertility in nitrogen.

Table.23. Nutrient indices of nitrogen in the flood affected areas of AEU 4 of Pathanamthitta district.

| Panchayat/Municipality | Nutrient index value | Rating |
|---|---|---|
| Nedumpuram | 1.15 | Low fertility |
| Peringara | 1.17 | Low fertility |
| Kuttoor | 1.17 | Low fertility |
| Niranam | 1.17 | Low fertility |
| Kadapra | 1.08 | Low fertility |
| Thiruvalla Municipality | 1.08 | Low fertility |

### 4.5.3. Nutrient indices of phosphorus

A perusal of the data in Table.24 revealed that the Nutrient index value of phosphorus in Peringara panchayat and Thiruvalla municipality had low phosphorus status whereas Nedumpuram, Kuttoor, Niranam and Kadapra panchayats had high phosphorus status with nutrient index value greater than 2.5.

### 4.5.4. Nutrient indices of potassium

Table.25. presents Nutrient index value of potassium. It was medium in Niranam and Thiruvalla municipality. Nedumpuram, Peringara, Kuttoor and Kadapra panchayat have low potassium status with nutrient index value less than 1.5.

Table.24. Nutrient indices of phosphorus in the flood affected areas of AEU 4 of Pathanamthitta district.

| **Panchayat/Municipality** | **Nutrient index value** | **Class** |
|---|---|---|
| Nedumpuram | 2.69 | High fertility |
| Peringara | 1.48 | Low fertility |
| Kuttoor | 2.50 | High fertility |
| Niranam | 2.50 | High fertility |
| Kadapra | 2.69 | High fertility |
| Thiruvalla Municipality | 1.42 | Low fertility |

Table.25. Nutrient indices of potassium in the flood affected areas of AEU 4 of Pathanamthitta district.

| **Panchayat** | **Nutrient index value** | **Class** |
|---|---|---|
| Nedumpuram | 1.42 | Low fertility |
| Peringara | 1.49 | Low fertility |
| Kuttoor | 1.49 | Low fertility |
| Niranam | 1.75 | Medium fertility |
| Kadapra | 1.15 | Low fertility |
| Thiruvalla Municipality | 1.83 | Medium fertility |

## 4.6. LAND QUALITY INDEX

Land quality index was determined on the basis of soil organic carbon stock as per the criteria given by Shalima Devi (2006). The study area had high organic carbon content. The highest land quality index was observed at Nedumpuram panchayat with soil organic carbon stock of 6.14 kg $m^{-2}$ and it falls in low quality category (Table.26) .The lowest value was noticed at Thiruvalla municipality with 4.37 kg $m^{-2}$ of soil organic carbon stock.

Table.26. Land quality index in the flood affected areas of AEU 4 of Pathanamthitta district.

| **Panchayat/ Municipality** | **LQI** | |
|---|---|---|
| | **Mean ± SD** | **Range** |
| Nedumpuram | 6.14 ± 2.26 | 1.82 - 8.39 |
| Peringara | 4.86 ± 1.53 | 2.87 - 8.20 |
| Kuttoor | 5.15 ± 1.83 | 2.87 - 7.95 |
| Niranam | 4.68 ± 1.41 | 3.13 - 7.45 |
| Kadapra | 4.76 ± 1.65 | 2.68 - 7.83 |
| ThiruvallaMunicipality | 4.37 ± 1.11 | 2.92 - 6.44 |
| **AEU 4 - Pathanamthitta** | 4.98 ± 1.69 | 1.82 - 8.39 |

## 4.7. GENERATION OF GIS MAPS

Spatial variability of soil pH, texture, organic carbon, available N, P, K, Ca and S in flood affected area of AEU 4 were mapped. Soil quality index, land quality index and nutrient indices of organic carbon and available primary nutrients were also mapped using ArcGIS software.

## 4.8. CORRELATION

### 4.8.1. Correlation between physical parameters

Critical appraisal of the data (Table.28) revealed that the bulk density was positively correlated with particle density (0.600$^{**}$), moisture content (0.461$^{**}$) and water stable aggregates (0.362$^{**}$) and negatively correlated with maximum water holding capacity (-0.346$^{**}$), porosity (-0.820$^{**}$), and percentage of clay (-0.601$^{**}$). Particle density was positively correlated with moisture content (0.303$^{**}$) and water stable aggregates (0.485$^{**}$) and negatively correlated with maximum water holding capacity (-0.528$^{**}$) and percentage of clay (-0.273$^{*}$). Maximum water holding capacity was negatively correlated with mean weight diameter (-0.279$^{*}$) and water stable aggregates (-0.406$^{**}$). Moisture content was positively correlated with water stable aggregates (0.289$^{*}$) and negatively correlated with porosity (-0.364$^{**}$) and percentage of clay (-0.360$^{**}$). Porosity had positive correlation with percentage of clay (0.550$^{**}$) and had negative correlation with percentage of sand (-0.317$^{**}$). MWD is positively correlated with WSA (0.593$^{**}$). Percentage of sand and silt were negatively correlated to each other.

### 4.8.2. Correlation between chemical parameters

The data in Table.29, revealed that pH was positively correlated with calcium (0.672$^{**}$), magnesium (0.531$^{**}$), manganese (0.765$^{**}$) and copper (0.447$^{**}$) and negatively correlated with electrical conductivity (-0.242$^{*}$), organic carbon (-0.399$^{**}$) and boron (-0.624$^{**}$). Electrical conductivity showed positive correlation with organic carbon (0.317$^{**}$), phosphorus (0.240$^{*}$), magnesium (0.339$^{**}$), sulphur (0.519$^{**}$) and zinc (0.584$^{**}$) and negative correlation with nitrogen (-0.452$^{**}$), calcium (-0.246$^{*}$), iron (-0.368$^{**}$) and manganese (-0.375$^{**}$). Organic carbon showed positive correlation with sulphur (0.317$^{**}$) and boron (0.280$^{*}$) and negative correlation with calcium (-0.438$^{**}$), iron (-0.473$^{**}$), manganese (-0.475$^{**}$) and copper (-0.241$^{*}$). Nitrogen had positive correlation with potassium (0.294$^{*}$), calcium (0.301$^{**}$), iron (0.236$^{*}$) and manganese (0.250$^{*}$) and negative correlation with magnesium (-0.305$^{**}$), sulphur (-0.276$^{*}$) and zinc (-0.360$^{**}$). Phosphorus had positive correlation with sulphur (0.237$^{*}$) and zinc (0.386$^{**}$). Potassium had positive and negative correlation with boron (0.397$^{**}$) and magnesium (-0.497$^{**}$) respectively. Calcium showed positive correlation with magnesium (0.373$^{**}$), iron (0.621$^{**}$), manganese (0.639$^{**}$) and copper (0.374$^{**}$) and negatively correlated with sulphur (-0.243$^{*}$), zinc (-0.233$^{*}$) and born (-0.462$^{**}$). Magnesium had positive correlation with sulphur (0.351$^{**}$), iron (0.368$^{**}$), zinc (0.477$^{**}$) and manganese (0.333$^{**}$) and negative correlation with boron (-0.428$^{**}$).

Among micronutrients, iron was positively correlated with manganese (0.892$^{**}$) and copper (0.639$^{**}$) and negatively correlated with boron (-0.482$^{**}$). Manganese had positive and negative correlation with copper (0.855$^{**}$) and boron (-0.570$^{**}$) respectively. Copper was negatively correlated with boron (-0.402$^{**}$).

### 4.8.3. Correlation between physical and chemical parameters

Table.27, revealed that the soil pH had significant positive correlation with maximum water holding capacity (0.350$^{**}$) and porosity (0.848$^{**}$) and significant negative correlation with bulk density (-0.723$^{**}$), particle density (-0.386$^{**}$), soil moisture content (-0.472$^{**}$) and mean weight diameter (-0.554$^{**}$). Electrical conductivity showed positive correlation with particle density (0.593$^{**}$), moisture content (0.503$^{**}$) and percentage of silt (0.235$^{*}$) and negatively correlated with maximum water holding capacity (-0.293$^{*}$), porosity (-0.426$^{**}$), and percentage of clay (-0.431$^{**}$).

Organic carbon was positively correlated with bulk density (0.263$^{*}$), particle density (0.503$^{**}$), maximum water holding (0.281$^{*}$), and moisture content (0.295$^{*}$) and negatively correlated with porosity (-0.525$^{**}$), particle density (-0.503$^{**}$) and percentage of clay (-0.543$^{**}$). Nitrogen showed positive correlated with maximum water holding capacity (0.356$^{**}$) and percentage of clay (0.302$^{**}$) and negatively correlated with particle density (-0.326$^{**}$). Phosphorus had positive correlation with particle density (0.298$^{**}$). Potassium was positively correlated with mean weight diameter (0.292$^{*}$). Calcium showed positive correlation with maximum water holding capacity (0.383$^{**}$), porosity (0.536$^{**}$) and percentage of clay (0.773$^{**}$) and negative correlation with bulk density (-0.413$^{**}$), particle density (-0.490$^{**}$), soil moisture content (-0.254$^{*}$), mean weight diameter (-0.367$^{**}$). Magnesium had positive correlation with porosity (0.310$^{**}$), percentage of clay (0.318$^{**}$) and negatively correlated with bulk density (-0.567$^{**}$) and mean weight diameter (-0.560$^{**}$). Sulphur showed positive correlation with particle density (0.455$^{**}$), soil moisture content (0.249$^{*}$) and percentage of silt (0.235$^{*}$) and showed negative correlation with maximum water holding capacity (-0.238$^{*}$), Porosity (-0.307$^{**}$), mean weight diameter (-0.249$^{*}$) and percentage of clay (-0.357$^{**}$).

Among micro nutrients, iron showed positive correlation with maximum water holding capacity (0.378$^{**}$), porosity (0.907$^{**}$) and percentage of clay (0.912$^{**}$) and negative correlation with bulk density (-0.662$^{**}$), particle density (-0.543$^{**}$), moisture content (-0.461$^{**}$) and mean weight diameter (-0.456$^{**}$). Zinc was positively correlated with particle density (0.425$^{**}$) and soil moisture content (0.234$^{*}$) and showed negative correlation with maximum water holding capacity (-0.312$^{**}$), porosity (-0.264$^{*}$) and percentage of clay (-0.323$^{**}$). Manganese had positive correlation with maximum water holding capacity (0.373$^{**}$), porosity (0.853$^{**}$) and percentage of clay (0.832$^{**}$) and negative correlation with bulk density (-0.601$^{**}$), particle density (-0.546$^{**}$), moisture content (-0.455$^{**}$) and mean weight diameter (-0.415$^{**}$). Copper was positively correlated with maximum water holding capacity (0.240$^{*}$), porosity (0.534$^{**}$) and percentage of clay (0.471$^{**}$) and negatively correlated with bulk density (-0.351$^{**}$), particle density (-0.330$^{**}$) and moisture content (-0.256$^{*}$).

Table.27. Correlation between physical and chemical parameters

| | Bulk density | Particle density | MWHC | Moisture content | Porosity | MWD | % of silt | % of clay |
|---|---|---|---|---|---|---|---|---|
| pH | $-0.723^{**}$ | $-0.386^{**}$ | $0.350^{**}$ | $-0.472^{**}$ | $0.848^{**}$ | $-0.554^{**}$ | $0.069^{NS}$ | $0.853^{**}$ |
| EC | $-0.086^{NS}$ | $0.593^{**}$ | $-0.293^{*}$ | $0.503^{**}$ | $-0.426^{**}$ | $0.000^{NS}$ | $0.235^{*}$ | $-0.431^{**}$ |
| OC | $0.263^{*}$ | $-0.503^{**}$ | $0.281^{*}$ | $0.295^{*}$ | $-0.525^{**}$ | $0.203^{NS}$ | $0.070^{NS}$ | $-0.543^{**}$ |
| N | $0.189^{NS}$ | $-0.326^{**}$ | $0.356^{**}$ | $-0.159^{NS}$ | $0.199^{NS}$ | $0.079^{NS}$ | $-0.105^{NS}$ | $0.302^{**}$ |
| P | $-0.019^{NS}$ | $0.298^{**}$ | $-0.129^{NS}$ | $0.161^{NS}$ | $-0.153^{NS}$ | $0.094^{NS}$ | $-0.017^{NS}$ | $-0.151^{NS}$ |
| K | $0.169^{NS}$ | $-0.071^{NS}$ | $-0.056^{NS}$ | $0.099^{NS}$ | $-0.051^{NS}$ | $0.292^{*}$ | $-0.043^{NS}$ | $-0.001^{NS}$ |
| Ca | $-0.413^{**}$ | $-0.490^{**}$ | $0.383^{**}$ | $-0.254^{*}$ | $0.536^{**}$ | $-0.367^{**}$ | $0.003^{NS}$ | $0.773^{**}$ |
| Mg | $-0.567^{**}$ | $0.035^{NS}$ | $0.029^{NS}$ | $-0.054^{NS}$ | $0.310^{**}$ | $-0.560^{**}$ | $0.193^{NS}$ | $0.318^{**}$ |
| S | $-0.137^{NS}$ | $0.455^{**}$ | $-0.238^{*}$ | $0.249^{*}$ | $-0.307^{**}$ | $-0.249^{*}$ | $0.235^{*}$ | $-0.357^{**}$ |
| Fe | $-0.662^{**}$ | $-0.543^{**}$ | $0.378^{**}$ | $-0.461^{**}$ | $0.907^{**}$ | $-0.456^{**}$ | $0.015^{NS}$ | $0.912^{**}$ |
| Zn | $-0.142^{NS}$ | $0.425^{**}$ | $-0.312^{**}$ | $0.234^{*}$ | $-0.264^{*}$ | $-0.060^{NS}$ | $0.134^{NS}$ | $-0.323^{**}$ |
| Mn | $-0.601^{**}$ | $-0.546^{**}$ | $0.373^{**}$ | $-0.455^{**}$ | $0.853^{**}$ | $-0.415^{**}$ | $0.076^{NS}$ | $0.832^{**}$ |
| Cu | $-0.351^{**}$ | $-0.330^{**}$ | $0.240^{*}$ | $-0.256^{*}$ | $0.534^{**}$ | $-0.174^{NS}$ | $0.153^{NS}$ | $0.471^{**}$ |

### 4.8.4. Correlation between chemical and biological parameters

When chemical and biological attributes were correlated, acid phosphatase activity in flood affected soils of AEU 4 in Pathanamthitta showed positive correlation with organic carbon ($0.317^{**}$) and potassium ($0.380^{**}$) and negative correlation with pH ($-0.668^{**}$), phosphorus ($-0.910^{**}$), calcium ($-0.506^{**}$), magnesium ($-0.432^{**}$), iron ($-0.540^{**}$), manganese ($-0.644^{**}$) and copper ($-0.466^{**}$). Table.30.

Table.28. Correlation between physical parameters

| | Bulk density | Particle density | MWHC | Moisture content | Porosity | MWD | WSA | % of sand | % of silt | % of clay |
|---|---|---|---|---|---|---|---|---|---|---|
| Bulk density | 1 | | | | | | | | | |
| Particle density | $0.600^{**}$ | 1 | | | | | | | | |
| MWHC | $-0.346^{**}$ | $-0.528^{**}$ | 1 | | | | | | | |
| Moisture content | $0.461^{**}$ | $0.303^{**}$ | $0.166^{NS}$ | 1 | | | | | | |
| Porosity | $-0.820^{**}$ | $-0.040^{NS}$ | $0.023^{NS}$ | $-0.364^{**}$ | 1 | | | | | |
| MWD | $0.218^{NS}$ | $0.186^{NS}$ | $-0.279^{*}$ | $-0.120^{NS}$ | $-0.132^{NS}$ | 1 | | | | |
| WSA | $0.362^{**}$ | $0.485^{**}$ | $-0.406^{**}$ | $0.289^{*}$ | $-0.092^{NS}$ | $0.593^{**}$ | 1 | | | |
| % of sand | $0.198^{NS}$ | $-0.088^{NS}$ | $0.068^{NS}$ | $0.186^{NS}$ | $-0.317^{**}$ | $-0.162^{NS}$ | $-0.057^{NS}$ | 1 | | |
| % of silt | $0.011^{NS}$ | $0.178^{NS}$ | $-0.099^{NS}$ | $-0.059^{NS}$ | $0.122^{NS}$ | $0.155^{NS}$ | $0.079^{NS}$ | $-0.942^{**}$ | 1 | |
| % of clay | $-0.601^{**}$ | $-0.273^{*}$ | $0.100^{NS}$ | $-0.360^{**}$ | $0.550^{**}$ | $0.005^{NS}$ | $-0.070^{NS}$ | $-0.079^{NS}$ | $-0.261^{*}$ | 1 |

Table.29. Correlation between chemical parameters

| | pH | EC | OC | N | P | K | Ca | Mg | S | Fe | Zn | Mn | Cu | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | | | | | | | |
| EC | -0.242$^{*}$ | 1 | | | | | | | | | | | | |
| OC | -0.399$^{**}$ | 0.317$^{**}$ | 1 | | | | | | | | | | | |
| N | 0.086$^{NS}$ | -0.452$^{**}$ | -0.217$^{NS}$ | 1 | | | | | | | | | | |
| P | -0.099$^{NS}$ | 0.240$^{*}$ | 0.190$^{NS}$ | 0.032$^{NS}$ | 1 | | | | | | | | | |
| K | -0.188$^{NS}$ | -0.060$^{NS}$ | 0.121$^{NS}$ | 0.294$^{*}$ | 0.222$^{NS}$ | 1 | | | | | | | | |
| Ca | 0.672$^{**}$ | -0.246$^{*}$ | -0.438$^{**}$ | 0.301$^{**}$ | -0.128$^{NS}$ | -0.090$^{NS}$ | 1 | | | | | | | |
| Mg | 0.531$^{**}$ | 0.339$^{**}$ | -0.134$^{NS}$ | -0.305$^{**}$ | 0.182$^{NS}$ | -0.497$^{**}$ | 0.373$^{**}$ | 1 | | | | | | |
| S | -0.049$^{NS}$ | 0.519$^{**}$ | 0.317$^{**}$ | -0.276$^{*}$ | 0.237$^{*}$ | -0.163$^{NS}$ | -0.243$^{*}$ | 0.351$^{**}$ | 1 | | | | | |
| Fe | 0.856$^{**}$ | -0.368$^{**}$ | -0.473$^{**}$ | 0.236$^{*}$ | -0.057$^{NS}$ | -0.002$^{NS}$ | 0.621$^{**}$ | 0.368$^{**}$ | -0.211$^{NS}$ | 1 | | | | |
| Zn | -0.093$^{NS}$ | 0.584$^{**}$ | 0.219$^{NS}$ | -0.360$^{**}$ | 0.386$^{**}$ | 0.005$^{NS}$ | -0.233$^{*}$ | 0.477$^{**}$ | 0.549$^{**}$ | -0.191$^{NS}$ | 1 | | | |
| Mn | 0.765$^{**}$ | -0.375$^{**}$ | -0.475$^{**}$ | 0.250$^{*}$ | -0.223$^{NS}$ | -0.112$^{NS}$ | 0.639$^{**}$ | 0.333$^{**}$ | -0.281$^{*}$ | 0.892$^{**}$ | -0.225$^{NS}$ | 1 | | |
| Cu | 0.447$^{**}$ | -0.224$^{NS}$ | -0.241$^{*}$ | 0.168$^{NS}$ | -0.149$^{NS}$ | -0.061$^{NS}$ | 0.374$^{**}$ | 0.200$^{NS}$ | -0.199$^{NS}$ | 0.639$^{**}$ | -0.078$^{NS}$ | 0.855$^{**}$ | 1 | |
| B | -0.624$^{**}$ | 0.127$^{NS}$ | 0.280$^{*}$ | -0.055$^{NS}$ | 0.054$^{NS}$ | 0.397$^{**}$ | -0.462$^{**}$ | -0.428$^{**}$ | 0.083$^{NS}$ | -0.482$^{**}$ | 0.036$^{NS}$ | -0.570$^{**}$ | -0.402$^{**}$ | 1 |

Table.30. Correlation between chemical and biological parameters

| | pH | EC | OC | N | P | K | Ca | Mg | S | Fe | Zn | Mn | Cu | B | AP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | | | | | | | | |
| EC | -0.242$^{*}$ | 1 | | | | | | | | | | | | | |
| OC | -0.399$^{**}$ | 0.317$^{**}$ | 1 | | | | | | | | | | | | |
| N | 0.086$^{NS}$ | -0.452$^{**}$ | -0.217$^{NS}$ | 1 | | | | | | | | | | | |
| P | -0.099$^{NS}$ | 0.240$^{*}$ | 0.190$^{NS}$ | 0.032$^{NS}$ | 1 | | | | | | | | | | |
| K | -0.188$^{NS}$ | -0.060$^{NS}$ | 0.121$^{NS}$ | 0.294$^{*}$ | 0.222$^{NS}$ | 1 | | | | | | | | | |
| Ca | 0.672$^{**}$ | -0.246$^{*}$ | -0.438$^{**}$ | 0.301$^{**}$ | -0.128$^{NS}$ | -0.090$^{NS}$ | 1 | | | | | | | | |
| Mg | 0.531$^{**}$ | 0.339$^{**}$ | -0.134$^{NS}$ | -0.305$^{**}$ | 0.182$^{NS}$ | -0.497$^{**}$ | 0.373$^{**}$ | 1 | | | | | | | |
| S | -0.049$^{NS}$ | 0.519$^{**}$ | 0.317$^{**}$ | -0.276$^{*}$ | 0.237$^{*}$ | -0.163$^{NS}$ | -0.243$^{*}$ | 0.351$^{**}$ | 1 | | | | | | |
| Fe | 0.856$^{**}$ | -0.368$^{**}$ | -0.473$^{**}$ | 0.236$^{*}$ | -0.057$^{NS}$ | -0.002$^{NS}$ | 0.621$^{**}$ | 0.368$^{**}$ | -0.211$^{NS}$ | 1 | | | | | |
| Zn | -0.093$^{NS}$ | 0.584$^{**}$ | 0.219$^{NS}$ | -0.360$^{**}$ | 0.386$^{**}$ | 0.005$^{NS}$ | -0.233$^{*}$ | 0.477$^{**}$ | 0.549$^{**}$ | -0.191$^{NS}$ | 1 | | | | |
| Mn | 0.765$^{**}$ | -0.375$^{**}$ | -0.475$^{**}$ | 0.250$^{*}$ | -0.223$^{NS}$ | -0.112$^{NS}$ | 0.639$^{**}$ | 0.333$^{**}$ | -0.281$^{*}$ | 0.892$^{**}$ | -0.225$^{NS}$ | 1 | | | |
| Cu | 0.447$^{**}$ | -0.224$^{NS}$ | -0.241$^{*}$ | 0.168$^{NS}$ | -0.149$^{NS}$ | -0.061$^{NS}$ | 0.374$^{**}$ | 0.200$^{NS}$ | -0.199$^{NS}$ | 0.639$^{**}$ | -0.078$^{NS}$ | 0.855$^{**}$ | 1 | | |
| B | -0.213$^{NS}$ | -0.340$^{**}$ | -0.095$^{NS}$ | 0.830$^{**}$ | 0.098$^{NS}$ | 0.357$^{**}$ | -0.070$^{NS}$ | -0.497$^{**}$ | -0.241$^{*}$ | -0.014$^{NS}$ | -0.330$^{**}$ | -0.077$^{NS}$ | -0.084$^{NS}$ | 1 | |
| AP | -0.668$^{**}$ | 0.160$^{NS}$ | 0.317$^{**}$ | -0.077$^{NS}$ | -0.910$^{**}$ | 0.380$^{**}$ | -0.506$^{**}$ | -0.432$^{**}$ | 0.110$^{NS}$ | -0.540$^{**}$ | 0.062$^{NS}$ | -0.644$^{**}$ | -0.466$^{**}$ | 0.222$^{NS}$ | 1 |

# DISCUSSION

# 5. DISCUSSION

A study was undertaken during 2018-20 to assess the soil quality of post-flood soils of AEU 4 in Pathanamthitta district, to develop maps on soil characters and quality using GIS techniques and to work out the Soil Quality Index. The study comprised of survey, collection and characterization of soil sample, development of minimum data set (MDS), and formulation of SQI, LQI and NI and generation of GIS maps. The results of the study are discussed in this chapter.

## 5.1. CHARACTERIZATION OF SOIL SAMPLES

Physical, chemical and biological parameters were considered for the characterization of soil samples.

### 5.1.1. Physical parameters

The results of physical parameters *viz.* bulk density, particle density, porosity, texture, maximum water holding capacity, soil moisture content and aggregate stability are discussed below.

#### *5.1.1.1. Bulk density*

Bulk density is the ratio of dry weight of soil to the total volume of soil including pore spaces (Morales-Olmedo *et al.*, 2015). Bulk density of 26.67% of samples had less than 1.2 Mg $m^{-3}$ whereas 29.33% of samples lies in the range of 1.2-1.4 Mg $m^{-3}$, 29.33% in 1.4 -1.6 Mg $m^{-3}$ range and 14.67% had bulk density greater than 1.6 Mg $m^{-3}$ (Fig.3).

Bulk density of 85.33% of samples analysed had values less than 1.6 Mg $m^{-3}$. Accumulation of materials such as debris, silt and microscopic organisms that were brought to soil by flood could be the reason for low bulk density, increase in porosity and moisture content (Njoku and Okoro, 2015).

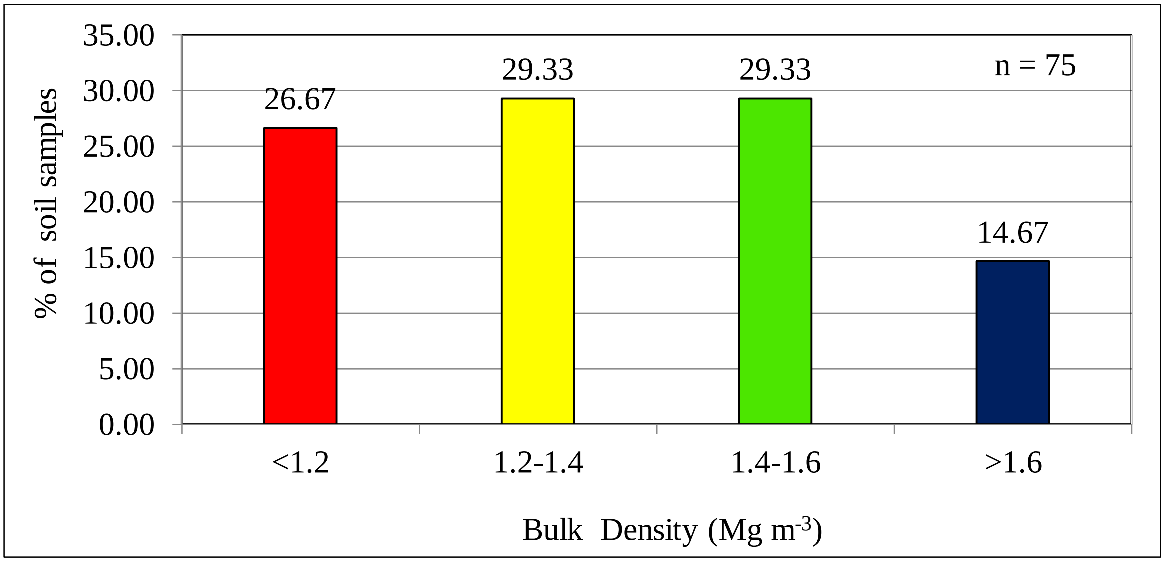



Fig.4. Frequency distribution of bulk density (Mg $m^{-3}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

### *5.1.1.2. Particle density*

Particle density of 84% of samples had less than 2.2 Mg $m^{-3}$ whereas 14.67% of samples lies in the range of 2.2-2.8 Mg $m^{-3}$ and 1.33% had greater than 2.6 Mg $m^{-3}$ (Fig.4 ).

The ideal particle density is 2.67 Mg $m^{-3}$. Majority of the soil samples had particle density less than 2.67 Mg $m^{-3}$. It may be attributed to high content of organic matter. In the the present study, there exists a negative correlation between organic carbon and particle density. Joerg *et al*., (2006) reported that when there is an increase in organic matter in soil, the particle density tends to decrease.

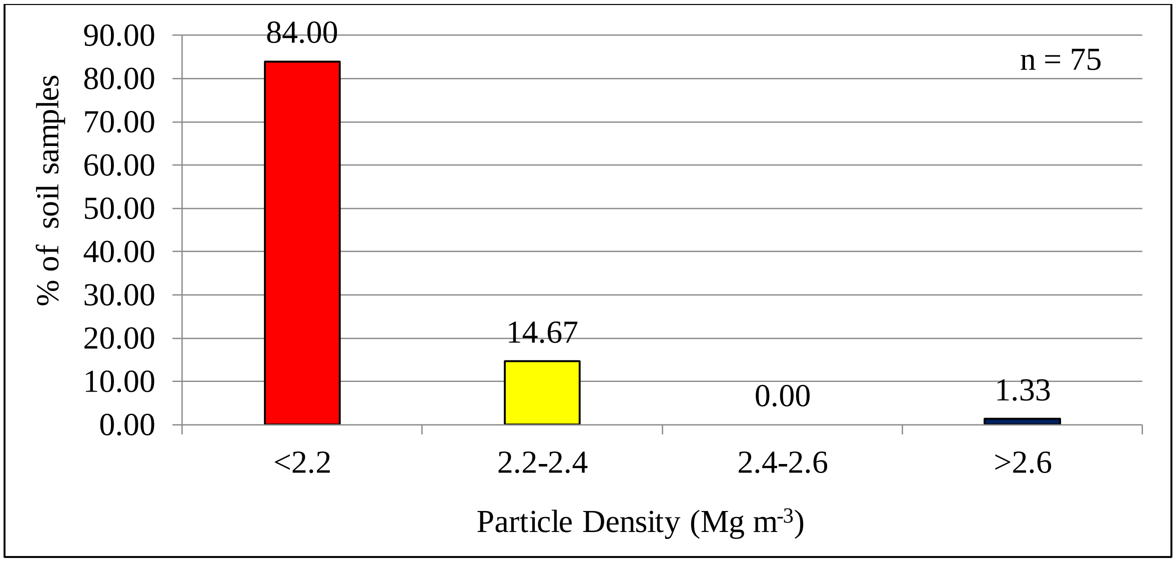



Fig. 5. Frequency distribution of particle density (Mg $m^{-3}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

***5.1.1.3. Porosity***

Porosity of 41.33% of samples had less than 30% whereas 57.33% of samples lie in the range of 30-50% and 1.33% had porosity between 50-70% (Fig.5).

Porosity increased due to flood as silt and clay content was prominent in this area. The increase in porosity after flood may be due to the accumulation of materials viz. Debris, silt and microscopic organisms (Njoku and Okoro, 2015)

Bulk density is an important property that influences soil porosity. Both had inverse relation with each other. Li and Shao (2006) reported that bulk density was negatively correlated with porosity. Fahmi *et al* (2014) also reported similar correlation of porosity and bulk density in the soil.

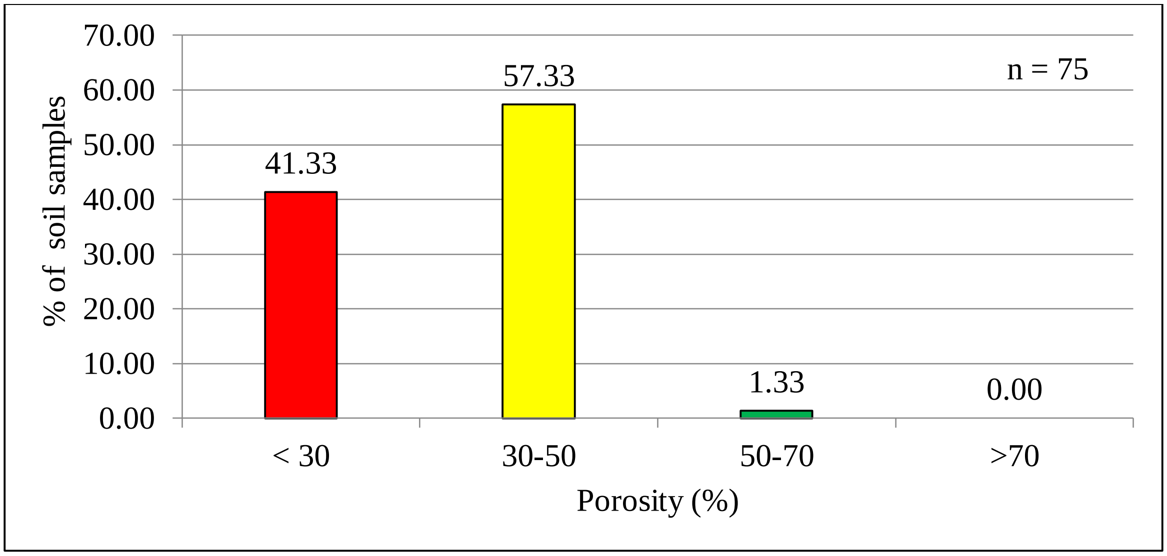



Fig.6. Frequency distribution of porosity (%) in the post-flood soils of AEU 4 in Pathanamthitta district.

***5.1.1.4. Texture***

The mean value of percentage of sand, silt and clay in AEU 4 of Pathanamthitta was 36%, 40.1% and 23.9% (Fig.6). The predominant soil texture in this area is silt loam. Other samples have textural classes such as clay loam, silty clay loam, sandy clay loam and sandy loam. Silty clay loam texture was more in Niranam panchayat. Sandy loam and silt loam texture was observed at Kadapra panchayat where silt deposition was more.

Fig.7. Frequency distribution of soil texture in the post-flood soils of AEU 4 in Pathanamthitta district.

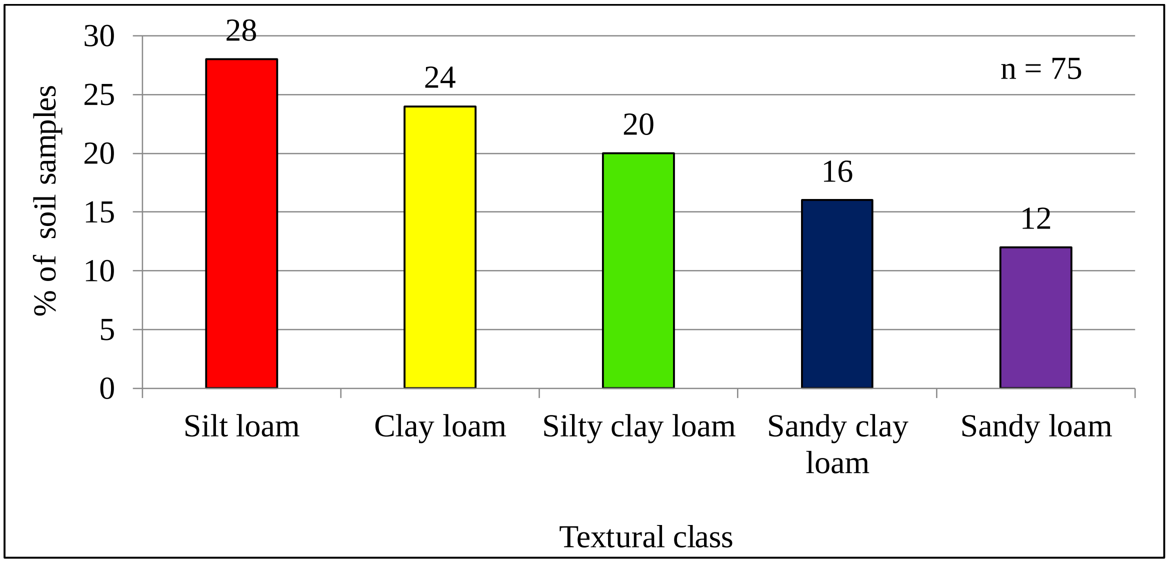
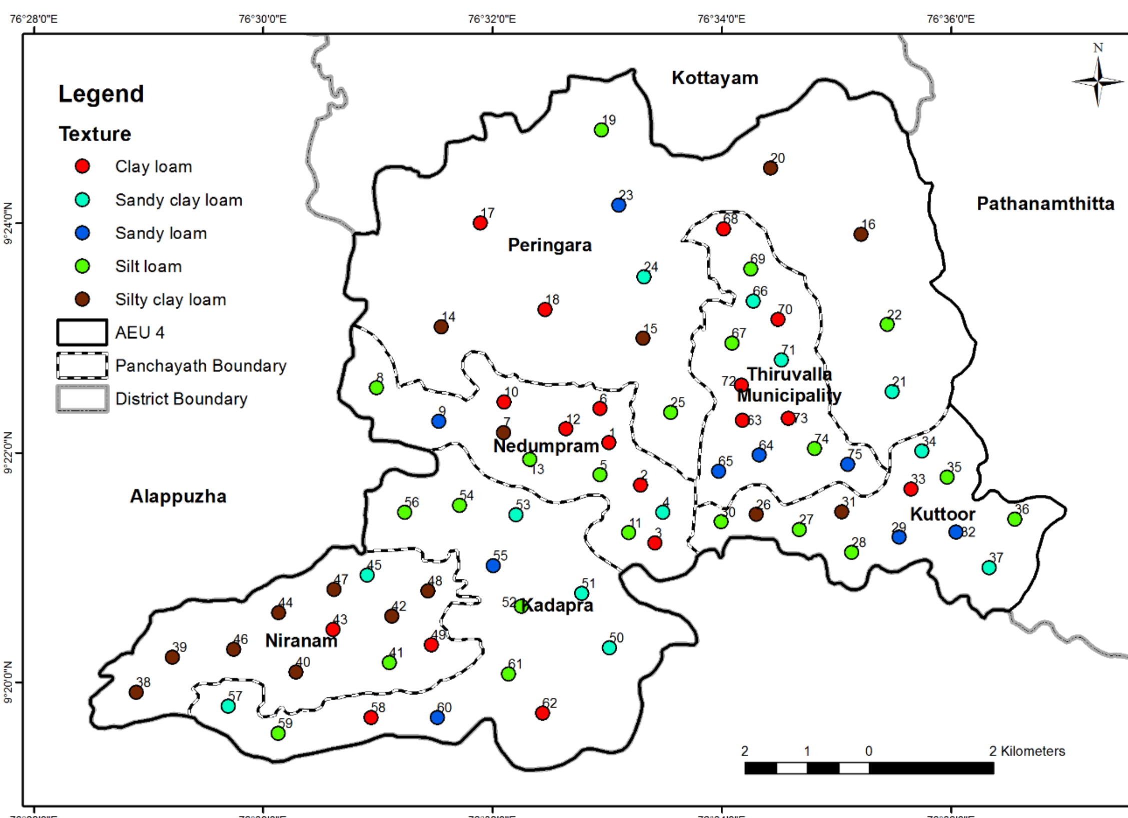



Fig.8. Spatial distribution of soil textural classes in the post-flood soil of AEU 4 in Pathanamthitta district



### *5.1.1.6. Maximum water holding capacity*

Maximum Water Holding Capacity (MWHC) of majority of samples (52%) range between 30-50% and 2.67% of samples had less than 30%, 33.33% lies between 50-70% and 12% had MWHC greater than 70% (Fig.8).

The present study showed that water holding capacity of 97.33% samples were greater than 30% which indicated that most of the soil had medium to high range of water holding capacity. It may be attributed to high content of soil organic matter. Hudson (1994) reported that for each one per cent increase in soil organic matter, the available water holding capacity in the soil is increased by 3.7 per cent. Another reason for increase in water holding capacity may be due to the deposition of silt and clay (Suzuki *et al*., 2007).

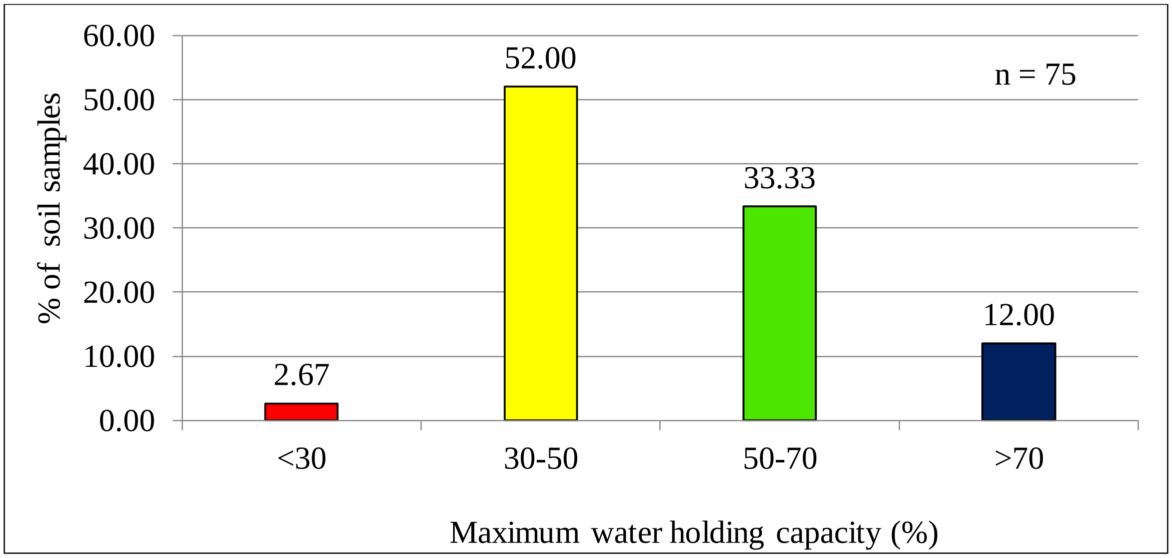



Fig.9. Frequency distribution of maximum water holding capacity (%) in the post-flood soils of AEU 4 in Pathanamthitta district.

### *5.1.1.7. Soil moisture content*

Soil moisture content of 22.67% of samples had less than 10% whereas 20% of samples lies in the range of 10-15%, 24% lies between 15-25% and 33.33% had soil moisture greater than 25% (Fig.9).

Majority of the samples showed soil moisture content higher than 25%. The results point to the fact that moisture content increases after flood. This may be due to the accumulation of materials such as debris, silt and microscopic organisms that were brought to soil by flood (Njoku and Okoro, 2015)

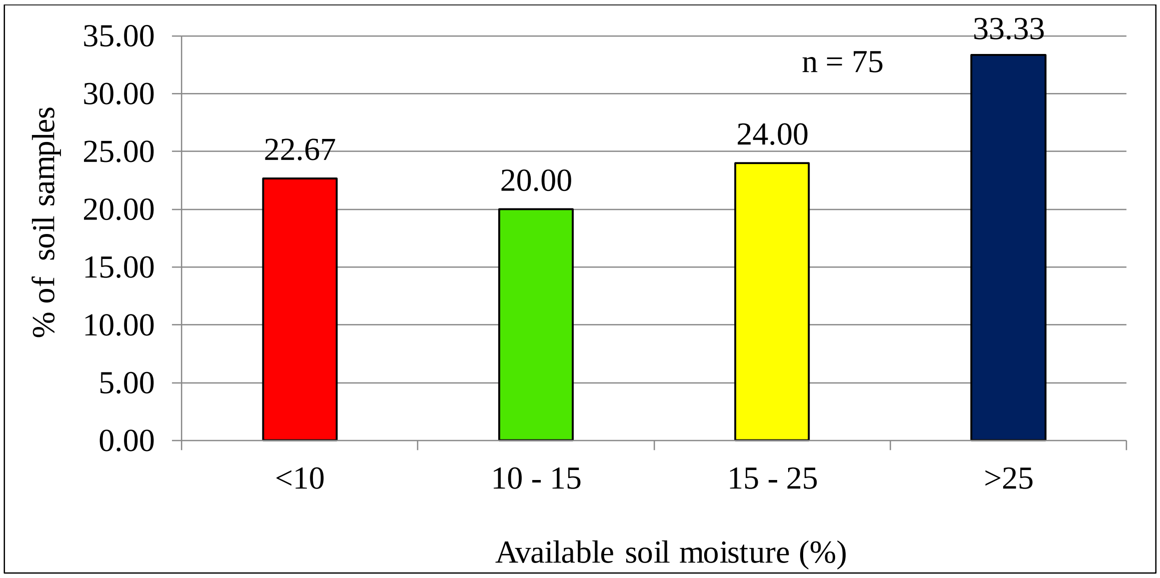



Fig.10. Frequency distribution of soil moisture content (%) in the post-flood soils of AEU 4 in Pathanamthitta district.

#### 5.1.1.8. Aggregate stability

Aggregate stability was measured in terms of mean weight diameter (MWD) and water stable aggregates (WSA). Mean weight diameter of 84% of samples had less than 1mm whereas 8% of samples lie in the range of 1-1.5 mm and 8% had mean weight diameter greater than 2% (Fig.10). Water stable aggregates of 22.67% of samples had less than 30% whereas 37.53% of samples lies in the range of 30-50%, 28% lies between 50-70% and 12% had water stable aggregates greater than 70% (Fig.11).

Highest MWD and WSA were observed at Niranam panchayat where organic carbon content was high. Soil aggregate stability is affected by soil characters such as texture and organic matter content. Increased organic matter content of soils causes stabilization of aggregates through its binding action and improved microbial activity (Bissonnais, 1996).

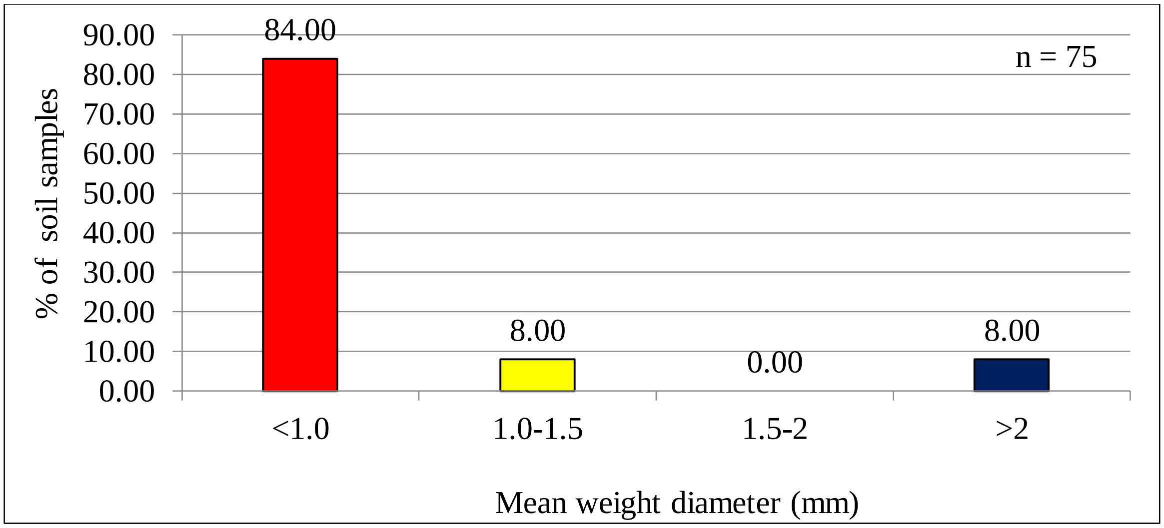



Fig.11. Frequency distribution of mean weight diameter (mm) in the post-soils of AEU 4 in Pathanamthitta district.

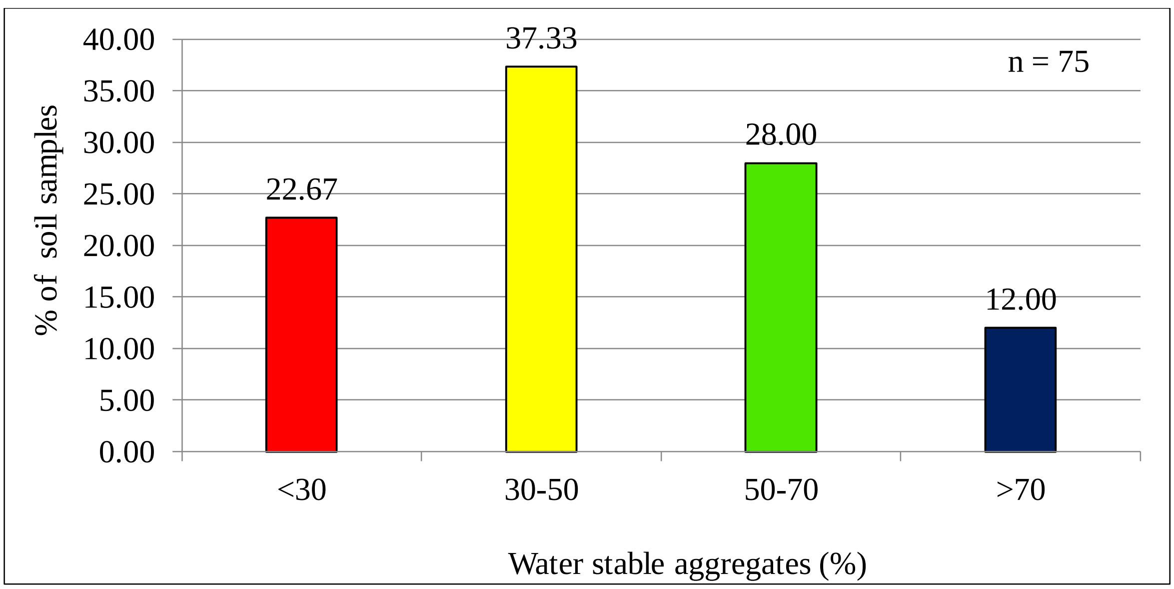



Fig .12. Frequency distribution of water stable aggregates (%) in the post-flood soils of AEU 4 in Pathanamthitta district.

### 5.1.2. Chemical parameters

The results of chemical parameters in the post-flood soils of AEU 4 of Pathanamthitta district are discussed below.

#### *5.1.2.1. pH*

The soils of AEU 4 in Pathanamthitta were extremely acidic to near neutral with overall pH ranging from 4.02 to 6.98. Majority of the samples reported pH in acidic range which includes 14.67% of samples as extremely acid, 28% of samples as very strongly acid, 17.33% of samples as strongly acid, 17.33% of samples as moderately acid, 18.67% of samples as slightly acid. pH of four per cent of samples fall in neutral range (Fig.12).

There was an observed change in pH range from extremely acid to strongly acid before flood to extremely acid to neutral after flood. Heavy rain might have washed away the soil acidity. When acid soil is submerged for long time, the pH of the soil increases to near neutrality (Ponnamperuma *et al*., 1966). In areas having pH less than 5.5, liming is required to restore soil fertility. Lime /Dolomite can be given to correct the acidity. If dolomite is applied, it can solve the problems of acidity and deficiencies of Ca and Mg. Liming reduces toxicity of Fe, Al and Mn ions in soil, improves bacterial activity, nutrient availability and act as a source of Ca and Mg for the crop (Sureshkumar *et al*., 2013).

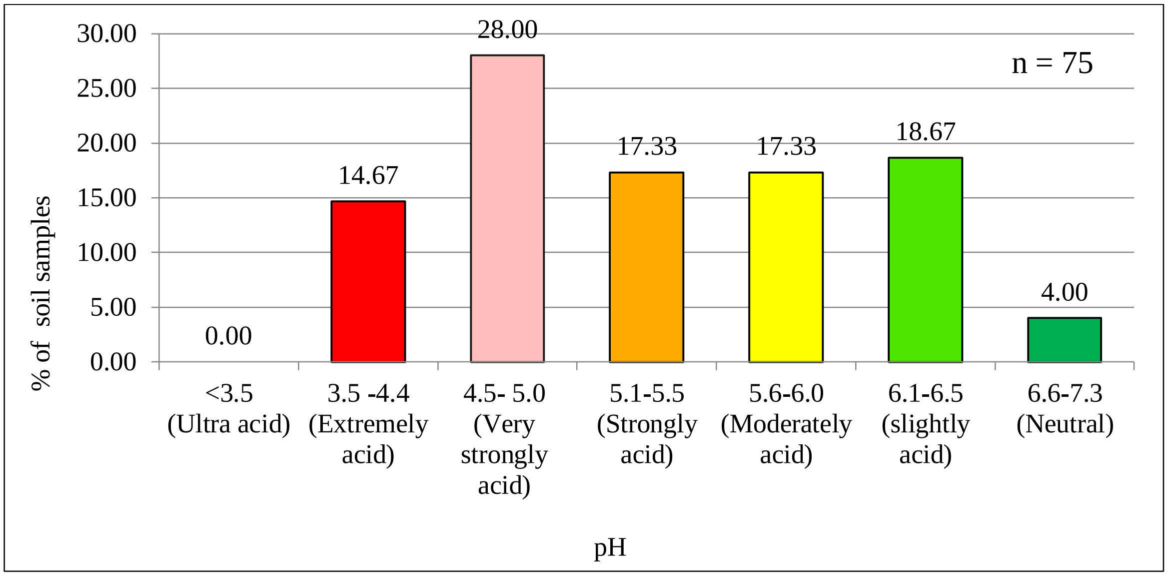



Fig.13. Frequency distribution of pH in the post-flood soils of AEU 4 in Pathanamthitta district.

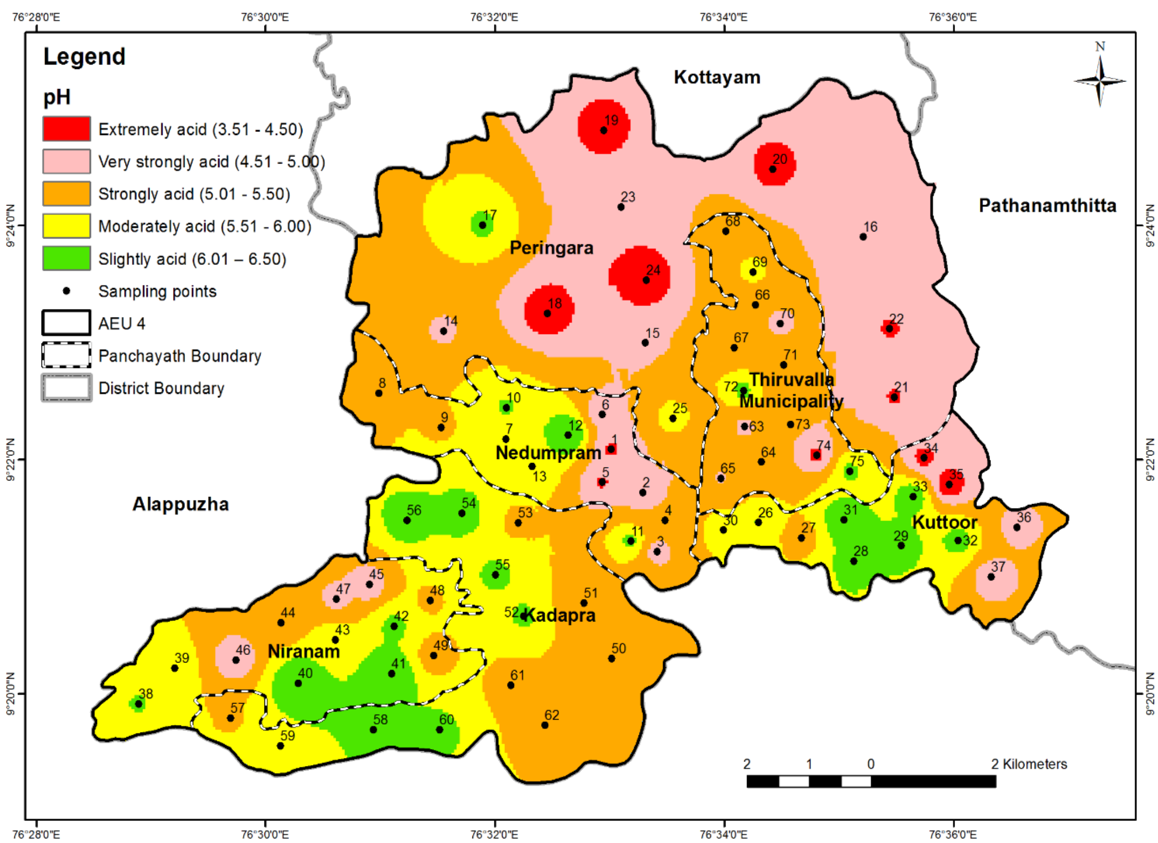



Fig.14. Spatial distribution of pH in the post-flood soils of AEU 4 in Pathanamthitta.

### *5.1.2.2. Electrical conductivity*

Electrical conductivity ranges from 0.04 to 1.99. Electrical conductivity of 80 per cent of samples had less than 1 $dSm^{-1}$ and 20 percent samples had EC between 1- 2 $dSm^{-1}$ (Fig.14).

EC value 0-2 $dSm^{-1}$ is optimum for plant growth (Biswas and Mukharjee, 2014). There was no negative impact of flood on EC of soil in the area. This study area had more silt and clay content and EC is positively correlated with percentage of silt content. Silty and clayey soils have better ability to hold and store cations and the loss of nutrients is minimum when compared with sandy soils.

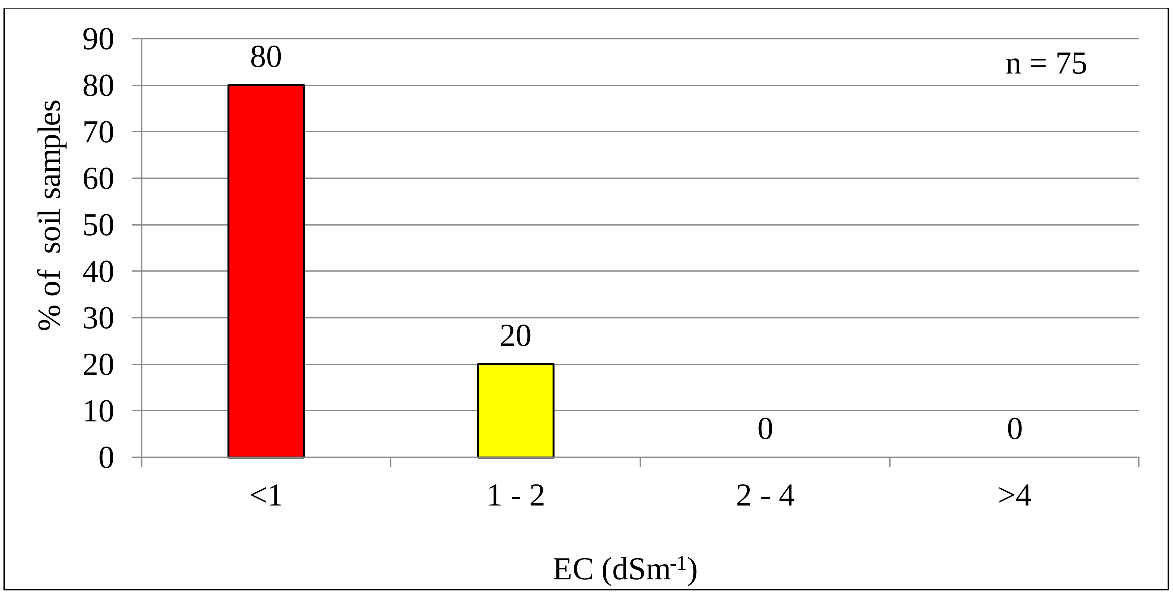



Fig.15. Frequency distribution of electrical conductivity ($dSm^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

### *5.1.2.3. Organic carbon*

Organic carbon content was high in 80 per cent of the samples and medium in 20 per cent. As per the pre flood data from KSPB (2013) organic carbon was medium in 35 and high in 43 per cent of soil samples (Fig.15).

There was an increase in organic carbon content from medium to high level after the occurrence of flood. It might be due to the reason that low temperature and high rainfall were conducive for the accumulation of organic matter in soil (Biswas and Mukharjee, 2014). Higher organic carbon content in soil increases the nutrient holding capacity of soil.

The rate of decomposition of organic matter in submerged soils is slower than in aerobic soils which results in the net accumulation of organic matter in the soils that remain flooded for long time (Sahrawat, 2003). Reduced or incomplete decomposition of organic matter, decreased humification results in increased accumulation of organic matter in wetland soils (Olk *et al*., 2000; Mahieu *et al*., 2002).

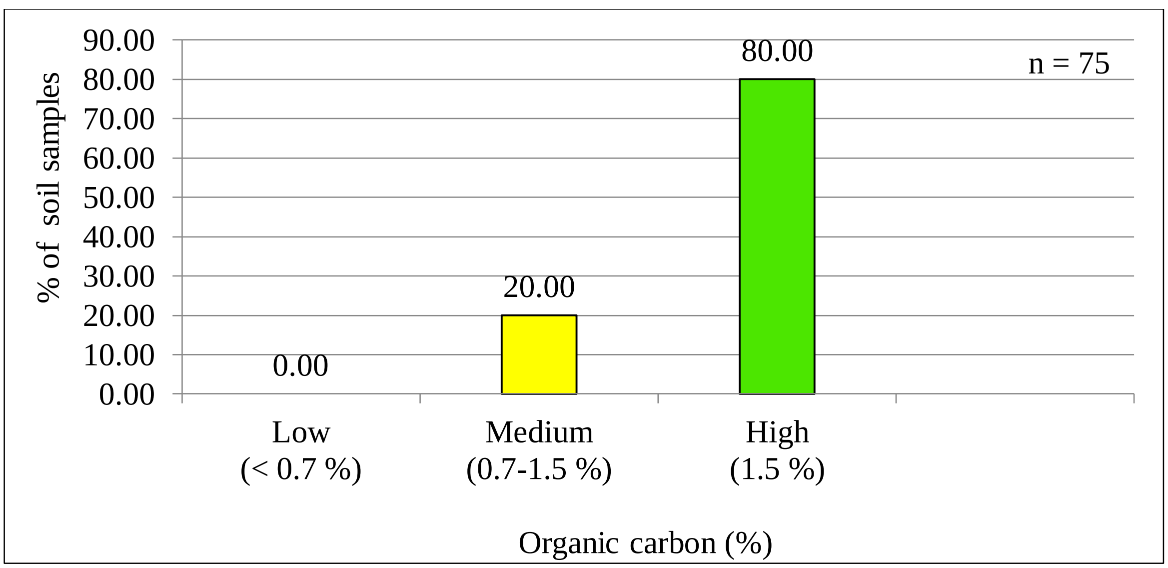



Fig.16. Frequency distribution of organic carbon (%) in the post-flood soils of AEU 4 in Pathanamthitta district.

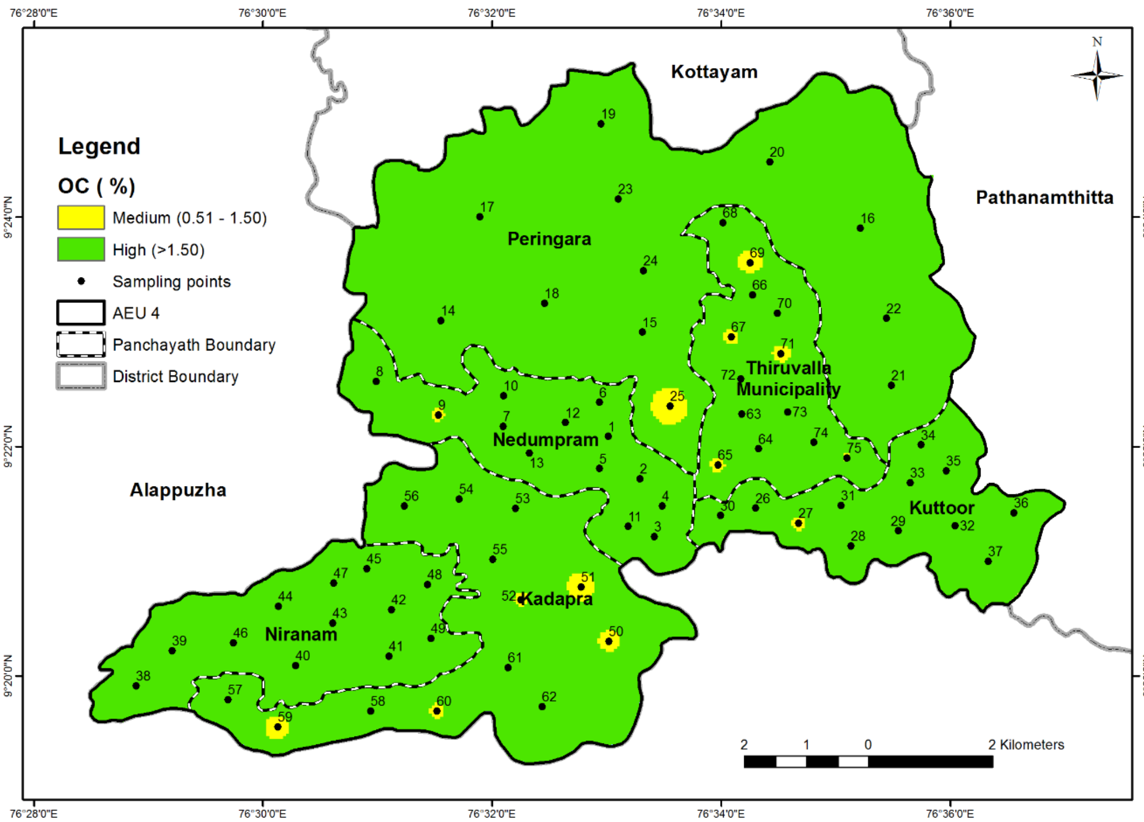



Fig.17. Spatial distribution of Organic Carbon in the post-flood soils areas of AEU 4 in Pathanamthitta.

### *5.1.2.4. Available nitrogen*

Nitrogen content was low in 61.33 per cent of the samples and medium in 38.67 per cent age (Fig.17). The mean value of available nitrogen in the study area came under low category. The low availability of nitrogen in soil might be due to leaching of nitrate nitrogen present in soil that occurred during flood and under anaerobic condition nitrate nitrogen loss may occur due to nitrate reduction and denitrification (Unger *et al*., 2009).

Nitrogen content in the soil was low though the organic carbon content was high. It might be due to the slow decomposition rate or slow mineralization of organic matter under submerged condition. Before adopting any N fertility management practice, soil pH should be brought up to at least 5.5 (Sureshkumar *et al*., 2013)

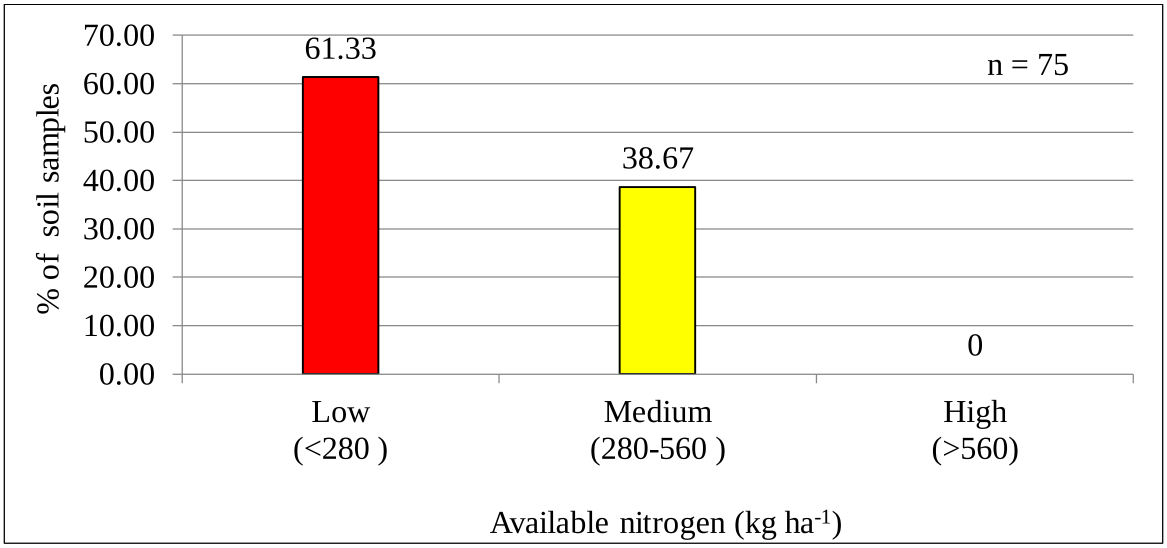



Fig.18. Frequency distribution of available nitrogen (kg ha$^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

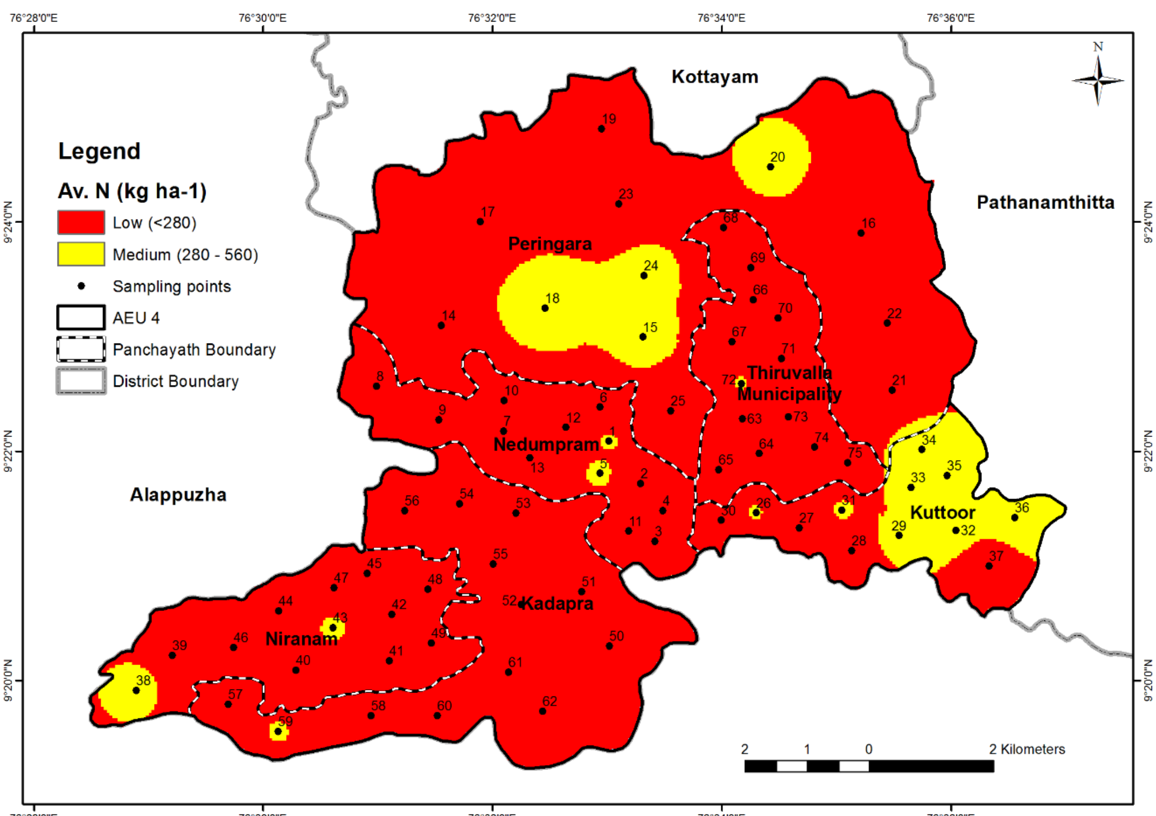



Fig.19. Spatial distribution of available nitrogen in post-flood soils of AEU 4 in Pathanamthitta.

### *5.1.2.5. Available phosphorus*

Phosphorus content was high in 56 per cent samples, medium in 14.67% and low in 29.33% samples (Fig.19). Phosphorus content remained high in the study area in both pre and post flood period (KSPB, 2013). Available P was high in the entire area since majority of the farmers were cultivating rubber, coconut, banana and cassava and were regularly applying phosphatic fertilizers.

The present study showed that phosphorus and iron contents were high. During flood, Phosphorus and iron release was enhanced due to the dissociation and microbial reduction of ferric oxides and the release of tightly bound $PO_4^{3-}$ ions (Wright et al., 2001; Zhang et al., 2003). Studies showed that the neutralization of pH due to flood, increased the hydrolysis and dissociation of iron and aluminium phosphates (Ponnamperuma, 1972; Wright et al., 2001; Zhang et al., 2003). The major soil factor controlling the availability of phosphorus is soil pH. The bioavailability of P in the soil is more in neutral soils. According to Krishnakumar, 1991, though the total P status of Kerala soils is high, the available P is only one to two per cent of total P. This may be attributed to low pH, high P fixing capacity, low CEC and low exchangeable bases.

The results of the study points to the possibility for reduction in the use of costly phosphatic fertilizer. As per the recommendations followed in Kerala, a soil with P >31kg $ha^{-1}$ P fertilizer applied is 25 per cent of package of practice recommendation (Aiyer and Nair, 1985). The possibility of further reduction or total skipping of P fertilizer can be decided only based on field trials. Excess P in soil solution may induce deficiency of micronutrients like zinc and boron. Addition of lime to correct acidity will further increase in P availability. Liming and application of mycorrhiza can contribute to increase in the availability of phosphorus (Venugopal *et al*., 2019).

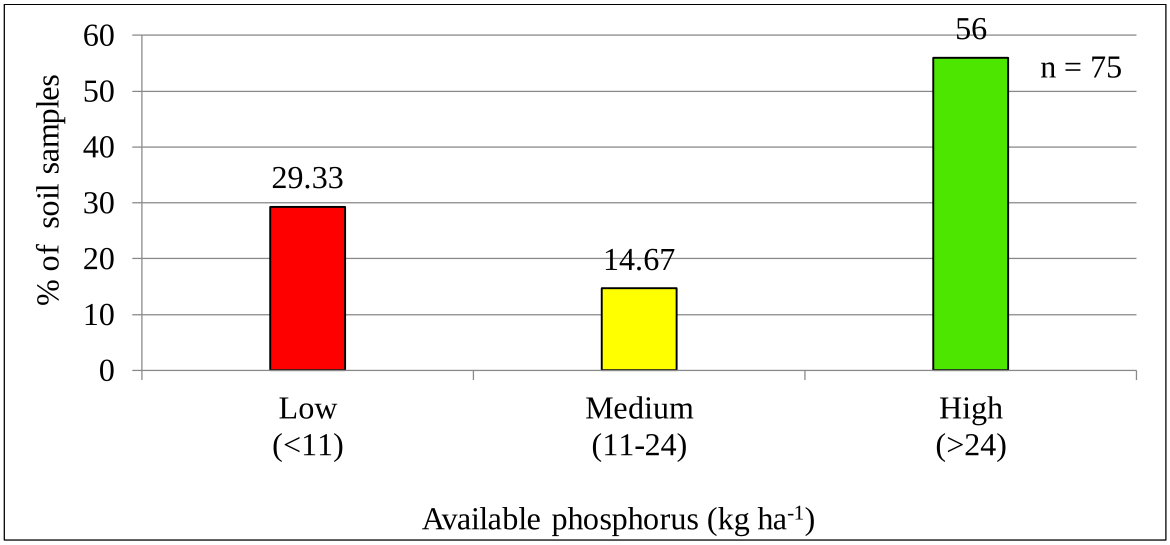



Fig.20. Frequency distribution of available phosphorus (kg ha$^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

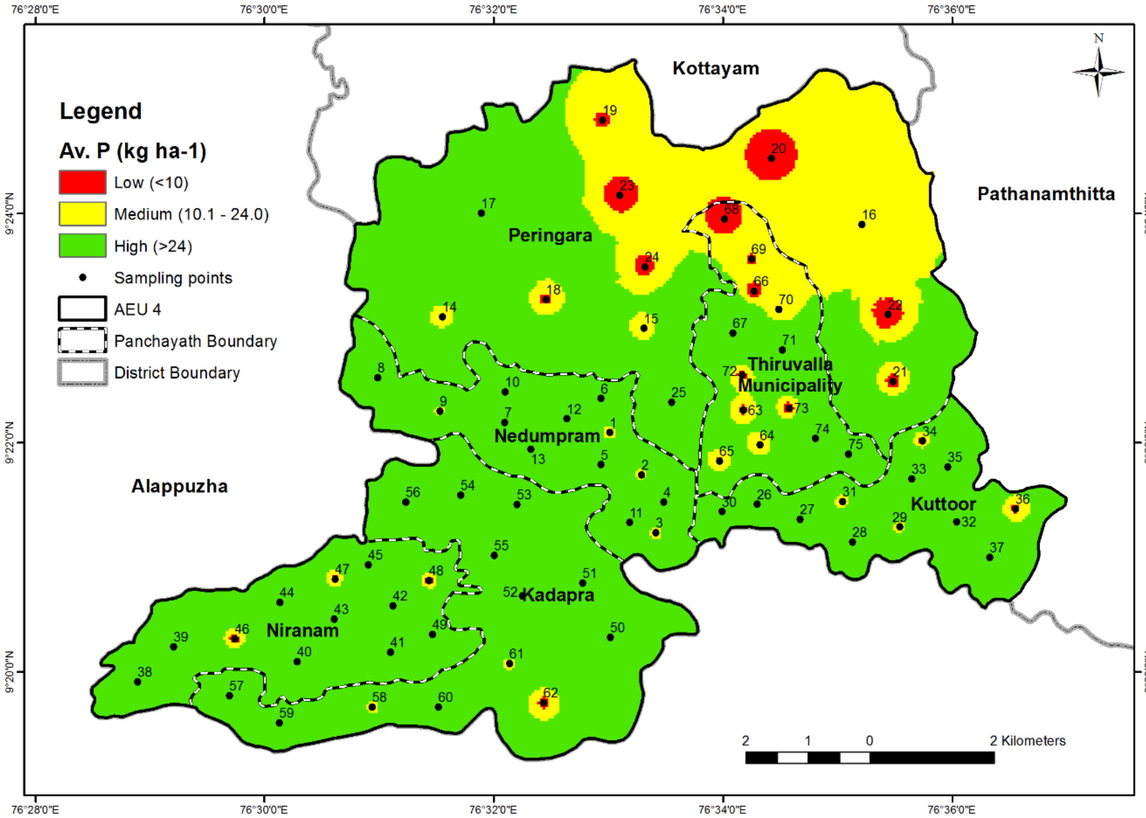



Fig 21. Spatial distribution of available phosphorus in the post-flood soils of AEU 4 in Pathanamthitta.

### *5.1.2.6. Available potassium*

Potassium content was high in 2.67 per cent of samples and medium in 49.33% and low in 48% samples (Fig.21). There was a change in potassium content from medium- high to low- medium after flood (KSPB, 2013).

A decrease in concentration of potassium content was observed in the flood affected areas. It was similar to the findings of Akpoveta *et al*., (2014) where reduced level of potassium was observed on flooding of farmlands of Asaba in Nigeria. Potassium might got leached out during flood. As potassium is a macronutrient, it is essential for plant growth and microbial functioning. So the reduction in potassium in the flood affected soil has a negative impact on soil quality. Hence potassium fertilization is essential for successful crop production. Medium K values were observed in some areas and high in areas with application of MOP. Application of higher doses of K fertilizers can restrict the activity of iron and manganese in soil solution, thereby enhancing the K uptake (Priya et al., 2007). Maintenance of high levels of organic matter and liming can go a long way in regulating potassium retention and supplying power of the soils. Potassium fertilizers must be applied only after equilibration of applied lime to avoid antagonistic effect of calcium on potassium uptake.

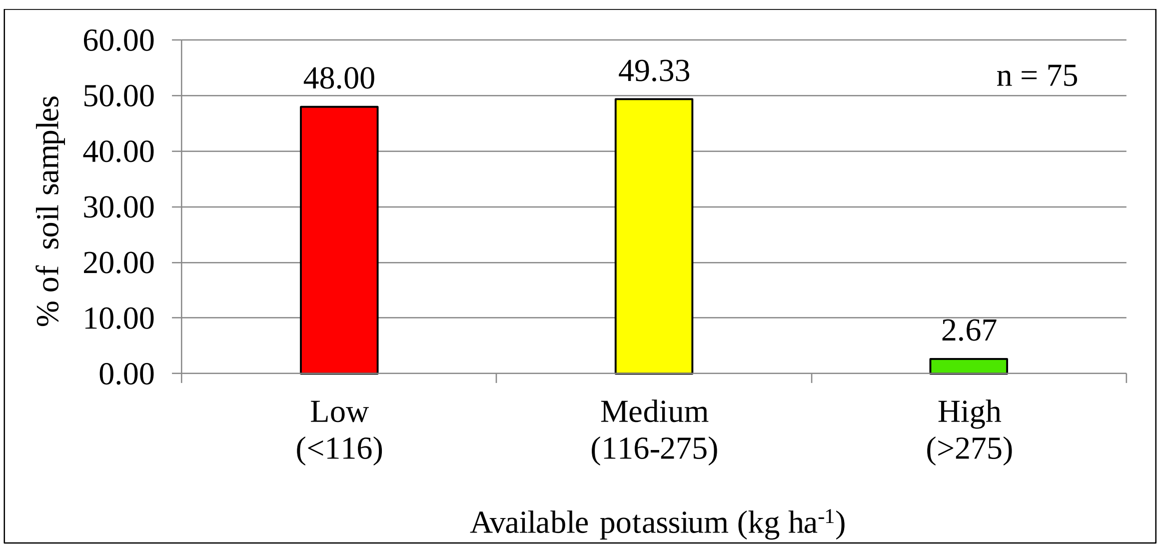



Fig.22. Frequency distribution of available potassium (kg $ha^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

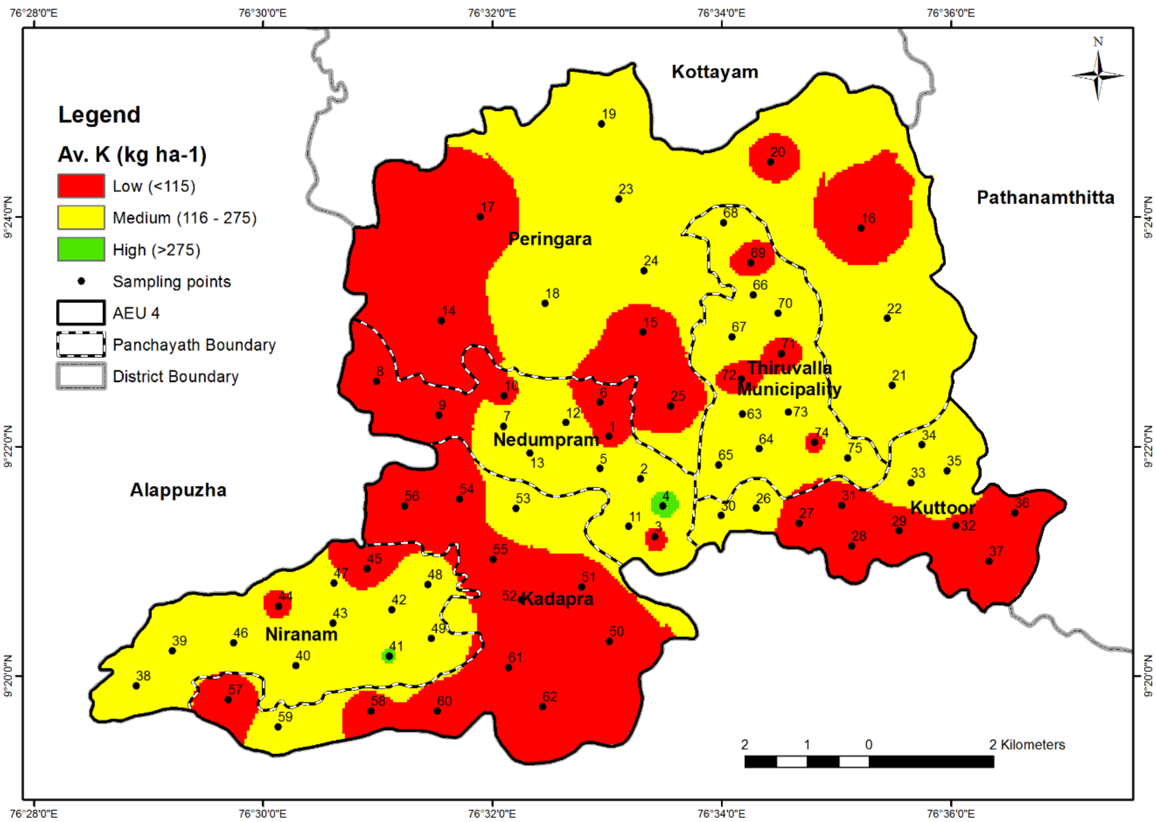



Fig.23. Spatial distribution of available potassium in the post-flood soils of AEU 4 in Pathanamthitta.

### *5.1.2.7. Available calcium*

Available calcium content was adequate in 34.67% and deficient in 65.33% of samples (Fig.23). Available Ca in the post flood area was deficient in majority of samples similar to pre-flood soils (KSPB, 2013). The low content of calcium may be due to high rainfall and consequent leaching of this nutrient. Liming of soil was practiced in areas of calcium sufficiency by the farmers growing rubber, coconut and banana.

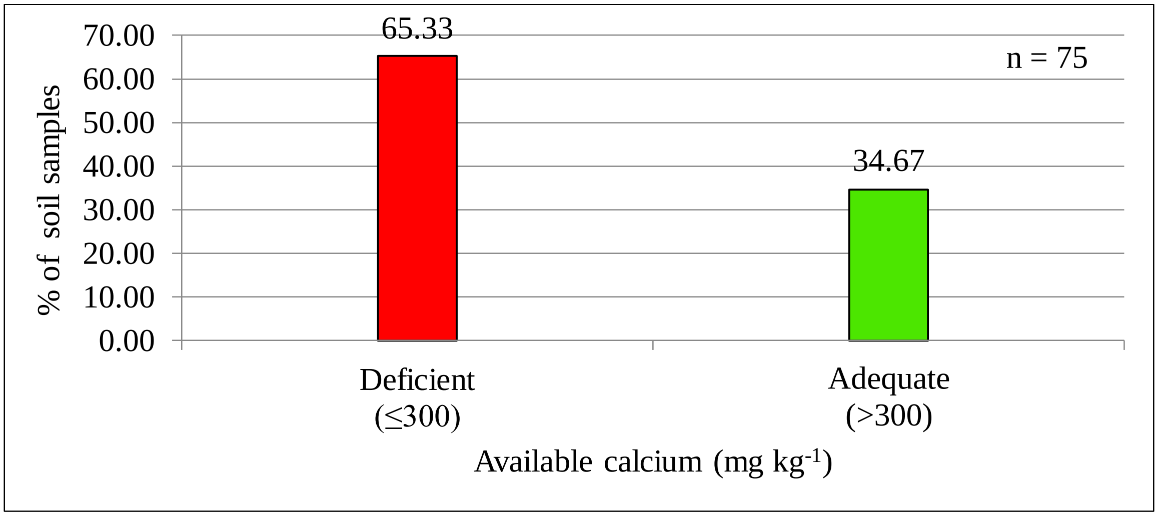



Fig.24. Frequency distribution of available calcium (mg kg $^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

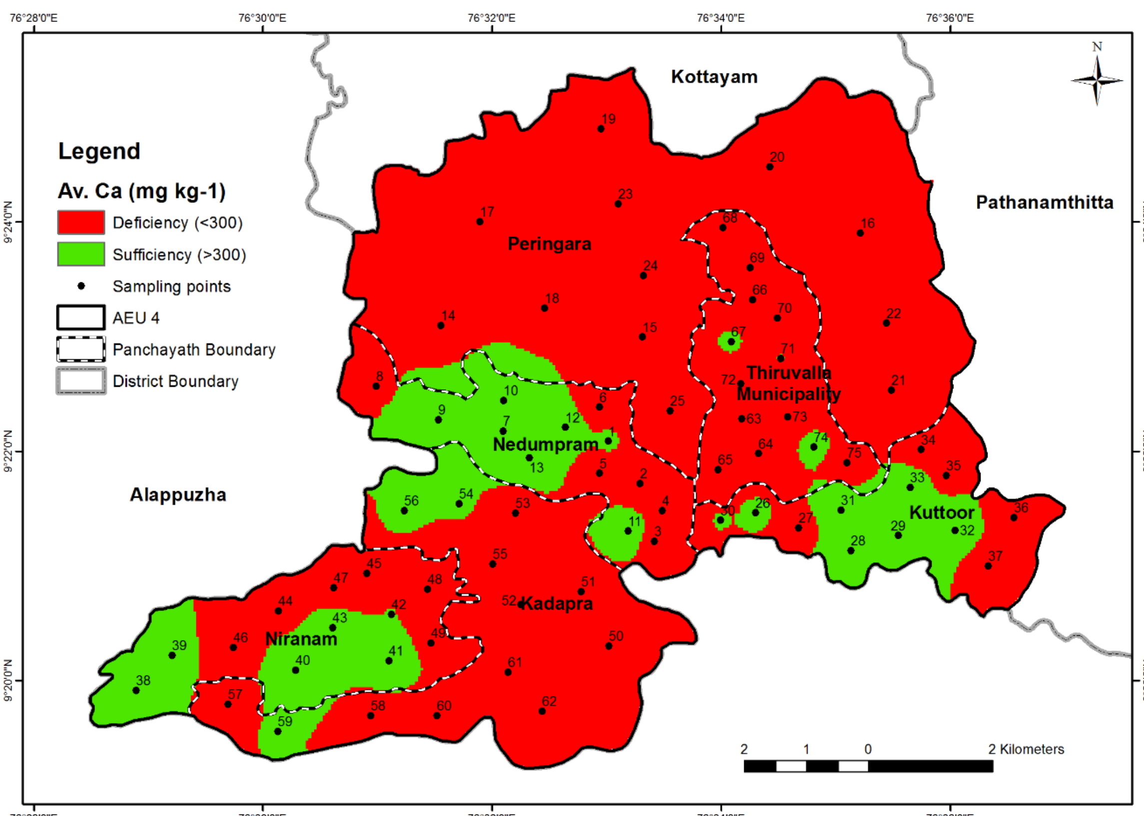



Fig.25. Spatial distribution of available calcium in the post-flood soils of AEU 4 in Pathanamthitta

### *5.1.2.8. Available magnesium*

Available magnesium content was deficient in 100% of samples (Fig.25) similar to pre-flood soil data (KSPB, 2013). Tropical climate leads to leaching loss of magnesium. In addition to this imbalanced fertilizer application and non-inclusion of magnesium fertilizers might have resulted in magnesium deficiency. The deficiency adversely affects crops like coconut, rubber, banana etc. (Mini, 2015). The need for magnesium supplementation through fertilizer application is necessary. Application of Ca and Mg with corresponding rise in pH followed by K application results in balanced as well as sufficient levels of these three nutrients reduces toxic levels of Fe, Mn, and Al. Application of $MgSo_4$ at the rate of 80 kg $ha^{-1}$ can be done to solve the problem of magnesium deficiency (KAU, 2016). Application of dolomite instead of lime solves both Ca and Mg deficiency problems.

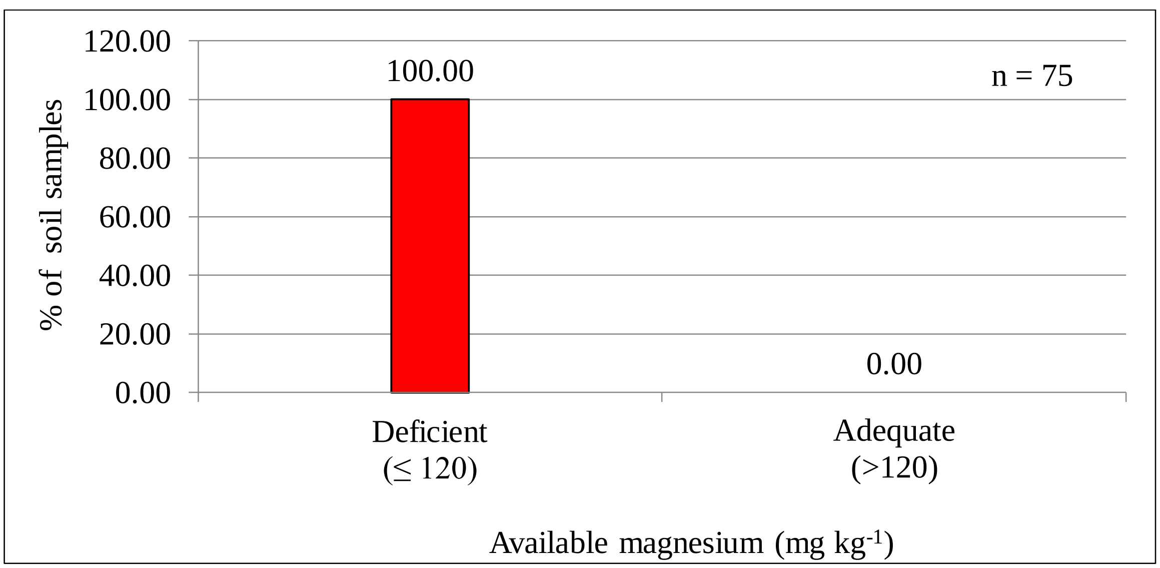



Fig.26. Frequency distribution of available magnesium (mg $kg^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

### *5.1.2.9. Available sulphur*

Available sulphur content was adequate in 25.33% and deficient in 74.67% of samples (Fig.26). Post flood samples showed a substantial decrease in sulphur when compared with the preflood values (KSPB, 2013). Hence sulphur fertilization is essential for successful crop production. Deficiency of sulphur can be corrected by the application of $MgSO_4$. Available S was observed to be higher in some areas where factamphos was applied in the previous year which resulted in buildup of available S.

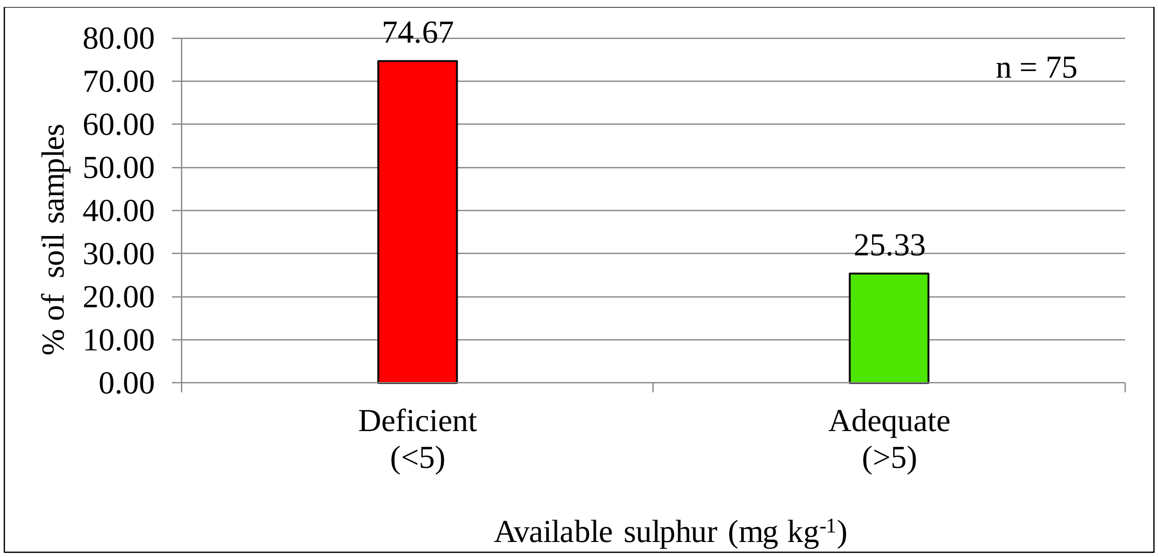



Fig.27. Frequency distribution of available sulphur (mg kg $^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

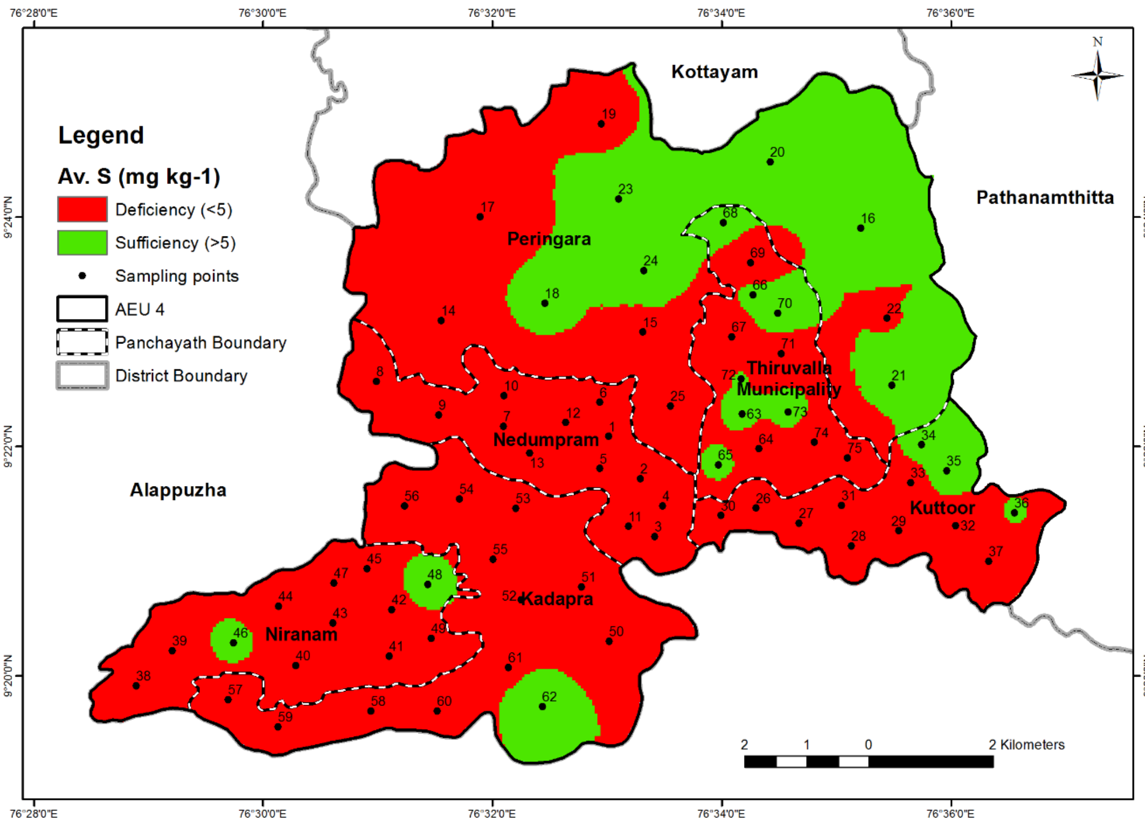



Fig.28. Spatial distribution of available sulphur in post-flood soils of AEU 4 in Pathanamthitta

### *5.1.2.10. Available iron*

Available iron content was adequate in 94.67% and deficient in 5.33% of samples (Fig.28). Iron content remained sufficient in the study area in both pre and post flood period (KSPB, 2013). The sufficiency of available iron in the post flood soil might be due to the reason that under submerged condition iron is reduced from its insoluble form to more soluble form $Fe^{2+}$ (Fageria *et al.*, 2011).Presence of iron rich parent material and leaching of basic materials from the surface layers of the soils could be the reason for high iron availability.

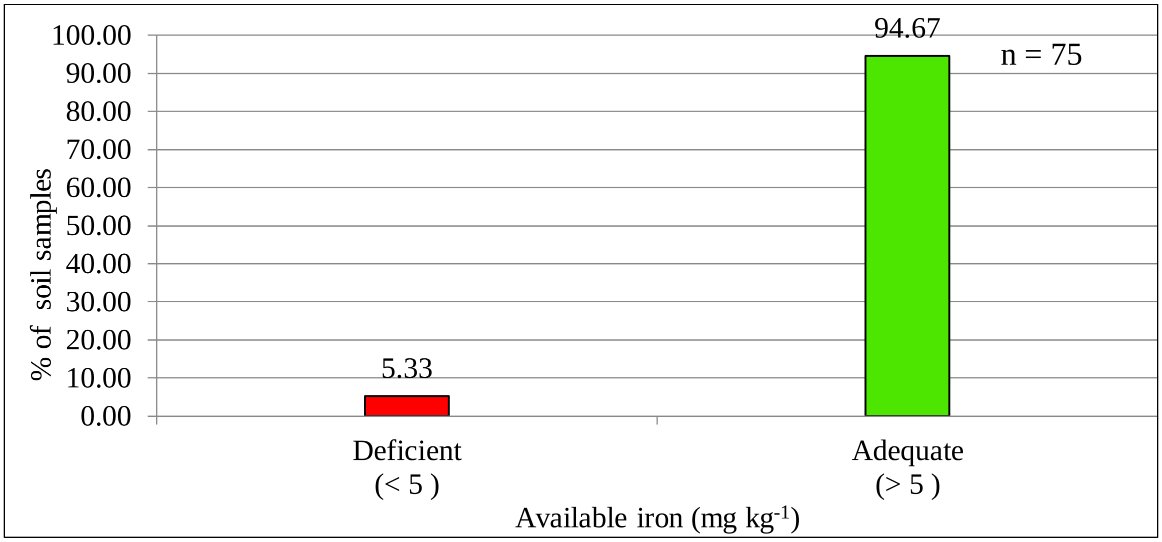



Fig.29. Frequency distribution of available iron (mg kg $^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

### *5.1.2.11. Available zinc*

Available zinc content was adequate in 97.33% and deficient in 2.67% of samples (Fig.29). Zinc content remained high in the study area in both pre and post flood period (KSPB, 2013). Intensive cultivation and application of phosphatic fertilizers result in accumulation of zinc. Most of the phosphatic fertilizers used contain zinc as a contaminant and the nutrient is comparatively immobile in soil which results in accumulation (Mini, 2015).

### *5.1.2.12. Available manganese*

Available manganese content was adequate in 100% of samples (Fig.30). Manganese content remained high in the study area in both pre and post flood period (KSPB, 2013).

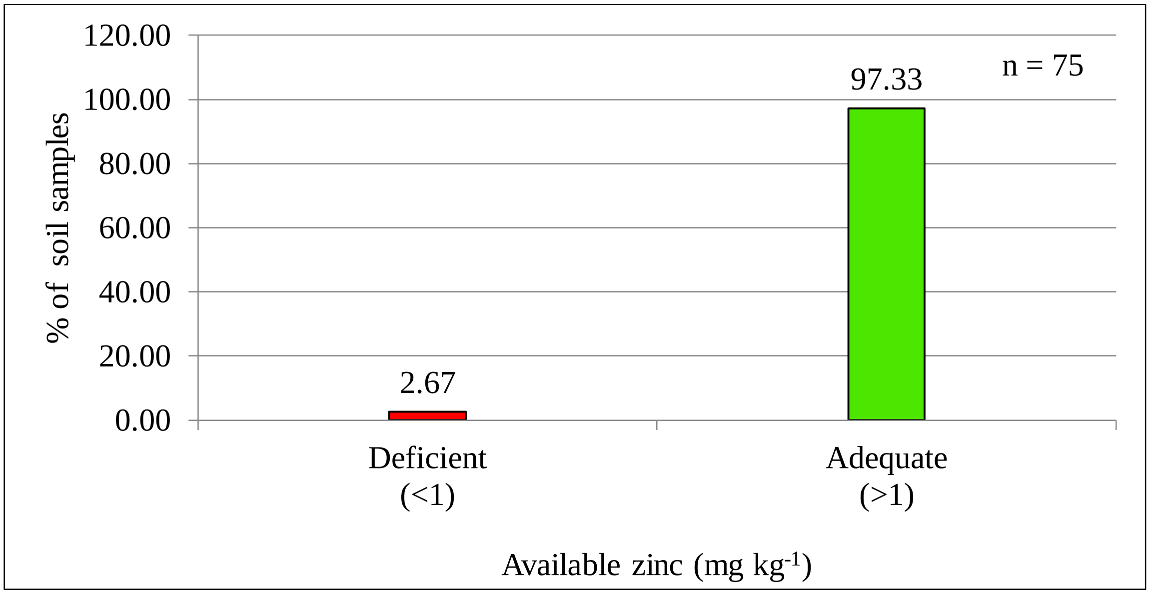



Fig.30. Frequency distribution of available zinc (mg $kg^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

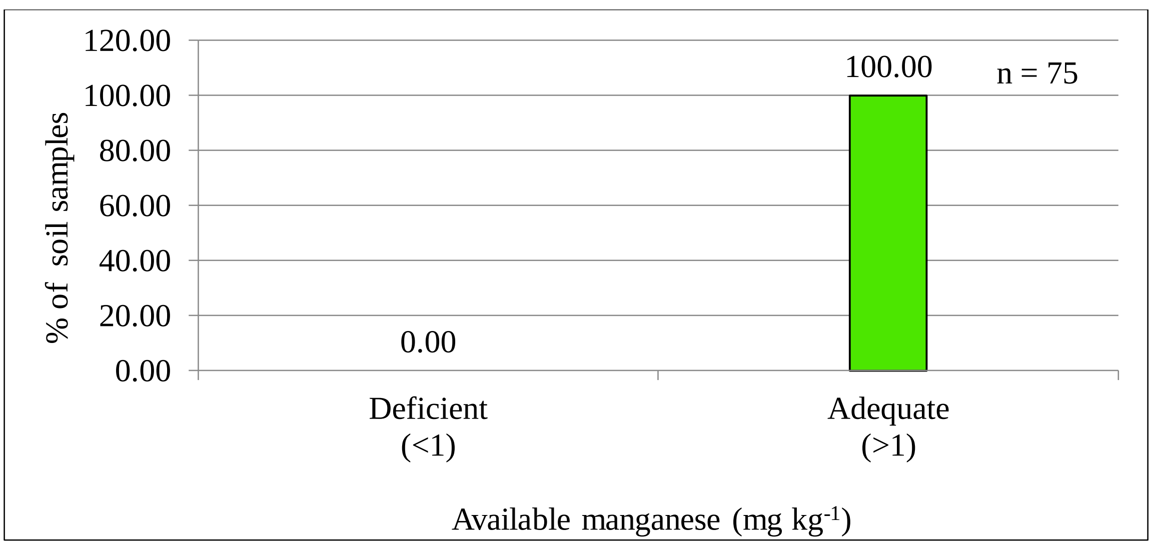



Fig.31. Frequency distribution of available manganese (mg $kg^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

### *5.1.2.13. Available copper*

Available copper content was adequate in 2.67% and deficient in 97.33% of samples (Fig.31). Post flood samples showed a substantial decrease in copper when compared with the pre flood values (KSPB, 2013). The reason for low copper status may be due to the antagonism between copper and phosphorus and formation of insoluble copper phosphate in soil (Wallace, 1984). Hence copper fertilization is essential for successful crop production. Application of $CuSO_4$ at the rate of 2 kg $ha^{-1}$ is recommended to correct the deficiency of copper (KAU, 2016).

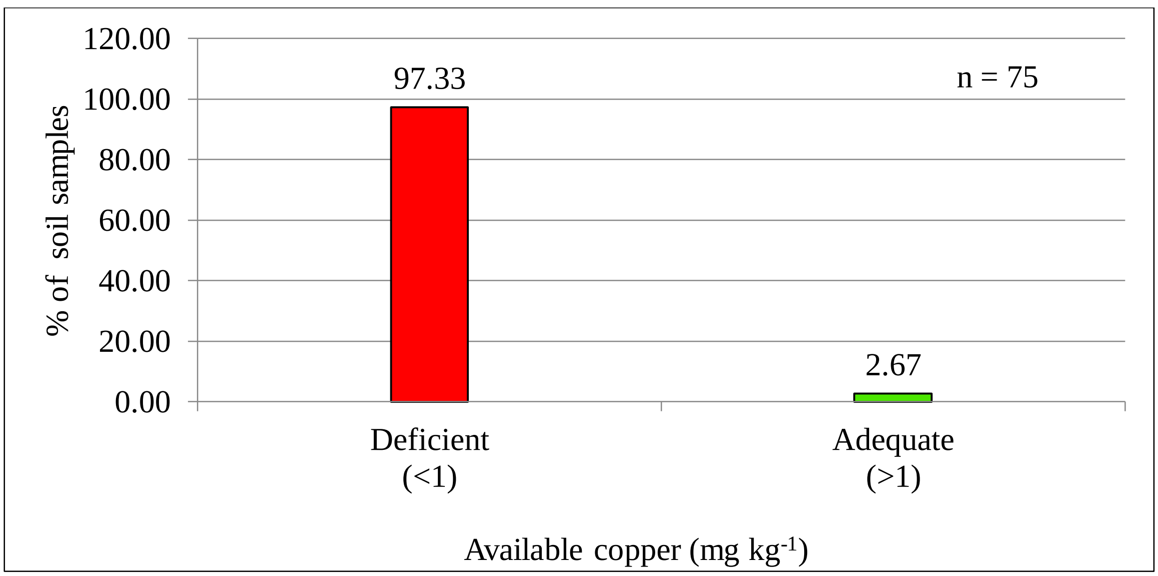



Fig.32. Frequency distribution of available copper (mg $kg^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

### *5.1.2.14. Available boron*

Available boron content was adequate in 100% of samples (Fig.32). Boron was available in sufficient quantity in post flood period. It might be due to the increase in organic matter because of silt deposition in the surface and subsurface soil. The present study showed significant positive correlation between organic carbon and boron. Organic matter can adsorb and retain boron both in acidic and alkaline pH. Mineralization of soil organic matter releases boron and makes it available to plants (Sureshkumar *et al.*, 2013).

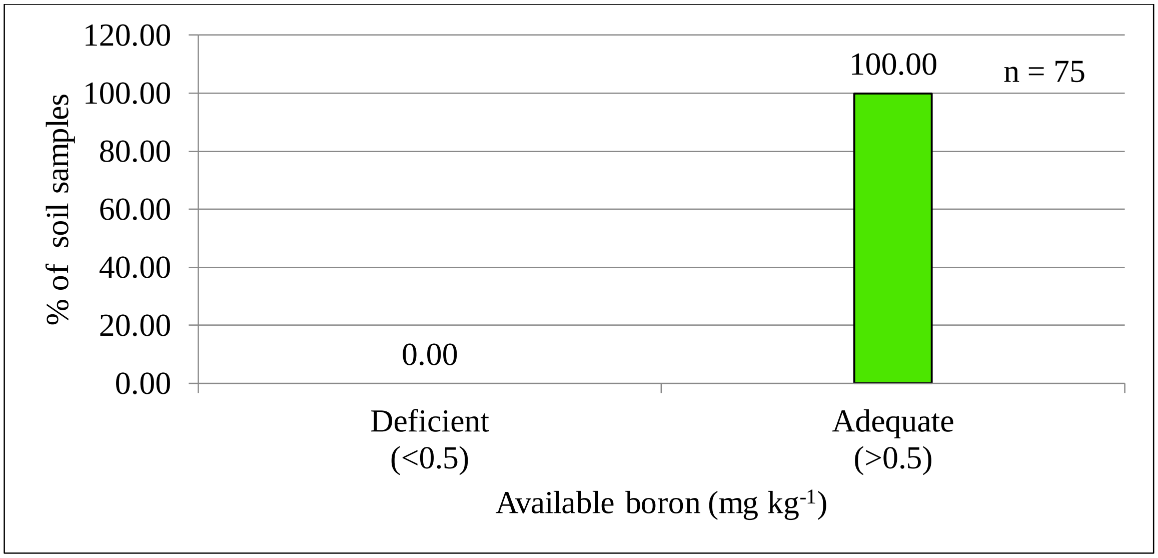



Fig.33. Frequency distribution of available boron (mg kg $^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

### 5.1.3. Biological parameter

The results of biological parameters in the post-flood soils of AEU 4 of Pathanamthitta district are discussed below.

#### *5.1.3.1. Acid phosphatase activity*

Acid phosphatase activity of 73.33% of samples had less than 10 µg PNP produced $g^{-1}$soil $h^{-1}$ whereas 25.33% of samples lies in the range of 10-25 µg PNP produced $g^{-1}$soil $h^{-1}$ and 1.33% lies in the range between 25-50 µg PNP produced $g^{-1}$soil $h^{-1}$ (Fig.33 ). Majority of the soil samples had low acid phosphatase activity

Huang *et al*, (2011) reported that the soil acid phosphatase activity had a significant negative correlation with soil pH and available phosphorus. The present study showed similar findings as acid phosphatase activity of the flood affected areas of AEU 4 in Pathanamthitta district has negative correlation with soil pH and available phosphorus. As the available phosphorus and soil pH were high, acid phosphatase activity in soil is less.

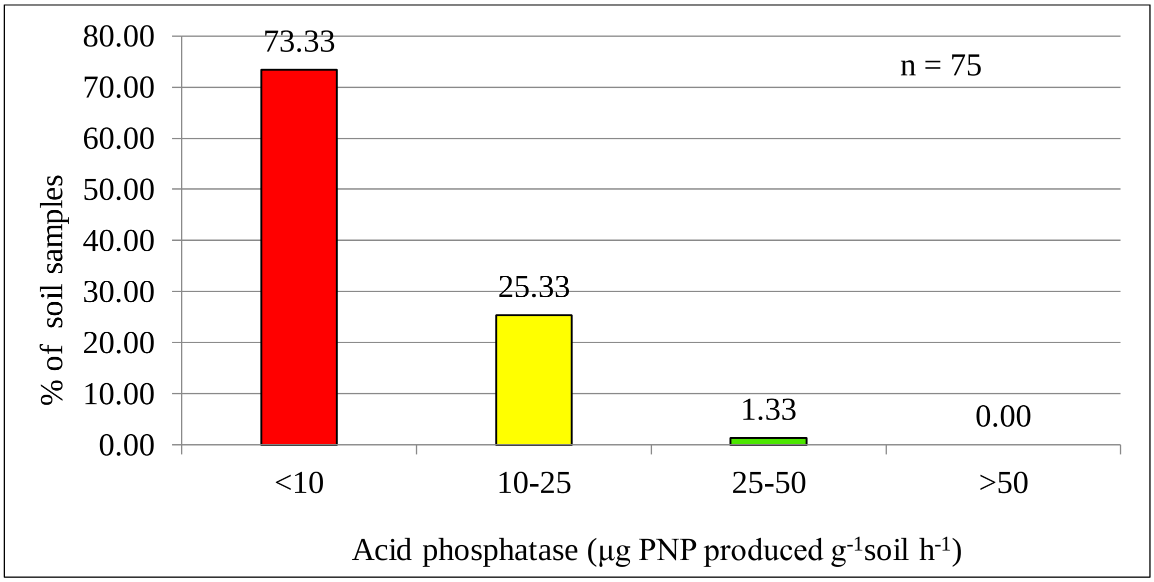



Fig.34. Frequency distribution of acid phosphatase activity (µg PNP produced $g^{-1}$soil $h^{-1}$) in the post-flood soils of AEU 4 in Pathanamthitta district.

## 5.2. SOIL QUALITY INDEX

A weighted soil quality index was calculated using a minimum data set of parameters obtained from principal component analysis. The minimum data set (MDS) developed from all the analyzed parameters consists of percentage of water stable aggregates,% of sand,% of silt and% of clay, pH, available phosphorus, potassium , magnesium, iron, manganese, magnesium and boron. According to the procedures by Lal and Mukherjee (2012) and Singh *et al*. (2017), scoring of MDS and assigning proper weightage to each parameter was done. Weighted additive method was used to calculate soil quality index. Relative soil quality index was developed from the calculated SQI. Relative soil quality index was rated as poor (<50%), medium (50%-70%) and good (>70%) (Kundu *et al*, 2012).

Medium soil quality was observed for 76 per cent of samples and good for 24 per cent (Fig 34). More number of samples with good soil quality was observed at Niranam panchayat (68.96%). The samples with good soil quality indicated that they were less acidic, high in available P and K and sufficiency in iron, manganese, and boron. Spatial distribution of soil quality is depicted in Fig.35.

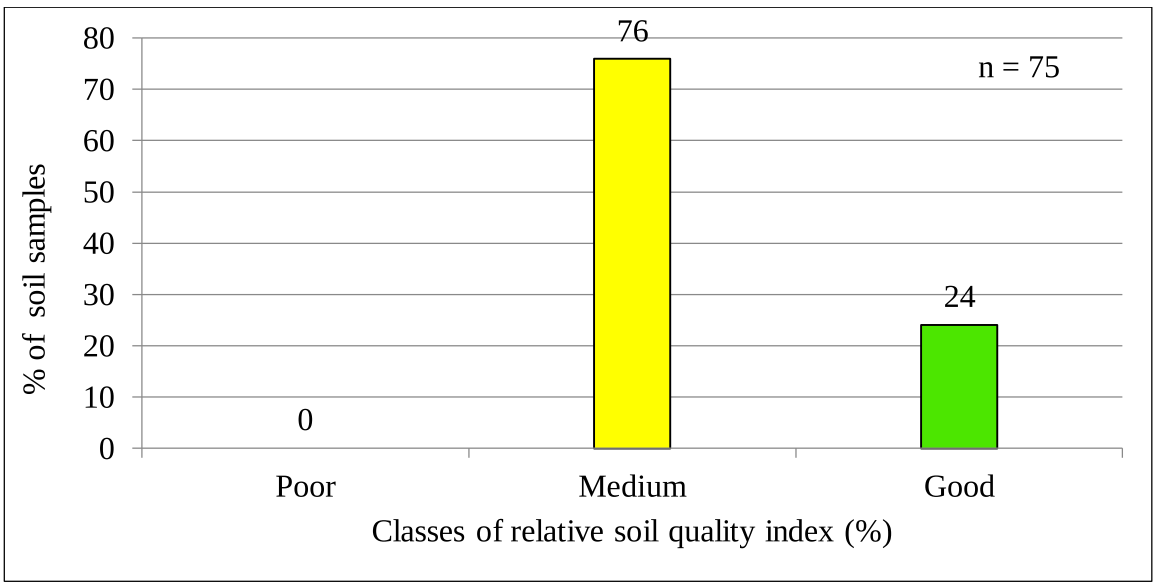



Fig.35. Frequency distribution of RSQI (%) in the post-flood soils of AEU 4 in Pathanamthitta district

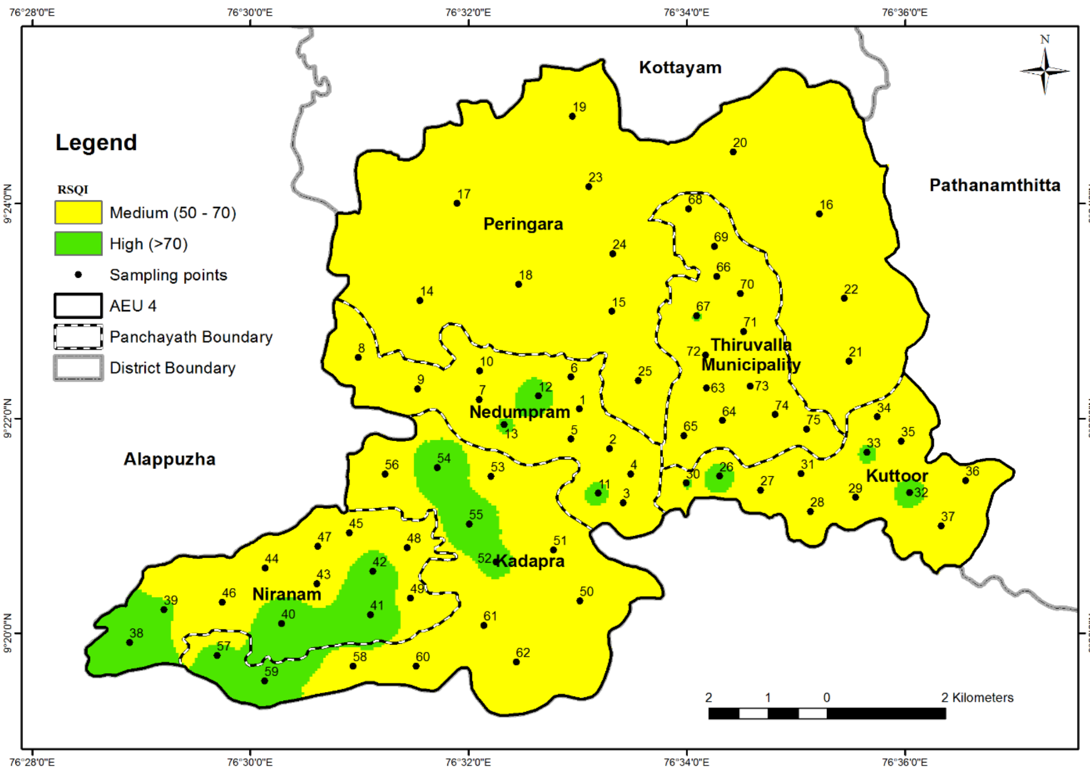



Fig.36.Spatial distribution of RSQI in the post-flood soils of AEU 4 in Pathanamthitta.

## 5.3. NUTRIENT INDEX

Nutrient index was used to assess the panchayat wise fertility status of soils based on the samples falling under low, medium, and high category (Parker et al., 1951). Nutrient index was developed for organic carbon, available nitrogen, phosphorus and potassium. The spatial distributions of nutrient indices are depicted in Fig 36, 37, 38 and 39.

Nutrient index for organic carbon and nitrogen was high and low in all areas. Nutrient index for phosphorus was high in all panchayats except Peringara and Thiruvalla Municipality as they had low fertility status for phosphorus. Phosphorus might have fixed in these areas where nutrient index for P is in low range.  Nutrient index for potassium was low in all panchayats except Niranam and Thiruvalla Municipality as they had medium fertility status for potassium. The relatively lower potassium levels of these areas had resulted in the low nutrient index.

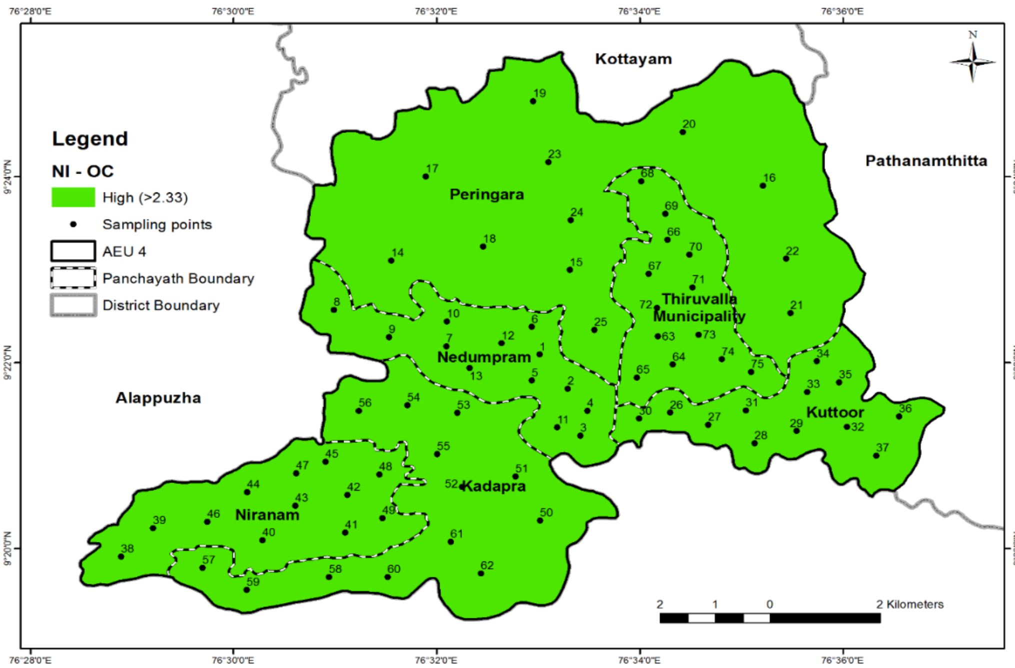



Fig.37.Spatial distribution of Nutrient index of organic carbon in the post-flood soils of AEU 4 in Pathanamthitta.

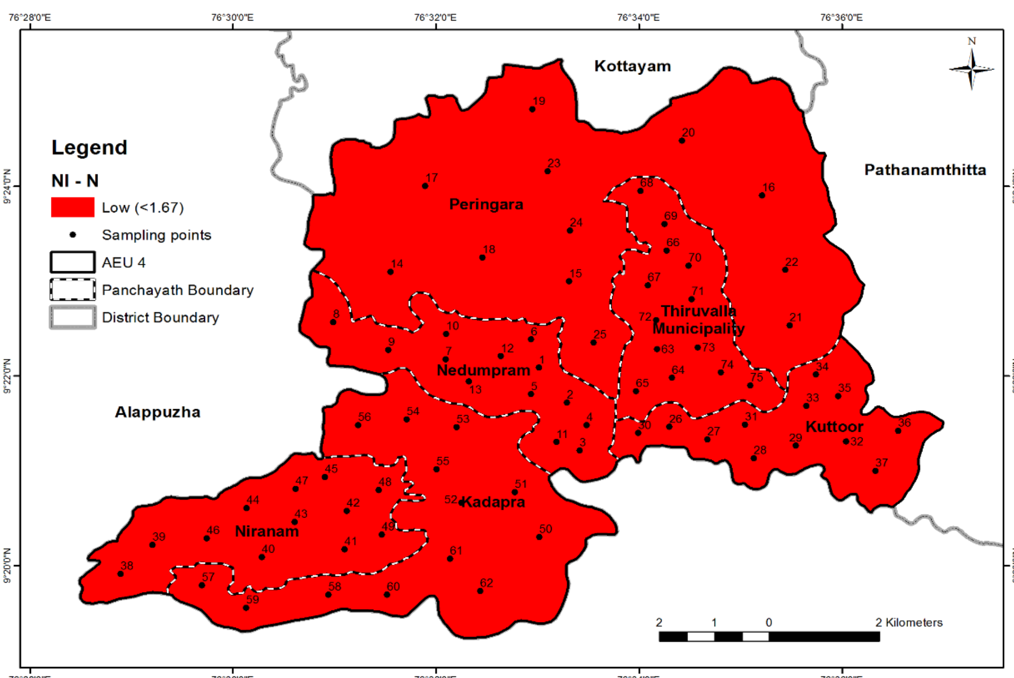



Fig.38 .Spatial distribution of Nutrient index of nitrogen in the post-flood soils of AEU 4 in Pathanamthitta.

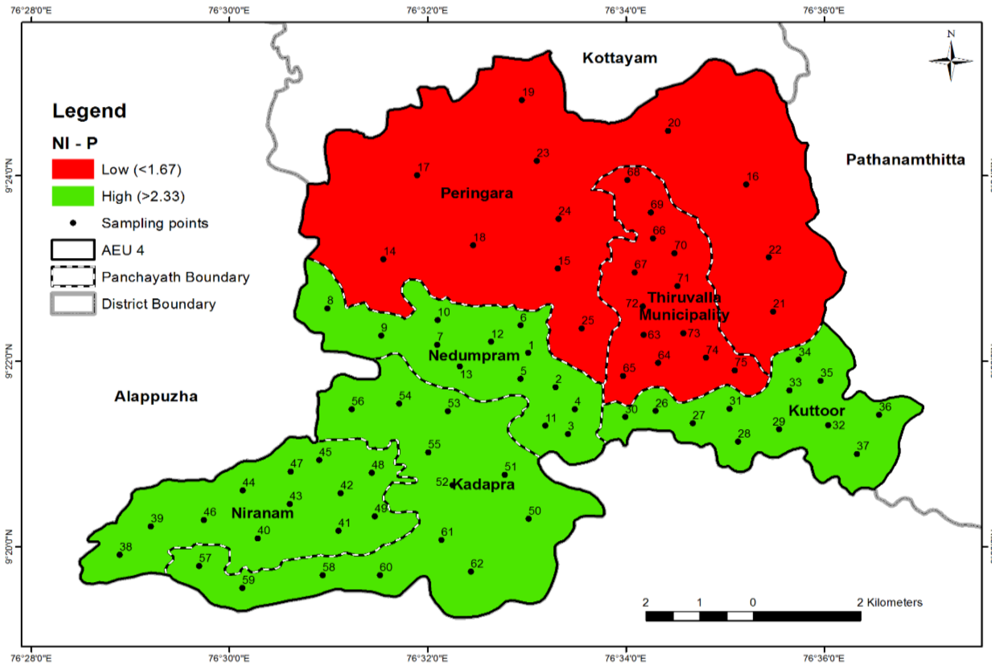



Fig.39.Spatial distribution of Nutrient index of phosphorus in the post-flood soils of AEU 4 in Pathanamthitta.

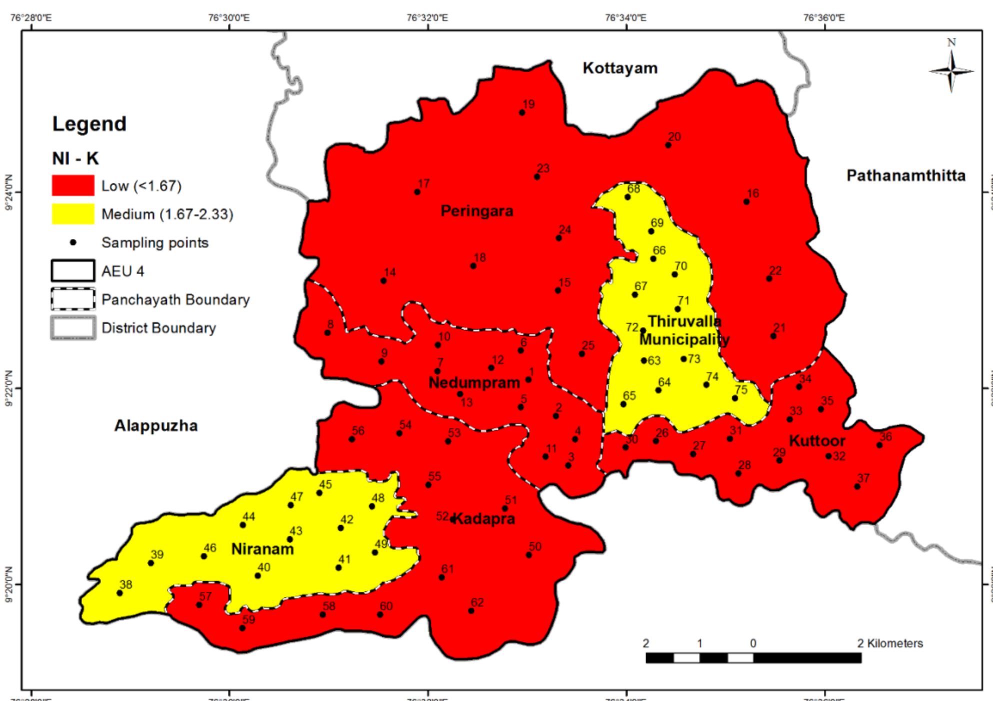



Fig.40. Spatial distribution of Nutrient index of potassium in the post-flood soils of AEU 4 in Pathanamthitta.

## 5.4 LAND QUALITY INDEX

Land quality index was estimated from Soil organic carbon stock which was calculated using soil organic carbon, bulk density and soil depth (Batjes, 1996). Land quality index were rated as very low, low, medium, moderate, high, very high based on the SOC stock (Shalima Devi, 2006). LQI was very low (<3 kg $m^{-2}$) for 8 per cent of samples, low (3– 6 kg $m^{-2}$) for 58.67 per cent of samples and medium (6-9 kg $m^{-2}$) for 33.33 percent of samples (Fig 40). Majority of the area had low to medium land quality which indicated that there was less loss of nutrients due to flood. The spatial distribution of LQI is presented in Fig 41

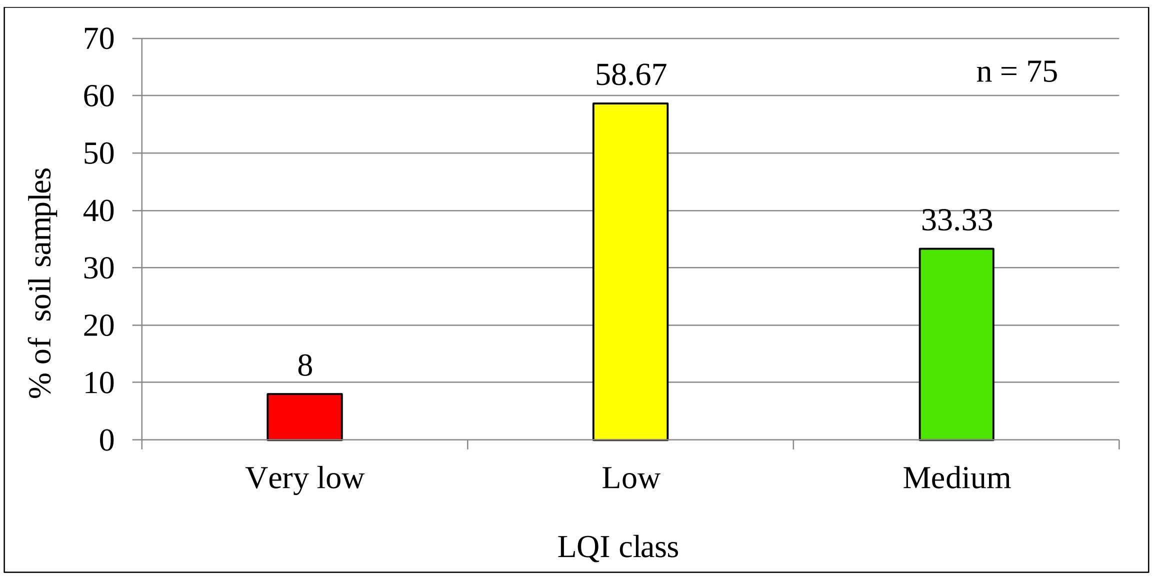



Fig.41. Frequency distribution of LQI (%) in the post-flood soils of AEU 4 in Pathanamthitta district.

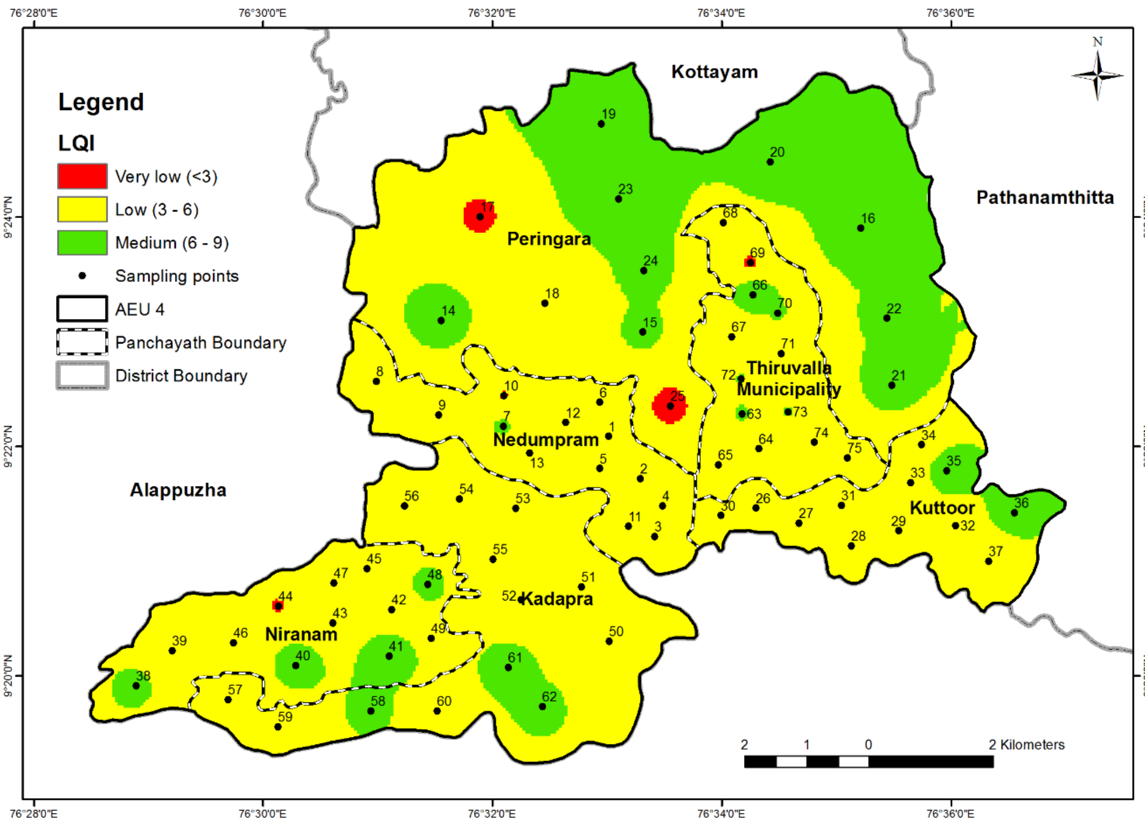



Fig.42. Spatial distribution of LQI in the post-flood soils of AEU 4 in Pathanamthitta.

## 5.5. COMPARISON OF PRE AND POST-FLOOD SOIL PROPERTIES

Agro ecological unit 4 in Pathanathitta was severely affected by the devastating flood which occurred in August, 2018. All the panchayats and Thiruvalla Municipality were fully affected. Flash flood was the major problem in this area. Large quantity of silt and clay deposition was observed in this area. Due to this deposition majority of the area under this AEU showed a shift in soil texture from sandy clay loam to silt loam or clay loam (KSPB, 2013). It would have influenced in lowering bulk density and improving porosity and moisture content of the soil.

In general there was an increased acidity in the post flood soils. Soils with extremely acid pH showed decrease in post flood study (5%) compared to pre flood data

(20%) whereas percentage of samples with very strongly acid, strongly acid, moderately acid and slightly acid increased (APPENDIX IV). Organic carbon content in this AEU recorded was high. There was an increase in the number of samples under high organic carbon content (80%) compared to pre flood data (43%). Organic carbon content was high in Nedumpuram and Niranam panchayat whereas it was increased from medium to high in Peringara, Kuttoor, Kadapra and Thiruvalla Municiaplity.

Available phosphorus remained high before and after the flood. It was observed that there was a reduction in percent number of samples under high category after flood (79% to 56%) whereas percent number of samples under low and medium had increased after flood**.** P content was high in all panchayats except Kadapra before and after flood. In Kadapra the shift was from medium to high category.

There observed a drastic reduction in the number of samples (42%) coming under high category of available potassium after flood (3%). Nedumpuram, Peringara, Kuttoor, and Niranam was under medium category before and after flood. Kadapra shifted from medium to low and Thiruvalla Municipality shifted from high to medium category. Available calcium and magnesium remained deficient after flood. 100% of samples were deficient in magnesium. Sulphur was deficient in post flood even though it was sufficient before flood. There was a drastic increase in per cent of samples coming under deficiency in available sulphur after flood (34% to 75%).

Available, Zn, Mn, Fe and B remained adequate before and after flood in near hundred percentage of samples. But copper became deficient after flood. Copper was deficient in 11% samples before flood but the shift was to 97% after flood. In general all the panchayats showed sufficiency in micronutrients except copper.

Mainly two rivers such as Pamba and Manimala flow through AEU 4 of Pathanamthitta. Nedumpuram, Peringara, Kuttoor and Thiruvalla Municipality were affected by Manimala River. Kadapra panchayat is completely drained by water from Pamba River. Both Manimala and Pamba river flows through Niranam panchayat.

There was an observed change in pH range from extremely acid to strongly acid before the flood to extremely acid to neutral after the flood. Reduction in soil acidity to near neutrality is good for crop production. In panchayats affected by rose in water level in Manimala River, organic carbon and available P remained high and available K remained medium. Available B and Zn were shown sufficiency after flood. Those panchayats which are affected by Pamba River showed High content of organic carbon and available phosphorus but available potassium was low to medium. Available B and Zn were shown sufficiency after flood. There was an innate advantage of siltation particularly alluvial clay, organic matter etc. Farmers reported that there was an enhancement in yield especially paddy on account of the nutrient contributions from sediments.

## 5.6. MANAGEMENT STRATEGIES FOR CROP PRODUCTION IN THE POST- FLOOD SOILS OF AEU 4 IN PATHANAMTHITTA DISTRICT

There were many changes occurred in physio-chemical properties of soil after the flood. Those changes will directly influence the crop production in this region. Major crops grown in this area were paddy, sugarcane, banana, coconut, cassava, nutmeg and vegetables etc. For a successful crop production it is necessary to bring changes in management and nutrient application according to the soil status after flood. Soil test based nutrient recommendations for each panchayat are given below.

Table.31. Summary of soil fertility status of Panchayats.

| **Panchayat/ Muncipality** | **pH (mean)** | **Fertility status** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **OC** | **P** | **K** | **Ca** | **Mg** | **S** | **Fe** | **Zn** | **Mn** | **Cu** | **B** |
| Nedumpuram | 5.32 | H | H | M | A | D | D | A | A | A | D | A |
| Peringara | 4.72 | H | H | M | D | D | A | A | A | A | D | A |
| Kuttoor | 5.56 | H | H | M | A | D | D | A | A | A | D | A |
| Niranam | 5.57 | H | H | M | A | D | D | A | A | A | D | A |
| Kadapra | 5.70 | H | H | L | D | D | D | A | A | A | D | A |
| Thiruvalla Muncipality | 5.23 | H | H | M | D | D | D | A | A | A | D | A |

H- High, M- Medium, L- Low, A- Adequate, D- Deficient

Table.32. Fertilizer recommendation of Panchayats according to KAU POP, 2016.

| Panchayat/ Muncipality | Lime (kg $ha^{-1}$) | % POP | | | Secondary and micro nutrients (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | N | P | K | $MgSO_4$ | S | $CuSO_4.5H_2O$ |
| Nedumpuram | 350 | 54 | - | 94 | 80 | 25 | 1.5-2.0 |
| Peringara | 600 | - | - | 94 | 80 | 25 | 1.5-2.0 |
| Kuttoor | 250 | 54 | - | 94 | 80 | 25 | 1.5-2.0 |
| Niranam | 250 | - | - | 83 | 80 | 25 | 1.5-2.0 |
| Kadapra | 250 | 54 | - | 106 | 80 | 25 | 1.5-2.0 |
| Thiruvalla Muncipality | 350 | 54 | - | 94 | 80 | 25 | 1.5-2.0 |

**Nedumpuram**

- Soil pH ranged from extremely acid to slightly acid (Fig.12) with a mean of 5.32. Hence liming @ 350 kg $ha^{-1}$ is recommended according to KAU POP (2016).
- Soil organic carbon was high most of the soils with mean of 2.32 % (Table.13) Organic manure application can be managed site specifically depending upon its soil status and crop needs. Nitrogen @ 54 % of the KAU POP recommendation can be done.
- Available phosphorus was high in majority of the soils (Fig.21) with a mean value of 97.6 kg $ha^{-1}$ (Table.14). The P application can be either skipped or reduced to 25-50% of the KAU POP depending upon the soil status and crop needs.
- Available potassium was medium in most of the area and low in some area (Fig.22). The mean value of potassium was 147 kg $ha^{-1}$ (Table.14). Potassium @ 94 % of KAU POP recommendation can be done.
- Available calcium was sufficient and deficient in this panchayat (Fig.24) Application of lime as per the lime requirement is sufficient to overcome the deficiency.
- Available magnesium was completely deficient (Fig. 25). Application of $MgSO_4$ @ 80 kg $ha^{-1}$ can be done to overcome this.

- Available sulphur was completely deficient (Fig. 27). Application of S @ 25 kg $ha^{-1}$ is necessary.
- Micronutrients such as available Fe, Zn, Mn and B were adequate in all soils.
- Available copper shown complete deficiency (Fig.31) in this panchayat. Application of 1.5-2.0 kg $CuSO_4.5H_2O$ $ha^{-1}$ can be done.

**Peringara**

- Soil reaction was extremely acid to slightly acid (Fig.12) with a mean of 4.72. Hence liming @ 600 kg $ha^{-1}$ is recommended according to KAU POP (2016).
- Soil organic carbon was high most of the soils with mean of 3.17 % (Table.13) Organic manure application can be managed site specifically depending upon its soil status and crop needs. Nitrogen application can be skipped.
- Available phosphorus was high in majority of the soils (Fig.21) with a mean value of 43.1 kg $ha^{-1}$ (Table.14). The P application can be either skipped or reduced to 25-50% of the KAU POP depending upon the soil status and crop needs.
- Available potassium was medium in most of the area and low in some area (Fig.22). The mean value of potassium was 128 kg $ha^{-1}$ (Table.14). Potassium @ 94 % of KAU POP recommendation can be done.
- Available calcium was deficient in most of the soils in this panchayat (Fig.24) Application of lime as per the lime requirement is sufficient to overcome the deficiency.
- Available magnesium was completely deficient (Fig. 25). Application of $MgSO_4$ @ 80 kg $ha^{-1}$ can be done to overcome this.
- Available sulphur shown adequacy and deficiency in this panchayat (Fig. 27). Application of S @ 25 kg $ha^{-1}$ is necessary to overcome deficiency.
- Micronutrients such as available Fe, Zn, Mn and B were adequate in all soils.
- Available copper shown complete deficiency (Fig.31) in this panchayat. Application of 1.5-2.0 kg $CuSO_4.5H_2O$ $ha^{-1}$ can be done.

**Kuttoor**

- ❖ Soil pH ranged from extremely acid to slightly acid (Fig.12) with a mean of 5.56. Hence liming @ 250 kg $ha^{-1}$ is recommended according to KAU POP (2016).
- ❖ Soil organic carbon was high most of the soils with mean of 2.35 % (Table.13) Organic manure application can be managed site specifically depending upon its soil status and crop needs. Nitrogen @ 54% of the KAU POP recommendation can be done.
- ❖ Available phosphorus was high in majority of the soils (Fig.21) with a mean value of 72.2 kg $ha^{-1}$ (Table.14). The P application can be either skipped or reduced to 25-50% of the KAU POP depending upon the soil status and crop needs.
- ❖ Available potassium was medium in most of the area and low in some area (Fig.22). The mean value of potassium was 118 kg $ha^{-1}$ (Table.14). Potassium @ 94 % of KAU POP recommendation can be done.
- ❖ Available calcium shown adequacy and deficiency in this panchayat (Fig.24) Application of lime as per the lime requirement is sufficient to overcome the deficiency.
- ❖ Available magnesium was completely deficient (Fig. 25). Application of $MgSO_4$ @ 80 kg $ha^{-1}$ can be done to overcome this.
- ❖ Available sulphur was deficient in most of the soils (Fig. 27). Application of S @ 25 kg $ha^{-1}$ is necessary to overcome deficiency.
- ❖ Micronutrients such as available Fe, Zn, Mn and B were adequate in all soils.
- ❖ Available copper shown complete deficiency (Fig.31) in this panchayat. Application of 1.5-2.0 kg $CuSO_4.5H_2O$ $ha^{-1}$ can be done.

**Niranam**

- ❖ Soil reaction was very strongly acid to slightly acid (Fig.12) with a mean of 5.57. Hence liming @ 250 kg $ha^{-1}$ is recommended according to KAU POP (2016).

- Soil organic carbon was high most of the soils with mean of 2.62 % (Table.13) Organic manure application can be managed site specifically depending upon its soil status and crop needs. Nitrogen application can be skipped.
- Available phosphorus was high in majority of the soils (Fig.21) with a mean value of 102 kg $ha^{-1}$ (Table.14). The P application can be either skipped or reduced to 25-50 % of the KAU POP depending upon the soil status and crop needs.
- Available potassium was medium in most of the area and low in some area (Fig.22). The mean value of potassium was 164 kg $ha^{-1}$ (Table.14). Potassium @ 83 % of KAU POP recommendation can be done.
- Available calcium shown adequacy and deficiency in this panchayat (Fig.24) Application of lime as per the lime requirement is sufficient to overcome the deficiency.
- Available magnesium was completely deficient (Fig. 25). Application of $MgSO_4$ @ 80 kg $ha^{-1}$ can be done to overcome this.
- Available sulphur was deficient in most of the soils (Fig. 27). Application of S @ 25 kg $ha^{-1}$ is necessary to overcome deficiency.
- Micronutrients such as available Fe, Zn, Mn and B were adequate in all soils.
- Available copper shown complete deficiency (Fig.31) in this panchayat. Application of 1.5-2.0 kg $CuSO_4.5H_2O$ $ha^{-1}$ can be done.

**Kadapra**

- Soil pH ranged from strongly acid to slightly acid (Fig.12) with a mean of 5.70. Hence liming @ 250 kg $ha^{-1}$ is recommended according to KAU POP (2016).
- Soil organic carbon was high most of the soils with mean of 2.18 % (Table.13) Organic manure application can be managed site specifically depending upon its soil status and crop needs. Nitrogen @ 54 % of the KAU POP recommendation can be done.

- Available phosphorus was high in majority of the soils (Fig.21) with a mean value of 134 kg $ha^{-1}$ (Table.14). The P application can be either skipped or reduced to 25-50% of the KAU POP depending upon the soil status and crop needs.
- Available potassium was medium in most of the area and low in some area (Fig.22). The mean value of potassium was 75.4 kg $ha^{-1}$ (Table.14). Potassium @ 106 % of KAU POP recommendation can be done.
- Available calcium was deficient in most of the area in this panchayat (Fig.24) Application of lime as per the lime requirement is sufficient to overcome the deficiency.
- Available magnesium was completely deficient (Fig. 25). Application of $MgSO_4$ @ 80 kg $ha^{-1}$ can be done to overcome this.
- Available sulphur was deficient in most of the soils (Fig. 27). Application of S @ 25 kg $ha^{-1}$ is necessary to overcome deficiency.
- Micronutrients such as available Fe, Zn, Mn and B were adequate in all soils.
- Available copper shown complete deficiency (Fig.31) in this panchayat. Application of 1.5-2.0 kg $CuSO_4.5H_2O$ $ha^{-1}$ can be done.

**Thiruvalla Municipality**

- Soil reaction was extremely acid to slightly acid (Fig.12) with a mean of 5.23. Hence liming @ 350 kg $ha^{-1}$ is recommended according to KAU POP (2016).
- Soil organic carbon was high most of the soils with mean of 2.43 % (Table.13) Organic manure application can be managed site specifically depending upon its soil status and crop needs. Nitrogen @ 54 % of the KAU POP recommendation can be done.
- Available phosphorus was high in majority of the soils (Fig.21) with a mean value of 57.9 kg $ha^{-1}$ (Table.14). The P application can be either skipped or reduced to 25-50% of the KAU POP depending upon the soil status and crop needs.

- Available potassium was medium in most of the area and low in some area (Fig.22). The mean value of potassium was 153 kg $ha^{-1}$ (Table.14). Potassium @ 94 % of KAU POP recommendation can be done.
- Available calcium was deficient in most of the area in this panchayat (Fig.24) Application of lime as per the lime requirement is sufficient to overcome the deficiency.
- Available magnesium was completely deficient (Fig. 25). Application of $MgSO_4$ @ 80 kg $ha^{-1}$ can be done to overcome this.
- Available sulphur was deficient in most of the soils (Fig. 27). Application of S @ 25 kg $ha^{-1}$ is necessary to overcome deficiency.
- Micronutrients such as available Fe, Zn, Mn and B were adequate in all soils.
- Available copper shown complete deficiency (Fig.31) in this panchayat. Application of 1.5-2.0 kg $CuSO_4.5H_2O$ $ha^{-1}$ can be done.

# SUMMARY

## SUMMARY

The present investigation "Assessment of soil quality in the post-flood scenario of AEU 4 in Pathanamthitta district of Kerala and generation of GIS maps" was carried out with the following objectives,

- The assessment of soil quality of post-flood soils of AEU 4 in Pathanamthitta district.
- To develop maps on soil characters and quality using GIS techniques.
- To work out the Soil Quality Index (SQI).

Seventy five geo referenced representative samples from the flood affected areas of AEU 4 in Pathanamthitta district using GPS. It covered an area of 8999 ha which includes Thiruvalla Municipality and panchayats such as Nedumpuram, Niranam, Kuttoor, Kadapra and Peringara. A survey was conducted simultaneously according to a pre designed questionnaire. The survey covered the basic details of farmer, crop details and nutrient management adopted. The collected samples were analysed for different physical (Bulk density, particle density, porosity, texture, depth of silt/clay/sand deposition, maximum water holding capacity, soil moisture and aggregate analysis), chemical (pH, electrical conductivity, organic carbon, available macro and micronutrients) and biological (Acid phosphatase) parameters for evaluating soil quality.

The best indicators which influence the soil quality were selected as minimum data set (MDS) by using principal component analysis (PCA) method. After considering 21 attributes, 11 parameters showered high degree of variability so they were selected for developing MDS. By weightage and scoring method soil quality index (SQI) and relative soil quality index (RSQI) were calculated from minimum data set. With the help of RSQI values, soils were categorized into poor, medium and good.

Correlation between physical, chemical and biological parameters were done using statistical tools to find out the significance of correlation. With the laboratory analyzed data of soil samples, land quality index (LQI), Nutrient indices of organic carbon,

available nitrogen, phosphorus and potassium were carried out. Spatial distribution maps of pH, textural class, available nutrients, land quality index, nutrient index and soil quality index were done through ArcGIS software.

Comparison of post flood data of AEU 4 in Pathanamthitta was done with the pre flood data of same place from Kerala state planning board (KSPB, 2013). The major findings of the present investigation are summarized and listed below.

- All areas of AEU 4 in Pathanamthitta was affected by 2018 flood. Severe crop loss was reported in this area.
- Major crops grown in these area were paddy, coconut, banana, cassava, sugarcane, nutmeg, rubber, vegetables etc. and farmers followed INM, organic and conventional farming.
- Majority of the farmers had land holdings less than 2 hectares (marginal and small farmers). Homestead farming was predominant in this area.
- Sediment deposition was observed in almost all areas as they are very near to Pamba and Manimala Rivers.

**Physical parameters**

- Bulk density of samples varied between 0.89 to 1.64 Mg $m^{-3}$ with a mean value of 1.36 Mg $m^{-3}$. Bulk density of 85.3% of samples had a safe range (< 1.6 Mg $m^{-3}$).
- Particle density ranged between 1.73 to 2.62 Mg $m^{-3}$ in the soil with a mean of 2.01 Mg $m^{-3}$.Particle density of 84% of samples had less than 2.20 Mg $m^{-3}$.
- Porosity varied from 15.7% to 51.1% in the soil with a mean of 32.5%.
- The predominant soil texture in this area is silt loam. Other samples have textural classes such as clay loam, silty clay loam, sandy clay loam and sandy loam.
- Available soil moisture varied from 0.15% to 62.1% with a mean of 21.1%.
- Maximum water holding capacity ranged from 24.2% to 89.8% with mean of 49.7%. Water holding capacity of 97.3% samples were greater than 30% which indicated that most of the soil had medium to high range.

- Percentage of water stable aggregate varied from 4.38% to 81.7% with a mean value of 46.2%.
- Mean weight diameter varied between 0.06 mm to 3.1 with a mean of 0.66 mm.

**Chemical parameters**

- The pH of the samples ranged from 4.02 to 6.56 with a mean value of 5.35 which indicated that the acidity of the soil were extremely acid to near neutral.
- Electrical conductivity ranged from 0.04 to 1.99 $dSm^{-1}$ with a mean of 0.41 $dSm^{-1}$ which suggested that there was no salt accumulation due to flood in this region.
- Majority of the samples (80%) were high in Organic Carbon (OC). It ranges from 0.75 to 4.53% with mean value of 2.5%. Twenty per cent of the samples were under medium OC.
- Available nitrogen content in soil ranges from 75.3 kg $h^{-1}$ to 452 kg $h^{-1}$ with a mean of 224 kg $h^{-1}$. Overall evaluation showed that 61.33% of samples were in low and 38.7% in medium category.
- Majority of the samples (56%) showed high phosphorus content whereas 29.3% and 14.7% in low and medium category respectively. The mean value of P in the area was 84.9 kg $h^{-1}$ and it ranges from 3.55 to 328 kg $h^{-1}$.
- Available potassium content in soil ranges from 26.1 kg $h^{-1}$ to 366 kg $h^{-1}$ with a mean of 131 kg $h^{-1}$. Overall evaluation showed that 48% of samples were in low, 49.3% in medium and 2.67% in high category.
- Deficiency of available calcium and magnesium was observed in 65.3% and 100% of the samples respectively whereas 34.7% of samples were sufficient in calcium. Both were deficient before and after flood in soils of this region. Ca and Mg showed a range of 0.99 to 3.12 mg $kg^{-1}$ and 5.9 to 19.9 mg $kg^{-1}$ respectively.
- Available sulphur showed a shift from adequate to deficiency after flood. The present study showed that it ranges between 0.09 to 13.9 mg $kg^{-1}$ with a mean value of 2.63 mg $kg^{-1}$.

- Near 100 per cent of samples showed sufficiency in available micronutrients such as iron, zinc, manganese and boron before and after flood whereas copper showed a shift from sufficiency to deficiency after flood.
- Highest mean of available Zn (8.25 mg kg $^{-1}$) and Cu (0.93 mg kg $^{-1}$) and lowest mean of $N_2$ (178 kg $h^{-1}$), Mg (10.2 mg kg $^{-1}$), S (0.32 mg kg $^{-1}$) and B (1.29 mg kg $^{-1}$) were observed at Nedumpuram panchayat.
- The mean values of organic carbon (3.17%), available S (5.25 mg kg $^{-1}$), Fe (209 mg kg $^{-1}$) and Mn (24.2 mg kg $^{-1}$) were high at Peringara panchayat and it had lowest mean value for available P (43.1 kg $h^{-1}$).
- Kuttoor panchayat had highest mean value for available nitrogen (283 kg $h^{-1}$).
- Highest mean values of available K (164 kg $h^{-1}$), Ca (336 mg kg $^{-1}$) and B (1.45 mg kg $^{-1}$) were observed at Niranam panchayat and it had lowest mean value for Cu (0.17 mg kg $^{-1}$).
- Kadapra panchayat had highest mean value for available P (134 kg $h^{-1}$) and lowest mean values of organic carbon (2.18%), available K (75.4 kg $h^{-1}$) and Mn (13.6 mg kg $^{-1}$)
- Thiruvalla municipality was observed with highest mean value of available Mg (16.7 mg kg $^{-1}$) and lowest mean value for available Ca (123 mg kg $^{-1}$), Fe (82 mg kg $^{-1}$) and Zn (3.87 mg kg $^{-1}$).

**Biological parameter**

- Acid phosphatase activity in soil ranges from 0.02 to 25.9 µg PNP produced $g^{-1}$soil $h^{-1}$ with a mean of 6.42 µg PNP produced $g^{-1}$soil $h^{-1}$. Present study showed that the lowest and highest mean at panchayat level were observed for Peringara (2.12 µg of p-nitrophenol g-1 soil h-1) and Kadapra (11 µg of p-nitrophenol g-1 soil h-1) respectively.

**Soil quality**

- Principal component analysis yielded MDS consists of percentage of water stable aggregates, % of sand, % of silt and% of clay, pH, available phosphorus, available potassium, available iron, available manganese, available magnesium and available boron.
- Highest soil quality was observed at Niranam panchayat with mean value 248 and Relative Soil Quality Index (RSQI) value of 61.9%. Lowest soil quality was observed at Peringara panchayat with mean value 276 and RSQI value of 62 %. It was observed that 76% of samples were in medium and 24% in good soil quality range.
- Nutrient index for organic carbon and nitrogen was high and low respectively in all areas respectively.
- Nutrient index for phosphorus was high in all panchayats except Peringara and Thiruvalla Municipality as they had low fertility status for phosphorus.
- Nutrient index for potassium was low in all panchayats except Niranam and Thiruvalla Municipality as they had Medium fertility status for potassium.
- LQI was very low (<3 kg $m^{-2}$) for 8% of samples, low (3-6 kg $m^{-2}$) for 58.7 % of samples and medium (6-9 kg $m^{-2}$) for 33.3% of samples.
- The highest land quality index was observed at Nedumpuram panchayat with soil organic carbon stock of 6.14 kg $m^{-2}$ and it fall in low quality category. The lowest was at Thiruvalla municipality with 4.37 kg $m^{-2}$ of soil organic carbon stock.

**Conclusion**

From this study, AEU 4 in Pathanamthitta showed that bulk density was in safe range (>1.6 Mg $m^{-3}$) and there was a slight reduction in particle density. There is a decrease in overall soil acidity and depletion in the status of nitrogen, potassium, sulphur, magnesium and copper. Organic carbon and available phosphorus was high and available

Fe, Zn, Mn and B were sufficient after flood. There was a reduction in acid phosphatase activity in the soil. The overall soil quality of the area was medium to high.

Soil acidity stays a major problem in this area even after the flood and it needs urgent reclamation measures to restore productivity. The sufficiency of some nutrients might be due to the silt deposition occurred along with flood. The sediment deposition had changed the characteristics of low land soil. The reduction in overall nutrients indicated that the nutrients might be lost due to flooding. It is necessary to restore the soil even though the soil lies in medium to high soil quality. Site specific and nutrient specific management practices are necessary to overcome the changes in soil due to flood. This will make the farmers aware about the changes in soil brought about by the flood and for adopting effective management measures for post flood soil. Alteration in nutrients application according to the current status of soil will help to achieve productivity.

**Future line of work**

- Alteration in fertilizer recommendation according to the current status of soil
- Development of site specific Nano technology
- Studies on nutrient interactions covering different crops, cropping systems and soil
- Studies on heavy metals in this area

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# ASSESSMENT OF SOIL QUALITY IN THE POST-FLOOD SCENARIO OF AEU 4 IN PATHANAMTHITTA DISTRICT OF KERALA AND GENERATION OF GIS MAPS.

*by*

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**ABSTRACT**

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# ABSTRACT

The present study entitled "Assessment of soil quality in the post-flood scenario of AEU 4 in Pathanamthitta district of Kerala and generation of GIS maps" was undertaken to evaluate the soil quality of post flood soils in this area and to develop maps on soil characters and quality using GIS technique and to work out soil quality index.

Seventy five geo referenced representative soil samples were collected from flood affected areas of Nedumpuram, Niranam, Kuttoor, Kadapra, Peringara panchayats and Thriuvalla Municipality. As per the survey details, rice, banana, nutmeg and vegetables are the major crops grown in the area. Majority of the farmers follow organic farming practices. In this region flood occurred mainly due to high rainfall and rise in water level in Pamba and Manimala rivers. Water stagnation continued in this area for 5-6 days and thick deposition of silt was observed in severely affected areas.

Soil samples collected were analyzed for different physical (bulk density, particle density, porosity, texture, depth of silt/clay/sand deposition, maximum water holding capacity, soil moisture and aggregate analysis), chemical (pH, electrical conductivity, organic carbon, available macro, secondary and micronutrients) and biological (Acid phosphatase) parameters for evaluating soil quality.

Selection of Minimum Data Set (MDS) was done by using Principal Component Analysis (PCA) method. The MDS which determine the SQI of these area are percentage of water stable aggregates, percentage of sand, silt and clay, pH, phosphorus, potassium, magnesium, manganese, iron and boron. These indicators are given weightage based on the influence of indicators on soil quality.

These scores are integrated to determine SQI (Kundu *et al*., 2018). Relative soil quality index (RSQI) was also determined from this. Thematic maps of soil quality, land quality and nutrient index were prepared in ArcGIS software. Correlation between different physical, chemical and biological parameters were done statistically. Bulk density of 85.33% samples lies below 1.6 Mg $m^{-3}$. Majority of the soil samples had particle density less than 2.67 Mg $m^{-3}$. The present study showed that water holding

capacity of 97.33% samples were greater than 30%. Mean weight diameter of 84% of samples had less than 1 mm. The predominant soil texture in this area is silt loam. Other samples have textural classes such as clay loam, silty clay loam, sandy clay loam and sandy loam.

The soils of AEU 4 in Pathanamthitta are extremely acidic to near neutral with overall pH ranging from 4.02 to 6.98. Electrical conductivity of 80 per cent of samples had less than 1 $dSm^{-1}$. The study area shown high content of organic carbon. Phosphorus was high in 56% of samples whereas 61.3% samples are low in Nitrogen and 49.33 5 of samples having medium potassium content. Majority of samples analysed were deficient in calcium, magnesium and sulphur. Near to 100% of the samples were having sufficiency in Fe, Zn, Mn and B whereas copper shown deficiency. 73.3% of samples had acid phosphatase activity less than 10 μg PNP produced $g^{-1}$soil $h^{-1}$.

The results are compared with pre flood scenario data from Kerala State Planning Board (2013). Organic carbon and phosphorus remained high before and after flood. There is a slight decrease in pH from strongly acidic to ultra-acidic in this region. There exist a decrease in potassium from high to medium level. Zn, Mn, Fe and B remained sufficient whereas calcium and magnesium remained deficient before and after flood. Sulphur and Copper showed a drastic change from sufficiency to deficiency.

According to the SQI analysis, highest soil quality was found in Niranam panchayat and lowest in Peringara. As per nutrient index analysis, all the Panchayats have high organic carbon and low nitrogen status. Peringara and Thiruvalla Municipality had low Phosphorus status and all others with high P status. Potassium was medium in Thiruvalla municipality and Niranam panchayat whereas all other panchayats have low K fertility status. Land Quality index (LQI) was high in Nedumpuram Panchayt.

From the present investigation, AEU 4 in Pathanamthitta showed that there is an increase in overall soil acidity and depletion in the status of nitrogen, potassium, sulphur and copper which indicates that the nutrients might be lost due to flooding. So site specific management practices are necessary. Alteration in nutrients application according to the current status of soil will help to achieve productivity.

# APPENDICES

## Appendix I

## Questionnaire

| | |
|---|---|
| Name of the Panchayat | : |
| Name of the farmer | : |
| Address | : |
| | |
| Size of the land holding | : |
| Survey number | : |
| Coordinates of the sampling location | |
| Latitude | : |
| Longitude | : |
| Crops cultivated | : |
| Nutrient management practices | : |
| Depth of sand/silt/clay deposition after flood | : |

**Appendix II – Area and crop management of sampled locations**

| Sl. No. | Holding size | Crops | Nutrient Management |
|---|---|---|---|
| 1 | 0.20 | Sugarcane | Conventional |
| 2 | 0.25 | Sugarcane | Conventional |
| 3 | 0.20 | Sugarcane | Conventional |
| 4 | 0.4 | Banana | Organic farming |
| 5 | 0.7 | Coconut | INM |
| 6 | 0.7 | Coconut | INM |
| 7 | 0.08 | Vegetables | Organic farming |
| 8 | 0.14 | Banana | Organic farming |
| 9 | 0.8 | Nutmeg | INM |
| 10 | 0.1 | Banana | Organic farming |
| 11 | 0.6 | Coconut | INM |
| 12 | 0.8 | Paddy | Conventional |
| 13 | 1.7 | Paddy | Conventional |
| 14 | 0.8 | Paddy | Conventional |
| 15 | 1 | Paddy | Conventional |
| 16 | 0.9 | Paddy | Conventional |
| 17 | 2.1 | Paddy | Conventional |
| 18 | 0.6 | Paddy | Conventional |
| 19 | 1.5 | Paddy | Conventional |
| 20 | 0.7 | Paddy | Conventional |
| 21 | 1.3 | Paddy | Conventional |
| 22 | 1.6 | Paddy | Conventional |
| 23 | 1.4 | Paddy | Conventional |
| 24 | 0.8 | Paddy | Conventional |
| 25 | 1.2 | Paddy | Conventional |
| 26 | 0.8 | Paddy | Conventional |
| 27 | 1.2 | Paddy | Conventional |
| 28 | 0.7 | Paddy | Conventional |
| 29 | 0.2 | Nutmeg | INM |
| 30 | 0.4 | Coconut | Conventional |
| 31 | 0.1 | Cassava | Organic farming |
| 32 | 0.2 | Banana | Organic farming |
| 33 | 0.1 | Banana | Organic farming |
| 34 | 0.08 | Vegetables | Organic farming |
| 35 | 0.14 | Banana | Organic farming |
| 36 | 0.2 | Nutmeg | INM |
| 37 | 0.12 | Vegetables | Organic farming |
| 38 | 0.3 | Nutmeg | INM |
| 39 | 0.18 | Banana | Organic farming |

(Appendix II- continued)

| Sl. No. | Holding size | Crops | Nutrient Management |
|---|---|---|---|
| 40 | 0.10 | Vegetables | Organic farming |
| 41 | 0.22 | Nutmeg | INM |
| 42 | 0.30 | Coconut | Conventional |
| 43 | 1.8 | Rubber, Nutmeg | Conventional |
| 44 | 2.1 | Rubber, Coconut | Conventional |
| 45 | 0.14 | Banana | Organic farming |
| 46 | 0.18 | Nutmeg | INM |
| 47 | 0.11 | Cassava | Organic farming |
| 48 | 0.08 | Vegetables | Organic farming |
| 49 | 0.12 | Banana | Organic farming |
| 50 | 0.20 | Nutmeg | INM |
| 51 | 0.30 | Coconut | INM |
| 52 | 0.15 | Cassava | Organic farming |
| 53 | 0.30 | Nutmeg | INM |
| 54 | 0.12 | Vegetables | Organic farming |
| 55 | 0.21 | Nutmeg | INM |
| 56 | 0.18 | Banana | Organic farming |
| 57 | 0.10 | Vegetables | Organic farming |
| 58 | 0.30 | Coconut | INM |
| 59 | 0.25 | Nutmeg | INM |
| 60 | 0.14 | Cassava | Organic farming |
| 61 | 0.12 | Vegetables | Organic farming |
| 62 | 0.30 | Nutmeg | INM |
| 63 | 0.30 | Banana | Organic farming |
| 64 | 0.8 | Vegetables | Organic farming |
| 65 | 0.35 | Nutmeg | INM |
| 66 | 0.20 | Cassava | Organic farming |
| 67 | 0.35 | Banana | Organic farming |
| 68 | 0.8 | Cassava | Organic farming |
| 69 | 0.25 | Banana | Organic farming |
| 70 | 0.65 | Coconut | INM |
| 71 | 0.30 | Banana | Organic farming |
| 72 | 0.20 | Banana | Organic farming |
| 73 | 0.10 | Vegetables | Organic farming |
| 74 | 0.25 | Banana | Organic farming |
| 75 | 0.12 | Vegetables | Organic farming |

# Appendix III

## Results of physical parameters (for individual samples)

| Sl. No. | Bulk Density (Mg m$^{-3}$) | Particle Density (Mg m$^{-3}$) | MWHC (%) | Moisture Content (%) | Porosity (%) | MWD (%) | WSA (%) | Sand (%) | Silt (%) | Clay (%) | Textural class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Nedumpuram** | | | | | | | | | | | |
| 1 | 1.56 | 1.85 | 60.6 | 24.77 | 15.68 | 0.892 | 47.4 | 42 | 26 | 32 | clay loam |
| 2 | 1.15 | 1.95 | 50.78 | 5.31 | 41.03 | 0.879 | 42.12 | 41 | 27 | 32 | clay loam |
| 3 | 1.12 | 1.83 | 47.33 | 5.95 | 38.80 | 1.044 | 49.26 | 41 | 29 | 30 | clay loam |
| 4 | 1.44 | 2.01 | 50.93 | 13.18 | 28.36 | 0.964 | 57.66 | 52 | 13 | 35 | Sandy clay loam |
| 5 | 1.34 | 1.92 | 62.14 | 15.97 | 30.21 | 0.404 | 48.92 | 18 | 64 | 18 | Silt loam |
| 6 | 1.11 | 1.96 | 52.79 | 7.64 | 43.37 | 0.188 | 20.98 | 28 | 40 | 32 | clay loam |
| 7 | 1.1 | 1.77 | 55.69 | 18.38 | 37.85 | 0.616 | 37.26 | 57 | 15 | 28 | Silty clay loam |
| 8 | 1.38 | 1.98 | 42.03 | 24.29 | 30.30 | 1.042 | 51.44 | 16 | 66 | 18 | Silt loam |
| 9 | 1.51 | 2 | 30.91 | 7.02 | 24.50 | 0.568 | 55.16 | 56 | 29 | 15 | Sandy loam |
| 10 | 1.18 | 1.99 | 47.86 | 13.89 | 40.70 | 0.728 | 49.9 | 41 | 27 | 32 | clay loam |
| 11 | 1.32 | 1.99 | 38.7 | 12.5 | 33.67 | 0.371 | 25.96 | 24 | 58 | 18 | Silt loam |
| 12 | 0.89 | 1.77 | 47.95 | 4.05 | 49.72 | 0.537 | 45.4 | 41 | 29 | 30 | clay loam |
| 13 | 1.5 | 2.14 | 45.85 | 55.65 | 29.91 | 1.225 | 55.76 | 25 | 57 | 18 | silt loam |
| **Peringara** | | | | | | | | | | | |
| 14 | 1.33 | 2.05 | 60.83 | 15.27 | 35.12 | 0.608 | 63.86 | 16 | 57 | 27 | Silty clay loam |
| 15 | 1.22 | 1.96 | 49.88 | 13.63 | 37.76 | 0.547 | 53.68 | 16 | 58 | 26 | Silty clay loam |
| 16 | 1.23 | 1.89 | 44.94 | 10.26 | 34.92 | 0.394 | 38.68 | 15 | 55 | 30 | Silty clay loam |
| 17 | 1.12 | 2.29 | 64.41 | 9.8 | 51.09 | 0.147 | 20.66 | 41 | 29 | 30 | Clay loam |
| 18 | 0.98 | 1.79 | 56 | 4.66 | 45.25 | 0.196 | 25.94 | 42 | 28 | 30 | Clay loam |
| 19 | 1.28 | 1.84 | 77.27 | 23.49 | 30.43 | 0.280 | 23.3 | 16 | 66 | 18 | Silt loam |
| 20 | 1.15 | 1.81 | 47.64 | 2.99 | 36.46 | 0.102 | 14.1 | 12 | 57 | 31 | Silty clay loam |
| 21 | 1.44 | 1.83 | 70.12 | 26.23 | 21.31 | 0.339 | 20.1 | 58 | 14 | 28 | Sandy clay loam |
| 22 | 1.23 | 1.81 | 72.58 | 19.2 | 32.04 | 0.674 | 47.52 | 24 | 58 | 18 | Silt loam |
| 23 | 1.48 | 1.87 | 74.36 | 37.18 | 20.86 | 0.129 | 18.54 | 65 | 18 | 17 | Sandy loam |
| 24 | 1.4 | 1.81 | 76.15 | 28.14 | 22.65 | 0.457 | 26.6 | 58 | 17 | 25 | Sandy clay loam |
| 25 | 1.59 | 2.35 | 29.21 | 5.78 | 32.34 | 0.102 | 8.2 | 24 | 57 | 19 | Silt loam |
| 26 | 1.44 | 2.29 | 34.51 | 14.99 | 37.12 | 1.286 | 66.98 | 57 | 15 | 28 | Silty clay loam |

Appendix III (Continued)

| Sl. No. | Bulk Density (Mg $m^{-3}$) | Particle Density (Mg $m^{-3}$) | MWHC (%) | Moisture Content (%) | Porosity (%) | MWD (%) | WSA (%) | Sand (%) | Silt (%) | Clay (%) | Textural class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Kuttoor** | | | | | | | | | | |
| 27 | 1.55 | 2.13 | 36.71 | 22.12 | 27.23 | 0.654 | 50.58 | 23 | 59 | 18 | Silt loam |
| 28 | 1.38 | 1.99 | 49.25 | 34.79 | 30.65 | 0.544 | 39.98 | 24 | 58 | 18 | Silt loam |
| 29 | 1.52 | 2.05 | 41.58 | 15 | 25.85 | 0.403 | 40.38 | 65 | 18 | 17 | Sandy loam |
| 30 | 1.43 | 2 | 44.75 | 19.02 | 28.50 | 1.050 | 61.2 | 26 | 56 | 18 | Silt loam |
| 31 | 1.29 | 1.94 | 33.75 | 0.15 | 33.51 | 0.364 | 24.12 | 16 | 54 | 30 | silty clay loam |
| 32 | 1.38 | 1.73 | 52.85 | 28.9 | 20.23 | 0.792 | 52.8 | 65 | 21 | 14 | Sandy loam |
| 33 | 1.16 | 2.21 | 54.96 | 5.69 | 47.51 | 0.494 | 49.48 | 38 | 33 | 29 | Clay loam |
| 34 | 1.31 | 1.75 | 89.79 | 30.03 | 25.14 | 0.443 | 31.2 | 58 | 14 | 28 | Sandy clay loam |
| 35 | 1.35 | 1.88 | 61.88 | 20.25 | 28.19 | 0.060 | 4.82 | 24 | 58 | 18 | Silt loam |
| 36 | 1.4 | 1.95 | 88.96 | 34.25 | 28.21 | 0.327 | 30.34 | 23 | 58 | 19 | Silt loam |
| 37 | 1.38 | 1.81 | 52.84 | 29.4 | 23.76 | 0.492 | 42.2 | 58 | 14 | 28 | Sandy clay loam |
| | **Niranam** | | | | | | | | | | |
| 38 | 1.2 | 1.94 | 72.89 | 26.32 | 38.14 | 0.602 | 63.88 | 18 | 56 | 26 | Silty clay loam |
| 39 | 1.41 | 2.05 | 34.25 | 8.4 | 31.22 | 0.843 | 65.12 | 12 | 57 | 31 | Silty clay loam |
| 40 | 1.37 | 2.14 | 38.8 | 22.32 | 35.98 | 2.036 | 77.76 | 16 | 52 | 32 | Silty clay loam |
| 41 | 1.55 | 2.1 | 39.54 | 12.7 | 26.19 | 3.098 | 75.24 | 24 | 59 | 17 | Silt loam |
| 42 | 1.44 | 2.16 | 34.18 | 11.43 | 33.33 | 2.415 | 81.7 | 16 | 52 | 32 | Silty clay loam |
| 43 | 1.14 | 2.12 | 58.05 | 30.47 | 46.23 | 0.457 | 41.92 | 38 | 33 | 29 | Clay loam |
| 44 | 1.18 | 1.92 | 46.8 | 10.4 | 38.54 | 0.426 | 40.98 | 16 | 54 | 30 | Silty clay loam |
| 45 | 1.59 | 2.12 | 42.4 | 10.6 | 25.00 | 2.036 | 62.28 | 61 | 16 | 23 | Sandy clay loam |
| 46 | 1.3 | 2.05 | 34.62 | 8.6 | 36.59 | 0.456 | 41.82 | 16 | 57 | 27 | Silty clay loam |
| 47 | 1.4 | 2.05 | 34.2 | 8.8 | 31.71 | 0.468 | 42.02 | 16 | 58 | 26 | Silty clay loam |
| 48 | 1.21 | 1.94 | 52.8 | 28.6 | 37.63 | 0.876 | 58.82 | 15 | 55 | 30 | Silty clay loam |
| 49 | 1.11 | 1.9 | 54.6 | 30.2 | 41.58 | 0.604 | 60.12 | 36 | 38 | 26 | Clay loam |
| | **Kadapra** | | | | | | | | | | |
| 50 | 1.61 | 2.21 | 36.47 | 44.78 | 27.15 | 0.423 | 47.24 | 62 | 16 | 22 | Sandy clay loam |
| 51 | 1.61 | 2.1 | 38.13 | 14.31 | 23.33 | 0.284 | 44.78 | 62 | 16 | 22 | Sandy clay loam |
| 52 | 1.62 | 2.25 | 56.62 | 27.87 | 28.00 | 0.387 | 64.5 | 22 | 60 | 18 | Silt loam |
| 53 | 1.56 | 2.13 | 53.31 | 62.13 | 26.76 | 0.341 | 65.74 | 61 | 16 | 23 | Sandy clay loam |
| 54 | 1.61 | 2.37 | 40.29 | 61.71 | 32.07 | 0.680 | 70.14 | 25 | 57 | 18 | Silt loam |

Appendix III (Continued)

| Sl. No. | Bulk Density (Mg $m^{-3}$) | Particle Density (Mg $m^{-3}$) | MWHC (%) | Moisture Content (%) | Porosity (%) | MWD (%) | WSA (%) | Sand (%) | Silt (%) | Clay (%) | Textural class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kadapra** | | | | | | | | | | | |
| 55 | 1.62 | 2.11 | 33.82 | 32.66 | 23.22 | 0.501 | 70.44 | 51 | 31 | 18 | Sandy loam |
| 56 | 1.62 | 2.21 | 42.9 | 47.64 | 26.70 | 0.301 | 44.44 | 24 | 58 | 18 | Silt loam |
| 57 | 1.55 | 2.27 | 24.17 | 23.28 | 31.72 | 0.425 | 70.26 | 58 | 14 | 28 | Sandy clay loam |
| 58 | 1.1 | 2.12 | 58.05 | 30.47 | 48.11 | 0.457 | 41.92 | 36 | 38 | 26 | Clay loam |
| 59 | 1.58 | 2.12 | 42.4 | 10.6 | 25.47 | 2.036 | 62.28 | 24 | 58 | 18 | Silt loam |
| 60 | 1.62 | 2.05 | 41.58 | 15 | 20.98 | 0.403 | 40.38 | 52 | 32 | 16 | Sandy loam |
| 61 | 1.38 | 1.99 | 49.25 | 34.79 | 30.65 | 0.544 | 39.98 | 24 | 57 | 19 | Silt loam |
| 62 | 0.95 | 1.79 | 56 | 10.66 | 46.93 | 0.196 | 25.94 | 38 | 33 | 29 | Clay loam |
| **Thiruvalla Municipality** | | | | | | | | | | | |
| 63 | 0.96 | 1.79 | 56 | 4.66 | 46.37 | 0.196 | 25.94 | 38 | 33 | 29 | Clay loam |
| 64 | 1.54 | 2.11 | 33.82 | 32.66 | 27.01 | 0.501 | 70.44 | 51 | 31 | 18 | Sandy loam |
| 65 | 1.64 | 2.05 | 41.58 | 15 | 20.00 | 0.403 | 4.38 | 51 | 31 | 18 | Sandy loam |
| 66 | 1.59 | 2.2 | 33.58 | 21.83 | 27.73 | 0.441 | 65.74 | 64 | 24 | 12 | Sandy clay loam |
| 67 | 1.62 | 2.62 | 38.82 | 36.66 | 38.17 | 0.602 | 72.42 | 24 | 58 | 18 | Silt loam |
| 68 | 1.18 | 1.95 | 50.78 | 5.31 | 39.49 | 0.879 | 42.12 | 36 | 38 | 26 | Clay loam |
| 69 | 1.62 | 2.32 | 40.42 | 38.44 | 30.17 | 0.632 | 74.64 | 24 | 58 | 18 | Silt loam |
| 70 | 1.12 | 1.83 | 47.33 | 5.95 | 38.80 | 1.044 | 49.26 | 38 | 33 | 29 | Clay loam |
| 71 | 1.64 | 2.13 | 53.31 | 62.13 | 23.00 | 0.341 | 65.74 | 58 | 15 | 27 | Sandy clay loam |
| 72 | 0.98 | 1.82 | 52 | 14.66 | 46.15 | 0.196 | 28.94 | 36 | 38 | 26 | Clay loam |
| 73 | 1.08 | 1.77 | 55.69 | 18.38 | 38.98 | 0.616 | 37.26 | 38 | 33 | 29 | Clay loam |
| 74 | 1.58 | 2.12 | 42.4 | 10.6 | 25.47 | 2.036 | 62.28 | 24 | 58 | 18 | Silt loam |
| 75 | 1.48 | 1.83 | 70.12 | 23.26 | 19.13 | 0.339 | 20.1 | 51 | 31 | 18 | Sandy loam |

## Results of chemical and biological parameters (for individual samples)

Appendix III (Continued)

| Sl. No. | pH | EC ($dSm^{-1}$) | OC % | N2 (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 $kg^{-1}$) | Zn (mg $kg^{-1}$) | Mn (mg $kg^{-1}$) | Cu (mg $kg^{-1}$) | B (mg $kg^{-1}$) | Acid phosphatase* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Nedumpuram** | | | | | | | | | | | | | | | |
| 1 | 4.41 | 1.38 | 2.46 | 301.06 | 14.99 | 80.64 | 342.9 | 11.43 | 0.219 | 57.24 | 4.944 | 10.73 | 2.36 | 1.376 | 0.5454 |
| 2 | 4.71 | 0.05 | 2.49 | 75.26 | 14.73 | 137.42 | 45.5 | 5.9 | 0.156 | 61.11 | 4.603 | 6.58 | 0.94 | 1.13 | 0.3636 |
| 3 | 4.82 | 0.28 | 3.33 | 163.07 | 11.99 | 62.72 | 90.7 | 9.72 | 0.85 | 131.2 | 12.56 | 22.36 | 5.49 | 1.212 | 0.02 |
| 4 | 5.03 | 0.14 | 1.74 | 225.79 | 259.63 | 366.8 | 149.9 | 9.89 | 0.163 | 122.4 | 6.184 | 6.89 | 0..01 | 1.334 | 15.9984 |
| 5 | 4.44 | 0.25 | 2.7 | 326.14 | 27.27 | 227.45 | 118.3 | 10.45 | 0.6 | 125.3 | 6.128 | 19.71 | 0.28 | 1.317 | 6.9084 |
| 6 | 4.65 | 0.15 | 2.34 | 100.35 | 105.54 | 48.38 | 62.17 | 9.13 | 0.275 | 167.3 | 6.033 | 6.94 | 0.1 | 1.237 | 15.453 |
| 7 | 5.61 | 0.32 | 3.9 | 188.16 | 181.63 | 177.41 | 535.6 | 11.36 | 0.388 | 358.2 | 13.69 | 21.61 | 0.41 | 1.39 | 13.2714 |
| 8 | 5.11 | 0.11 | 2.13 | 125.44 | 27.27 | 86.91 | 273.6 | 10.4 | 0.113 | 78.55 | 4.647 | 10.97 | 0.05 | 1.301 | 7.3629 |
| 9 | 5.42 | 0.07 | 1.44 | 100.35 | 20.45 | 26.1 | 415 | 11.36 | 0.181 | 104.6 | 5.066 | 12.26 | 0.11 | 1.203 | 7.272 |
| 10 | 6.07 | 0.08 | 1.65 | 250.88 | 117.27 | 100.24 | 476.4 | 11.13 | 0.231 | 92.95 | 12.42 | 11.87 | 0.99 | 1.291 | 4.0905 |
| 11 | 6.14 | 0.1 | 1.68 | 263.42 | 133.36 | 248.3 | 683.4 | 10.99 | 0.238 | 99.75 | 7.912 | 10.14 | 0.01 | 1.326 | 7.9992 |
| 12 | 6.62 | 0.12 | 2.43 | 112.91 | 66.54 | 155.68 | 558.2 | 10.95 | 0.4 | 111.7 | 15.48 | 23.89 | 0.23 | 1.229 | 8.0901 |
| 13 | 5.73 | 0.08 | 1.89 | 75.26 | 288.54 | 189.84 | 471.9 | 10.35 | 0.381 | 148.9 | 7.594 | 27.1 | 0.15 | 1.466 | 20.1798 |
| **Peringara** | | | | | | | | | | | | | | | |
| 14 | 4.93 | 1.13 | 3.9 | 225.79 | 16.09 | 57.34 | 114.7 | 10.55 | 3.181 | 136.3 | 7.555 | 14.32 | 0.19 | 1.381 | 0.2727 |
| 15 | 4.94 | 1.47 | 3.69 | 388.86 | 15.55 | 58.8 | 108.8 | 10.63 | 3.489 | 282.5 | 9.315 | 22.95 | 0.03 | 1.322 | 0.1818 |
| 16 | 4.51 | 1.96 | 3.87 | 175.62 | 12.27 | 66.53 | 86.02 | 10.5 | 5.457 | 252 | 9.648 | 22.5 | 0.02 | 1.306 | 0.2727 |
| 17 | 6.08 | 0.07 | 1.56 | 150.53 | 235.63 | 71.01 | 286.6 | 9.53 | 0.156 | 57.04 | 5.211 | 14.53 | 0.39 | 1.389 | 13.2714 |
| 18 | 4.11 | 1.99 | 2.16 | 451.58 | 8.18 | 217.17 | 135.8 | 10.89 | 8.769 | 223.3 | 9.014 | 29.99 | 0.13 | 1.45 | 0.1818 |
| 19 | 4.39 | 1.4 | 4.17 | 200.7 | 9.27 | 175.62 | 87.62 | 10.59 | 3.975 | 199.4 | 7.186 | 23.61 | 0.13 | 1.377 | 0.0909 |
| 20 | 4.36 | 1 | 4.11 | 351.23 | 6.27 | 101.92 | 174.2 | 11.2 | 9.1 | 348.2 | 9.892 | 37.3 | 0.06 | 1.402 | 0.03 |
| 21 | 4.47 | 0.87 | 3.54 | 112.91 | 5.99 | 188.72 | 152.4 | 11.4 | 7.131 | 194.4 | 6.652 | 29.54 | 0.17 | 1.291 | 0.02 |
| 22 | 4.48 | 1 | 3.51 | 100.35 | 3.55 | 152.88 | 157.6 | 12.37 | 4.888 | 131.4 | 6.241 | 28.99 | 0.18 | 1.376 | 0.04 |
| 23 | 4.66 | 1.2 | 3.54 | 87.81 | 4.91 | 226.02 | 165 | 12.21 | 7.738 | 281.5 | 8.514 | 30.61 | 0.2 | 1.363 | 0.03 |
| 24 | 4.02 | 1.1 | 3.21 | 363.78 | 7.09 | 171.81 | 149.2 | 11.17 | 8.95 | 289.5 | 9.314 | 34.43 | 0.18 | 1.273 | 0.0909 |
| 25 | 5.7 | 0.04 | 0.75 | 175.62 | 192.54 | 47.49 | 79.12 | 9.21 | 0.15 | 116.4 | 4.807 | 1.62 | 0.55 | 1.054 | 11.0898 |

(*Acid phosphatase (µg PNP g $soil^{-1}h^{-1}$))

| Sl. No. | pH | EC ($dSm^{-1}$) | OC % | N2 (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 $kg^{-1}$) | Zn (mg $kg^{-1}$) | Mn (mg $kg^{-1}$) | Cu (mg $kg^{-1}$) | B (mg $kg^{-1}$) | Acid phosphatase* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kuttoor** | | | | | | | | | | | | | | | |
| 26 | 6.01 | 0.1 | 1.56 | 288.51 | 110.18 | 173.82 | 369.3 | 10.9 | 0.256 | 26.07 | 7.732 | 14.41 | 0.28 | 1.606 | 3.2724 |
| 27 | 5.15 | 0.07 | 1.44 | 125.44 | 63.27 | 45.02 | 114.2 | 10.11 | 0.275 | 12.78 | 6.145 | 11.49 | 0.44 | 1.296 | 4.2723 |
| 28 | 6.17 | 0.04 | 1.8 | 275.97 | 80.73 | 66.3 | 427.7 | 11.86 | 0.088 | 195.9 | 8.455 | 11.03 | 0.21 | 1.352 | 1.6362 |
| 29 | 6.32 | 0.09 | 2.46 | 288.51 | 19.09 | 60.14 | 537.4 | 12.25 | 0.319 | 27.01 | 8.102 | 21.21 | 0.22 | 1.329 | 8.6355 |
| 30 | 5.84 | 0.07 | 2.1 | 263.42 | 37.91 | 194.54 | 312.5 | 11.79 | 0.138 | 52.39 | 6.048 | 13.58 | 0.34 | 1.352 | 3.1815 |
| 31 | 6.52 | 0.12 | 2.58 | 288.51 | 14.73 | 54.66 | 678.4 | 11.97 | 0.269 | 16.13 | 5.997 | 15.33 | 0.31 | 1.64 | 2.3634 |
| 32 | 6.24 | 0.04 | 2.52 | 301.06 | 78.54 | 113.23 | 564.8 | 11.53 | 0.119 | 39.11 | 7.034 | 21.77 | 0.24 | 1.416 | 3.4542 |
| 33 | 6.46 | 0.22 | 2.43 | 288.51 | 118.91 | 165.76 | 573.7 | 11.79 | 0.388 | 29.29 | 6.23 | 20.37 | 0.39 | 1.632 | 17.1801 |
| 34 | 4.35 | 1.58 | 2.01 | 388.86 | 6.55 | 258.38 | 82.97 | 10.07 | 7.413 | 248.3 | 15.46 | 23.46 | 0.23 | 1.43 | 0.8181 |
| 35 | 4.08 | 1 | 3.96 | 338.69 | 227.18 | 181.44 | 172.9 | 11.7 | 11.288 | 336.1 | 8.909 | 29.1 | 0.17 | 1.195 | 12.3624 |
| 36 | 4.86 | 1.33 | 3.48 | 326.14 | 7.91 | 53.09 | 94.85 | 12.01 | 5.425 | 25.41 | 8.816 | 16.8 | 0.15 | 1.47 | 0.6363 |
| 37 | 4.71 | 1.03 | 1.8 | 225.79 | 101.45 | 45.58 | 84.16 | 15.35 | 0.186 | 84.85 | 5.329 | 1.506 | 0.44 | 1.308 | 9.2718 |
| **Niranam** | | | | | | | | | | | | | | | |
| 38 | 6.02 | 0.24 | 3.66 | 313.6 | 53.73 | 191.52 | 724 | 11.94 | 0.606 | 168.6 | 9.737 | 29.52 | 0.12 | 1.486 | 1.1817 |
| 39 | 5.81 | 0.2 | 1.53 | 263.42 | 201.81 | 161.84 | 465.3 | 11.81 | 0.413 | 206.1 | 8.212 | 26.43 | 0.16 | 1.564 | 9.9081 |
| 40 | 6.93 | 0.14 | 3.84 | 200.7 | 78.27 | 178.08 | 701.5 | 17 | 0.169 | 41.04 | 7.569 | 11.78 | 0.06 | 1.504 | 8.5446 |
| 41 | 6.73 | 0.14 | 3.42 | 250.88 | 247.9 | 292.32 | 742.3 | 12.27 | 0.356 | 27.16 | 11.24 | 23.67 | 0.35 | 1.273 | 18.7254 |
| 42 | 6.18 | 0.06 | 1.74 | 225.79 | 251.18 | 241.02 | 302.9 | 10.79 | 0.344 | 42.08 | 5.875 | 6.75 | 0.33 | 1.418 | 19.1799 |
| 43 | 5.79 | 0.42 | 3.09 | 313.6 | 144.54 | 181.44 | 514.2 | 11.84 | 0.281 | 111 | 8.31 | 14.76 | 0.12 | 1.586 | 11.2716 |
| 44 | 5 | 0.28 | 1.62 | 163.07 | 142.09 | 100.91 | 154.1 | 17.96 | 0.538 | 112.5 | 4.449 | 20.36 | 0.18 | 1.494 | 10.1808 |
| **Kadapra** | | | | | | | | | | | | | | | |
| 45 | 4.55 | 1.1 | 2.01 | 175.62 | 55.91 | 34.72 | 177.3 | 18.34 | 0.25 | 43.76 | 1.902 | 12.33 | 0.08 | 1.314 | 2.9088 |
| 46 | 4.5 | 0.84 | 1.62 | 112.9 | 5.73 | 184.46 | 18.75 | 15.99 | 8.613 | 122.1 | 3.164 | 19.43 | 0.24 | 1.298 | 0.05 |
| 47 | 4.81 | 0.28 | 1.83 | 150.88 | 7.91 | 118.38 | 10.11 | 19.88 | 3.875 | 125.4 | 7.242 | 32.53 | 0.24 | 1.424 | 0.0909 |
| 48 | 5.4 | 0.27 | 3.72 | 175.62 | 5.73 | 131.94 | 7.375 | 15.71 | 13.175 | 140.3 | 4.083 | 29.61 | 0.1 | 1.423 | 0.08 |
| 49 | 5.13 | 0.18 | 3.39 | 213.25 | 32.99 | 154.45 | 211.2 | 18.84 | 0.644 | 121.5 | 7.223 | 10.48 | 0.06 | 1.587 | 2.1816 |
| 50 | 5.03 | 0.11 | 1.41 | 250.88 | 144.81 | 53.76 | 127.5 | 11.77 | 0.263 | 134 | 7.061 | 3.67 | 0.27 | 1.523 | 11.5443 |
| 51 | 5 | 0.1 | 1.35 | 275.97 | 102.82 | 38.42 | 72.55 | 10.41 | 0.206 | 176.4 | 4.817 | 3.48 | 0.3 | 1.366 | 9.9081 |
| 52 | 6.09 | 0.08 | 1.44 | 225.79 | 254.45 | 79.63 | 265.4 | 10.07 | 0.225 | 51.07 | 5.121 | 22.82 | 0.54 | 1.357 | 19.7253 |
| 53 | 5.31 | 0.05 | 1.65 | 225.79 | 327.81 | 201.38 | 68.71 | 9.43 | 0.469 | 105.1 | 5.131 | 8.02 | 0.49 | 1.557 | 25.9974 |
| 54 | 6.23 | 0.08 | 1.95 | 213.25 | 215.45 | 48.61 | 316.8 | 10.05 | 0.275 | 24.6 | 6.047 | 10.74 | 0.38 | 1.238 | 18.5436 |

(*Acid phosphatase (µg PNP g $soil^{-1}h^{-1}$))

Appendix III (Continued)

| Sl. No. | pH | EC ($dSm^{-1}$) | OC % | N2 (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 $kg^{-1}$) | Zn (mg $kg^{-1}$) | Mn (mg $kg^{-1}$) | Cu (mg $kg^{-1}$) | B (mg $kg^{-1}$) | Acid phosphatase* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kadapra** | | | | | | | | | | | | | | | |
| 55 | 6.13 | 0.05 | 1.8 | 200.7 | 205.36 | 60.37 | 275.3 | 10.09 | 0.231 | 22.69 | 6.374 | 15.43 | 0.43 | 1.425 | 16.9074 |
| 56 | 6.41 | 0.09 | 2.07 | 238.34 | 142.36 | 51.74 | 377.5 | 10.89 | 0.263 | 13.11 | 4.95 | 17.16 | 0.52 | 1.437 | 9.6354 |
| 57 | 5.44 | 0.05 | 1.77 | 188.16 | 168.54 | 32.48 | 70.94 | 9.37 | 0.175 | 69.42 | 5.055 | 17.01 | 0.54 | 1.539 | 9.8172 |
| 58 | 6.11 | 0.1 | 4.02 | 225.79 | 19.09 | 64.96 | 21.21 | 16.18 | 3.769 | 158.4 | 4.71 | 8.559 | 0.02 | 1.376 | 7.272 |
| 59 | 5.8 | 0.16 | 1.32 | 288.51 | 33.27 | 132.83 | 321.6 | 16.89 | 0.469 | 122.5 | 6.768 | 13.82 | 0.07 | 1.398 | 2.5452 |
| 60 | 6.14 | 0.12 | 1.38 | 263.42 | 94.08 | 47.38 | 10.79 | 11.78 | 0.213 | 0.8177 | 0.6161 | 4.856 | 0.63 | 1.31 | 7.9083 |
| 61 | 5.24 | 0.09 | 3.6 | 200.7 | 20.18 | 58.46 | 14.46 | 15.98 | 4.231 | 110.1 | 3.889 | 18.34 | 0.3 | 1.285 | 1.9998 |
| 62 | 5.12 | 0.18 | 4.53 | 213.25 | 7.36 | 110.32 | 42.83 | 16.22 | 11.3 | 157 | 5.303 | 33.29 | 0.01 | 1.276 | 0.909 |
| **Thiruvalla Municipality** | | | | | | | | | | | | | | | |
| 63 | **4.91** | **0.26** | **4.35** | **213.25** | **7.36** | **186.5** | **65.67** | **17.41** | **7.119** | **131.8** | **4.727** | **21.29** | **0.39** | **1.231** | **0.909** |
| 64 | 5.14 | 0.32 | 1.77 | 225.79 | 10.09 | 158.93 | 79.64 | 17.47 | 0.913 | 103.1 | 6.14 | 21.13 | 0.04 | 1.408 | 3.636 |
| 65 | 4.98 | 0.41 | 1.38 | 163.07 | 8.45 | 133.39 | 35.68 | 16.48 | 7.544 | 168.5 | 5.138 | 23.77 | 0.25 | 1.408 | 3.636 |
| 66 | 5.01 | 0.11 | 3.09 | 163.07 | 4.63 | 180.43 | 0.998 | 16.22 | 5.969 | 77.38 | 2.004 | 22.89 | 0.2 | 1.44 | 0.05 |
| 67 | 5.1 | 0.16 | 1.26 | 200.7 | 200.45 | 229.04 | 374.2 | 17 | 0.306 | 88.12 | 2.627 | 11.63 | 0.14 | 1.67 | 14.1804 |
| 68 | 5.34 | 0.07 | 3.15 | 188.16 | 5.18 | 195.44 | 42.68 | 17.73 | 7.138 | 99.95 | 2.127 | 22.77 | 0.31 | 1.474 | 0.06 |
| 69 | 5.68 | 0.28 | 0.93 | 263.42 | 9.27 | 62.61 | 146.1 | 15.25 | 0.244 | 1.628 | 2.53 | 8.559 | 0.48 | 1.644 | 0.909 |
| 70 | 4.92 | 0.18 | 3.66 | 213.25 | 8.73 | 197.79 | 23.67 | 16.19 | 9.788 | 133.5 | 7.634 | 27.49 | 0.32 | 1.482 | 0.909 |
| 71 | 5.21 | 0.23 | 1.17 | 188.16 | 57.54 | 61.94 | 304.8 | 18.55 | 0.406 | 43.58 | 4.331 | 8.004 | 0.13 | 1.281 | 3.2724 |
| 72 | 6.16 | 0.15 | 4.14 | 288.51 | 5.99 | 52.98 | 43.61 | 15.18 | 5.206 | 130 | 4.38 | 19.04 | 0.24 | 1.339 | 0.04 |
| 73 | 5.01 | 0.14 | 3.78 | 225.79 | 4.09 | 248.98 | 29.39 | 17.99 | 7.656 | 85.31 | 3.465 | 23.37 | 0.18 | 1.423 | 0.5 |
| 74 | 4.37 | 0.86 | 1.5 | 112.9 | 223.36 | 100.58 | 448.1 | 18.4 | 0.331 | 1.402 | 4.704 | 19.91 | 0.41 | 1.426 | 15.8166 |
| 75 | 6.11 | 0.13 | 1.47 | 263.42 | 208.36 | 175.39 | 1.14 | 13.51 | 0.238 | 1.106 | 0.4434 | 5.547 | 0.63 | 1.423 | 10.1808 |

(*Acid phosphatase (µg PNP g $soil^{-1}h^{-1}$))

## SQI and LQI (for individual samples)

Appendix III (Continued)

| Sl. No. | SQI | RSQI | Class | Soil organic carbon stock (Mg ha$^{-1}$) | LQI (kg m$^{-2}$) | Class |
|---|---|---|---|---|---|---|
| **Nedumpuram** | | | | | | |
| 1 | 242 | 60.5 | Medium | 57.56 | 5.76 | low |
| 2 | 248 | 62 | Medium | 42.95 | 4.30 | low |
| 3 | 242 | 60.5 | Medium | 55.94 | 5.59 | low |
| 4 | 280 | 70 | Medium | 37.58 | 3.76 | low |
| 5 | 266 | 66.5 | Medium | 54.27 | 5.43 | low |
| 6 | 254 | 63.5 | Medium | 38.96 | 3.90 | low |
| 7 | 273 | 68.25 | Medium | 64.35 | 6.44 | moderate |
| 8 | 262 | 65.5 | Medium | 44.09 | 4.41 | low |
| 9 | 256 | 64 | Medium | 34.78 | 3.48 | low |
| 10 | 280 | 70 | Medium | 29.21 | 2.92 | very low |
| 11 | 292 | 73 | High | 33.26 | 3.33 | low |
| 12 | 299 | 74.75 | High | 32.44 | 3.24 | low |
| 13 | 281 | 70.25 | High | 42.53 | 4.25 | low |
| **Peringara** | | | | | | |
| 14 | 256 | 64 | Medium | 77.81 | 7.78 | moderate |
| 15 | 256 | 64 | Medium | 67.53 | 6.75 | moderate |
| 16 | 242 | 60.5 | Medium | 71.40 | 7.14 | moderate |
| 17 | 280 | 70 | Medium | 26.21 | 2.62 | very low |
| 18 | 248 | 62 | Medium | 31.75 | 3.18 | low |
| 19 | 242 | 60.5 | Medium | 80.06 | 8.01 | moderate |
| 20 | 236 | 59 | Medium | 70.90 | 7.09 | moderate |
| 21 | 242 | 60.5 | Medium | 76.46 | 7.65 | moderate |
| 22 | 242 | 60.5 | Medium | 64.76 | 6.48 | moderate |
| 23 | 248 | 62 | Medium | 83.90 | 8.39 | moderate |
| 24 | 242 | 60.5 | Medium | 67.41 | 6.74 | moderate |
| 25 | 241 | 60.25 | Medium | 18.23 | 1.82 | very low |
| **Kuttoor** | | | | | | |
| 26 | 294 | 73.5 | High | 33.70 | 3.37 | low |
| 27 | 249 | 62.25 | Medium | 33.48 | 3.35 | low |
| 28 | 280 | 70 | Medium | 37.26 | 3.73 | low |
| 29 | 274 | 68.5 | Medium | 59.78 | 5.98 | low |
| 30 | 281 | 70.25 | High | 45.05 | 4.50 | low |
| 31 | 268 | 67 | Medium | 49.92 | 4.99 | low |
| 32 | 294 | 73.5 | High | 52.16 | 5.22 | low |
| 33 | 286 | 71.5 | High | 42.28 | 4.23 | low |
| 34 | 248 | 62 | Medium | 39.50 | 3.95 | low |
| 35 | 260 | 65 | Medium | 80.19 | 8.02 | moderate |
| 36 | 236 | 59 | Medium | 73.08 | 7.31 | moderate |
| 37 | 228 | 57 | Medium | 37.26 | 3.73 | low |

Appendix III (Continued)

| Sl. No. | SQI | RSQI | Class | Soil organic carbon stock (Mg $ha^{-1}$) | LQI (kg $m^{-2}$) | Class |
|---|---|---|---|---|---|---|
| **Niranam** | | | | | | |
| 38 | 294 | 73.5 | High | 65.88 | 6.59 | moderate |
| 39 | 281 | 70.25 | High | 32.36 | 3.24 | low |
| 40 | 315 | 78.75 | High | 78.91 | 7.89 | moderate |
| 41 | 327 | 81.75 | High | 79.52 | 7.95 | moderate |
| 42 | 308 | 77 | High | 37.58 | 3.76 | low |
| 43 | 273 | 68.25 | Medium | 52.84 | 5.28 | low |
| 44 | 254 | 63.5 | Medium | 28.67 | 2.87 | very low |
| 45 | 262 | 65.5 | Medium | 47.94 | 4.79 | low |
| 46 | 242 | 60.5 | Medium | 31.59 | 3.16 | low |
| 47 | 236 | 59 | Medium | 38.43 | 3.84 | low |
| 48 | 250 | 62.5 | Medium | 67.52 | 6.75 | moderate |
| 49 | 268 | 67 | Medium | 56.44 | 5.64 | low |
| **Kadapra** | | | | | | |
| 50 | 241 | 60.25 | Medium | 35.96 | 3.60 | low |
| 51 | 241 | 60.25 | Medium | 33.21 | 3.32 | low |
| 52 | 288 | 72 | High | 34.99 | 3.50 | low |
| 53 | 274 | 68.5 | Medium | 41.09 | 4.11 | low |
| 54 | 296 | 74 | High | 50.02 | 5.00 | low |
| 55 | 296 | 74 | High | 46.44 | 4.64 | low |
| 56 | 267 | 66.75 | Medium | 50.30 | 5.03 | low |
| 57 | 283 | 70.75 | High | 46.46 | 4.65 | low |
| 58 | 274 | 68.5 | Medium | 66.33 | 6.63 | moderate |
| 59 | 281 | 70.25 | High | 31.28 | 3.13 | low |
| 60 | 228 | 57 | Medium | 33.53 | 3.35 | low |
| 61 | 248 | 62 | Medium | 74.52 | 7.45 | moderate |
| 62 | 236 | 59 | Medium | 64.55 | 6.46 | moderate |
| **Thiruvalla Municipality** | | | | | | |
| 63 | 242 | 60.5 | Medium | 62.64 | 6.26 | moderate |
| 64 | 264 | 66 | Medium | 46.20 | 4.62 | low |
| 65 | 242 | 60.5 | Medium | 33.95 | 3.39 | low |
| 66 | 250 | 62.5 | Medium | 78.33 | 7.83 | moderate |
| 67 | 282 | 70.5 | High | 34.40 | 3.44 | low |
| 68 | 242 | 60.5 | Medium | 55.76 | 5.58 | moderate |
| 69 | 226 | 56.5 | Medium | 26.78 | 2.68 | very low |
| 70 | 242 | 60.5 | Medium | 61.49 | 6.15 | moderate |
| 71 | 262 | 65.5 | Medium | 29.48 | 2.95 | very low |
| 72 | 262 | 65.5 | Medium | 60.86 | 6.09 | moderate |
| 73 | 248 | 62 | Medium | 61.24 | 6.12 | moderate |
| 74 | 223 | 55.75 | Medium | 35.55 | 3.56 | low |
| 75 | 247 | 61.75 | Medium | 32.63 | 3.26 | low |

## Appendix IV

**Pre and Post flood status of soil reaction and nutrients in AEU 4 in Pathanamthitta**

| Parameters | Fertility class | Per cent samples | |
|---|---|---|---|
| | | Pre flood (KSPB, 2013) | Post flood |
| pH | Extremely acidic | 20 | 5 |
| | Very strongly acidic | 22 | 28 |
| | Strongly acidic | 15 | 17 |
| | Moderately acidic | 17 | 17 |
| | Slightly acidic | 12 | 19 |
| | Neutral | 14 | 4 |
| OC (%) | Low | 22 | 0 |
| | Medium | 35 | 20 |
| | High | 43 | 80 |
| Available P (kg $ha^{-1}$) | Low | 10 | 29 |
| | Medium | 11 | 15 |
| | High | 79 | 56 |
| Available K (kg $ha^{-1}$) | Low | 16 | 48 |
| | Medium | 42 | 49 |
| | High | 42 | 3 |
| Available Ca (ppm) | Deficient | 75 | 65 |
| | Sufficient | 25 | 35 |
| Available Mg (ppm) | Deficient | 80 | 100 |
| | Sufficient | 20 | 0 |
| Available S (ppm) | Deficient | 34 | 75 |
| | Adequate | 66 | 25 |
| Available Zn (ppm) | Deficient | 15 | 3 |
| | Sufficient | 85 | 97 |
| Available Cu (ppm) | Deficient | 11 | 97 |
| | Sufficient | 89 | 3 |
| Available B (ppm) | Deficient | 35 | 0 |
| | Sufficient | 65 | 100 |