ASSESSMENT OF SOIL QUALITY IN THE POST-FLOOD SCENARIO OF AEU 3 IN ALAPPUZHA DISTRICT OF KERALA AND GENERATION OF GIS MAPS

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by

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DECLARATION

I, hereby declare that this thesis entitled **"ASSESSMENT OF SOIL QUALITY IN THE POST-FLOOD SCENARIO OF AEU 3 IN ALAPPUZHA 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 3 IN ALAPPUZHA DISTRICT OF KERALA AND GENERATION OF GIS MAPS"** is a record of research work done independently by **Ms. Mariya Denny (2018-11-150)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Mariya Denny

Dedicated to,

The Lord Almighty

&

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LIST OF ABBREVIATIONS

%	Per cent
°C	Degree Celcius
µg	Micro gram
AEU	Agro-ecological unit
Avail.	Available
AP	Acid phosphatase
B	Boron
BD	Bulk density
Ca	Calcium
CEC	Cation exchange capacity
Cd	Cadmium
cm	Centimeter
Cr	Chromium
Cu	Copper
DH	Dehydrogenase
d Sm^{-1}	Decisiemens per metre
et al.	and others
EC	Electrical conductivity
Fe	Iron
Fig.	Figure
GIS	Geographic Information System
GPS	Global Positioning System
ha	Hectare
ID	Identity
INM	Integrated nutrient management
K	Potassium
KAU	Kerala Agricultural University

kg	Kilogram
kg ha^{-1}	Kilogram per hectare
LQI	Land quality index
MDS	Minimum data set
Mg	Magnesium
Mg m^{-3}	Megagram per meter cube
Mg ha^{-1}	Megagram per hectare
mg kg^{-1}	Milligram per kilogram
mm	Millimeter
Mn	Manganese
MOP	Muriate of Potash
MWD	Mean weight diameter
N	Nitrogen
No.	Number
Ni	Nickel
OC	Organic carbon
P	Phosphorus
Pb	Lead
PCA	Principal component analysis
PD	Particle density
RH	Relative humidity
RSQI	Relative soil quality index
S	Sulphur
SD	Standard Deviation
SQI	Soil quality index
viz.	Namely
WHC	Water holding capacity
WSA	Water stable aggregates
Zn	Zinc

1. INTRODUCTION

Soil is the most precious natural resource on this planet which demands to be constantly unbroken beneath high productivity for sustenance on the planet. “Essentially, there is no life without soil and no soil without life, they have evolved together” (Kellog, 1938). Soil could be a non-renewable resource on human time scales, in terms of its vulnerability to degradation that relies on complex interactions between processes, factors and causes happening at a range of spatial and temporal scales (Lal, 2015). Land degradation and soil quality deterioration are prominent among the causes for agrarian stagnation coupled with perpetuation of hunger and malnutrition. Moreover, it raises a major threat to country’s environment and food security (Mandal and Sharma, 2001).

In a state like Kerala with high population density, land is definitely a scarce resource. Moreover, higher than 67 per cent of the total geographic area of the state is subjected to soil degradation due to various factors like erosion, landslides, water logging, acidification, pollution etc. This resulted in a higher rate of soil loss, compared to the national average. According to Mandal *et al.* (2009), water logging, salinity, alkalinity and formation of acid sulphate soils are the predominant reasons for land degradation and poor soil quality. Quality of soils also relies upon climate, landform and most importantly, people, because, it is their decisions and actions that ultimately determine the sustainability of an agricultural production system on a given soil (Arshad and Coen, 1992).

Kerala State is among those Indian states that receive very high rainfall during the monsoon season. In August 2018, the state received unprecedented rainfall causing much havoc to entire state, except Kasaragod district. The state received 2346.6 mm of rainfall till the end of August, against a normal value of 1649.5 mm. The devastating flood has greatly damaged the soil environment, in numerous aspects. Saturated conditions over an extended period might have brought several changes in soil, affecting the biological, chemical and physical soil health. Flooded soil might experience the “post-flood syndrome”, similar to the “fallow syndrome”, where the land is left unplanted to any crop for the entire season. Heavy rains and flood have left many farm fields in a need of physical repair. Flood water eroded the exposed soils, leaving deep gullies, drifted crop residues, building materials, as well as other types of debris. The flood resulted in landslides, water stagnation and deposition of sand/silt/clay in these areas in different dimensions, which needs urgent attention for restoring and sustaining soil productivity.

Soil fertility and productivity have been disturbed. Thus, site specific investigation on different soil fertility parameters is an immediate requirement. The floods have triggered alarming changes in soil quality, posing a threat to crop production in Kerala (Nandakumar, 2018). Plant nutrition has to be relooked into, and revised based on the altered soil fertility status. Specific management practices suitable to varied locations should be recommended. The productive potential of soil depends on its health. In this context, assessment of soil quality is the basic and urgent step which should be carried out for restoring soil productivity in the flood affected areas.

Soil quality has been defined as "the capacity of a specific kind of soil to function with its surroundings, sustain plant and animal productivity, maintain or enhance soil, water and air quality and support human health and habitation" (Karlen *et al.,* 1997). Being an ideal indicator of sustainable land management, soil quality assists the assessment of the overall soil condition, and its response to management, along with the resilience towards natural and anthropogenic forces (Doran and Parkin, 1994). Decline of soil quality is crucial in land degradation (Drechsel *et al.*, 2004). Soil quality is an assessment of the present functioning capacity of the soil and how well it will be preserved for future use. As soil quality cannot be measured directly, it must be inferred from measuring changes in attributes of the ecosystem, referred to as indicators.

Measurable soil attributes that influence the capacity of soil to perform crop production or environmental functions are referred as the soil quality indicators (Arshad and Martin, 2002). Identifying key soil attributes that are sensitive to soil functions allows the establishment of minimum data sets (MDS). Such data sets are composed of a minimum number of soil properties that will provide a practical assessment of one or several soil processes of importance for a specific soil function (Seybold *et al.,* 1997). Use of MDS reduces the need for determining a large number of indicators to assess soil quality (Rezaei *et al.*, 2006). Key attributes of soil quality include different physical, chemical and biological properties which interact in complex ways to determine its potential fitness or capacity to produce healthy and nutritious crops (Parr *et al.,* 1992).

Soil quality indicators based on a combination of soil properties could better reflect the status of soil quality degradation as compared to individual parameters. Soil quality index (SQI) can reflect the extend of degradation and suggest appropriate remedial measures such as optimal fertilizer rate and suitable land management practices considering potentials and constraints of different fields at large scale. Soil quality index combine various information effectively and hence is an effective tool for multi-objective decision making (Karlen and Stott, 1994).

Information on soil resources collected through soil survey could be utilized in a GIS environment to create various thematic maps such as soil texture, land capability, soil and land irrigability, soil fertility, soil productivity constraints, which can be used for specific management purposes. Satellite data combined with GIS could be effectively utilized to find out soil productivity potential, relate crop growth with soil productivity parameters and to identify the soil constraints.

The requirements of agricultural and environmental sustainability have dramatically redefined soil quality. The traditional view of soil quality, as measured by soil performance and productivity, is now considered inadequate for what it does not and cannot reveal. Accordingly, the emerging definition of soil quality extends beyond crop production, to issues of food safety, human and animal health and water quality.

The sandy plain region of Kerala comprises a unique agro-ecological unit designated as Onattukara sandy plain (AEU 3) extended over 43 panchayaths in Kollam and Alappuzha districts, covering an area of 67,447 ha. The soils of this region exhibit wide spatial variability in their properties. These soils are generally coarse textured with immature profiles and low nutrient and water retention capacity. In older days this region was considered as Onam-oottumkara but now it has become an area of low productivity, with many constraints limiting production (Premachandran, 1998). Onattukara soils is unique in its characteristics and classified as a special type of soil.

Deficiency of organic matter and majority of plant nutrients in the soil are clearly reflected in the poor yields of prevalent crops here, like rice, coconut, sesame, banana and vegetables. Excess levels of phosphorus and wide spread deficiencies of calcium, magnesium, boron and zinc are the major limitations to crop production in this region (Mini and Mathew, 2015). The ultimate purpose of assessing soil quality is to protect and improve long term agriculture productivity, water quality and habitats of all organisms including human. So the present study will help to evaluate soil quality, and in turn, help to enhance the environmental sustainability. Soil health test reports developed will allow for an overall assessment, as well as the identification of specific soil constraints and soil quality build up will help in the resilience of degraded soils.

The devastating flood in August 2018, heavily impacted the agricultural sector in the Onattukara area of Alappuzha district especially in Mavelikkara and Bharanikkavu block panchayaths. Farmers should be made well aware about the changes that had occurred in the soil due to the flood, and the strategies for the effective implementation of post-flood management activities in the agriculture sector. A detailed study on soil quality of post-flood soils of various AEUs, covering predominant cropping systems prevailing in those AEUs will help in formulating sustainable crop management strategies in these flood affected areas. Hence, the present study has been undertaken with the objectives:

- To assess the soil quality of post-flood soils of AEU 3 in Alappuzha district.
- To develop maps on soil characters and quality using GIS techniques.
- To workout soil quality index (SQI).

2. REVIEW OF LITERATURE

The survival and extinction for most land based life is distinguished by the thin layer of soil that forms the interface between the environment and agriculture (Doran and Parkin, 1994). Management of soil is regarded fundamental to all agricultural systems and is attributed to the wide spread degradation of soil in areas with intensive agriculture. Soil health or rather soil quality, including the physical and biological properties, is a factor closely linked to the soil fertility decline (Venugopal *et al*., 2018).

2.1. ONATTUKARA SANDY PLAIN

Onattukara sandy plain (AEU 3) is a distinct agro ecological unit of Kerala state, spread over 67,447 ha area, mainly in Alappuzha and Kollam districts. The name 'Onattukara' is derived from 'Onam-oottumkara', as it was an area of high productivity in the past. But later this region turned to be an area with much production constraints (Premachandran, 1998).

The coarse textured soils of this region are characterized by immature profile. Water and nutrient stress due to minimal storage of water in the root zone, and the increased leaching losses of the primary nutrients retards the growth and development of the crops raised in this region (Bhaskaran *et al.,* 2009).

Wide spatial variability is exhibited by the soil in its properties, in this region. Organic matter content and available plant nutrient status is generally very low. Deficiencies of nutrients like calcium, magnesium, boron and zinc and excess levels of phosphorus are prominent in this region, which limits the crop production (Mini and Mathew, 2015).

Most of the soils are reported to be moderately acidic to strongly acidic with low CEC due to the excess use of fertilizers per unit area (KSPB, 2013). Major land use of the low lands in the region is rice. Sesame, vegetables and pulses are cultivated during summer in these rice fields. Coconut and tuber crops are prominent in the uplands of Onattukara (KSHIS, 2020).

2.2. KERALA FLOOD, 2018

The state of Kerala is abundantly gifted throughout, with all sorts of natural resources and varied topography. ‘Gods own country’ is also a land of rains and rivers. The south west monsoon from end of May to early July and the north east monsoon from mid- October to mid- November are the prominent rainy seasons of the state. The south west monsoon of 2018 had a tragic impact on the state, as it resulted in a disastrous flood in 13 districts out of 14. The unprecedented steady rainfall from 8th to 18th of the August 2018 caused wide spread destruction in all the sectors of the state (GOK, 2018).

Kerala received 2346.6 mm rainfall during 1st June to 19th August, which was about 42% in excess of the normal rainfall. According to the rainfall records, the rainfall depth recorded during 15th to 17th August was comparable to the severe storm that occurred in the year 1924. The rainfall in Alappuzha district was 1784 mm against a normal of 1380.6 mm (CWC, 2018).

The devastating rains caused exorbitant losses to the agricultural sector affecting the small and marginal farmers. The net area cultivated in the year 2017 -18 was 2,048,109 ha. Over an area of 59,345.37 ha, the crop loss estimated was more than 33 per cent, in which 12095.55 ha area was in Alappuzha district alone (GOK, 2018).

The flood that had catastrophic effects on the lives and property of Kerala also triggered alarming changes in the quality of the soil, greatly threatening the crop production. The torrential rainfall causing flood, soil erosion and deposition of silt and sand have changed the soil environment. Hence, the implementation of site-specific, soil test based recommendations along with general recommendations is crucial (Nandakumar, 2018).

2.3. EFFECTS OF FLOODING ON SOIL

Flooding or submergence of air dry soil causes a series of physical, chemical and biological changes that deeply influence the quality of soil as a plant growth medium. The type and extent of changes rely on the properties of soil and the duration of submergence.

When a soil is flooded, the water occupies the pore space in between the soil particles and the gaseous exchange is limited to slow molecular diffusion. Moreover, the remaining oxygen in the soil gets consumed by the microorganisms within few hours of flooding. Poor aeration in soil leads to various plant and soil changes that are harmful to growth (Kozlowski *et al.*, 1991).

Alterations to soil structure such as, breakage of the aggregates, de-flocculation of clay and destruction of cementing agents happens. The decomposition rate of organic matter is reduced to half, since aerobic microbes are absent in the flooded soil. Flooding also reduces the soil redox potential, increases the pH of acidic soil (Fe^{3+} changes to Fe^{2+}) and decreases the pH of alkaline soil (the accumulated CO_2 converts to H_2CO_3).

Toxic compounds produced by the roots, such as ethanol, acetaldehyde, cyanogenic compounds are accumulated in the flooded soils. Anaerobic bacteria in soil produce compounds like, gases (N_2, CO_2, methane and H_2), hydrocarbons, alcohols, carbonyls, volatile fatty acids, non-volatile acids, phenolic acids and volatile sulphur compounds (Ponnamperuma, 1984).

2.4. SOIL QUALITY

The advancement of the concept of soil quality was in around 1990’s in regards to the worldwide increased significance on sustainable land use, rather than erosion control (Karlen *et al.*, 2003).

Larson and Pierce, (1991) emphasized the issues related to soil use, besides the productivity. They were among the first to explain soil quality, as the ability of soil to function within and interact positively outside the ecosystem boundaries. Soil conditions together with its response to management activities or to the stress created through both natural and anthropogenic actions can be recorded through soil quality, in a sensitive and dynamic way (Arshad and Coen, 1992).

Papendick and Parr (1992) stated that, when properly evaluated, soil quality can indicate the ability of soil to enhance human and animal life, to produce safe, nutrient rich food and to overcome the degradation processes. Karlen and Stott (1994) suggested that soil quality describes the actual ability of soil i) to accept, hold and release water and plant nutrients, ii) to promote and sustain plant growth, iii) to maintain suitable biotic habitat, iv) to respond to management and to resist degradation. The quality and health of soil determines the agricultural and environmental sustainability (Acton and Gregorich, 1995).

Karlen *et al.* (1997) defined soil quality as "the capacity of a specific kind of soil to function with its surroundings, sustain plant and animal productivity, maintain or enhance soil, water and air quality and support human health and habitation". Soil quality, along with its definition, criteria and assessment methods with respect to functions in soil is a continuously developing concept.

According to Nortcliff (2002), unlike air and water, soil reacts slowly to changes, and this can delay the identification of the changes in the soil quality leading to irreversible damage. Hence, the quality assessment of soil turns to be more complex, as it contains solid, liquid and gaseous components within and serves a large variety of functions in the ecosystem. Moreover, soil being an exhaustible resource, may be lost within short span of time with seldom chances of regeneration and getting back to its previous condition.

Soil quality distinguishes between the inherent and the dynamic properties of the soil. The inherent soil quality is influenced by the pedological (static) processes. Attributes of inherent quality of a soil such as minerology, particle size distribution show little changes or have short term effects of management activities. Dynamic soil quality considers the properties that show relative variation over short period of time and are responsive to the human management and agronomic practices (Carter, 2002).

Soil organic matter is both, inherent and dynamic property (Carter, 2002). According to Karlen *et al.* (2003) soil quality is more centered on the dynamic properties that is highly influenced by management activities and monitored in the surface horizon (0-25 cm). Schwilch *et al.*, 2016 suggested that, the distinction between inherent (static) and manageable (dynamic) attributes are however, not absolute, but dependent on the context.

The terms 'soil quality' and 'soil health' are often used interchangeably, though they are distinct from one another. Soil quality is related to the fitness of soil for use while soil health represents the ability of soil to act as a dynamic living system and maintain its function (Laishram *et al.*, 2012).

2.4.1. Soil quality assessment

Soil quality assessment can be classified mainly in to two types, i) comparative assessment and ii) dynamic assessment (Larson and Pierce, 1994).

Comparative assessment includes the identification of indicators using multivariate statistical analyses and interpretation of the correlation between them. These are mainly based on various land uses under the same soil group (Brejda *et al.*, 2000) or different land uses under different management strategies (Govaerts *et al.*, 2006).

Dynamic assessment involves the monitoring of the timely variations in the key indicators. This helps in inferring the trend in soil quality under the prevailing conditions, whether it is, inclining, declining or remains unchanged (Karlen *et al.*, 2008). Complexity in functional concept of soil quality does not allow its direct measurement in the field or laboratory, rather it can only be inferred from a range of identified soil characteristics or parameters (Mukherjee and Lal, 2014).

2.4.2. Soil quality indicators

Measurable soil attributes that influence the capacity of soil to perform crop production or environmental functions are referred as the soil quality indicators (Arshad and Martin, 2002). While defining soil quality indicators, a holistic rather than reductionist approach is proper.

Selected indicators should explain the ecological functions in soil, and the measurements taken reflects the conditions of field under the given management system (Doran and Parkin, 1997). The physical, chemical and biological properties of soil interact in a complex way to give soil its capacity to function (Seybold *et al.,* 1997).

According to Nortcliff (2002), selection of soil indicators has to be done based on the soil functions under consideration, and the threshold values assigned is in accordance with the prevailing local conditions, so that the outcome i.e. the soil quality index turns out to be meaningful.

Some of the features for a good indicator suggested by Burger and Kelting (1999) are; i) it should possess an available base line to compare the change, ii) it provide a sensitive and timely measure of a soils ability to function, iii) it is applicable over a large area but specifically sensitive, iv) it should be subjective to continuous assessment, v) it is inexpensive, easy to use, collect and calculate, vi) it should be able to distinguish between changes due to natural and due to management strategies, vii) it should be highly correlated to long term response, viii) it should be responsive to the remedial measures.

Bouma (2002) suggested that, as both environment and soil functions exhibit wide variations, there is hardly any scope for a universal set of indicators. Hence, it is difficult to have a general agreement on the standardized set of indicators for soil quality (Lima *et al.,* 2013).

According to Singer and Ewing (2000), the principal soil quality indicators at micro and macro farm scale are divided as physical, chemical and biological indicators.

Physical indicators includes, passage of air, structural stability, bulk density, clay minerology, soil strength, soil tilth, structural type, temperature, colour, consistence, depth of root limiting layer, hydraulic conductivity, oxygen diffusion rate, particle size distribution, penetration resistance, pore conductivity, pore size distribution, total porosity and water holding capacity.

Base saturation percent, cation exchange capacity, pH, electrical conductivity, exchangeable sodium percentage, nutrient cycling rates, plant nutrient availability, plant nutrient content, sodium absorption ratio, presence, concentration, availability and mobility of contaminants are the chemical indicators.

Biological indicators are organic carbon, biomass carbon or total organic carbon, microbial biomass carbon, total biomass, oxidizable carbon, soil respiration, potentially mineralizable nitrogen, enzyme activity viz. dehydrogenase, phosphatse, arylsulfatase, microbial community finger printing, substrate utilization, fatty acid analysis and nucleic acid analysis.

It is crucial to select the properties in accordance with the task from the given exceptionally large number of soil properties. According to the nature of function considered, the actual selection of indicators will vary (Nortcliff, 2002). Soil organic matter is widely considered as a salient attribute for assessing soil quality under different land use and management (Shukla *et al.,* 2006). The attributes that might be used as indicators of soil quality can be broadly grouped into:

i) Visual attributes/indicators: These can be analysed through observation or photographic interpretation and can give clear indication of threats to soil and also create awareness in public. The set back of such indicators is that they are often exposed long after the damage occurred. Exposure of subsoil, change in soil colour change, ephemeral gullies, ponding of water, runoff, plant response, weed species, blowing soil, depositions are some of them (USDA, 2006).

ii) Physical attributes/indicators: Primarily associated with the structure, aeration and hydrological status of the soil and includes soil texture, top soil depth, dry bulk density, porosity, aggregate strength and stability, soil crusting and compaction. Their assessment reflects the limitations to root growth, seedling emergence, infiltration or water movement within the profile and they also provide details about the soils ability to withstand physical action of rain water on soil aggregates, dispersion and erosion (USDA, 2006).

Physical properties such as bulk density and chemical characteristics including nutrient availability, acidity, electrical conductivity, and salinity can be considered important with regard to sustaining plant growth. Organic matter concentrations and mineralogy are critical to aggregate formation and stability. A soil aggregate is the basic component of soil structure (Karlen and Stott 1994).

A well aggregated soil maintains a structure that allows a variety of pore spaces (Lynch and Bragg, 1985). Organic matter addition enhances soil water holding capacity. Sullivan (1990) proposed that organic matter improve the air encapsulation within the soil during water uptake that reduce water uptake rates and prevents slaking and breakdown of aggregates. Perfect *et al.* (1990) found that antecedent water content immensely influenced the stability of aggregates and clay dispersibility.

iii) Chemical attributes/indicators: pH, aeration, salinity, organic matter content, cation exchange capacity, status of plant nutrients, nutrient cycling, concentration of potentially toxic elements, the buffering capacity of soil. The chemical conditions of soil influence the water quality, soil-plant relations, and certain physical conditions like dispersion and crusting (Nortcliff, 2002).

Effect of pH depends on soil type, for example organic matter input favourably may affect the pH of acidic soils (Bunemann *et al.*, 2018). Soil pH is a very relevant and easily measured, soil quality indicator. It controls nutrient availability of crops. If soil pH is too high, nutrients such as phosphorus, copper, manganese, iron and boron become unavailable to crops. If pH is too low, potassium, phosphorus, calcium, magnesium and molybdenum become unavailable.

Soil pH also influences certain pathogens to thrive, and beneficial organisms to effectively colonize roots. Microbial biomass and activity of soils is closely correlated to pH (Moebius-Clune *et al*., 2008).

iv) Biological attributes/indicators: It includes population of micro, meso and macro organisms, respiration rate or other indicators of microbial activity, and more detailed characterization of soil organic matter. These parameters are highly sensitive to changes in soil conditions and hence preferred for short term evaluations (Nortcliff, 2002).

Soil organisms are an integral part of soil functioning. Barrios (2007) suggested that including biological and biochemical indicators can highly improve the soil quality assessments. Biological indicators are important link between the abiotic components of soil and the changes in soil functions due to biochemical and biophysical transformations.

Microbial biomass content is a meaningful indicator of the microbial significance in soil since it is one of the few fractions of soil organic matter that is sensitive to management or pollution (Powlson, 1994).

Even though indicators and indices of various types are widely popular for soil quality and soil health, a globally acceptable and applicable norms or methodology is not yet proposed (Laishram *et al.*, 2012).

2.4.3. Soil quality index

It is generally agreed that the soil quality holds mainly three broad areas within it i) plant and biological productivity ii) environmental quality and iii) human and animal health. Any approach to assess soil quality must involve functions in regard to these issues (Parr *et al.,* 1992). In accordance with this, Doran and Parkin (1994), proposed a soil quality index consisting of six elements.

$$SQ = f\,(SQ_{E1}, SQ_{E2}, SQ_{E3}, SQ_{E4}, SQ_{E5}, SQ_{E6})$$

where, the soil quality elements are SQ_{E1} is food and fiber production, SQ_{E2} is erosivity, SQ_{E3} is ground water quality, SQ_{E4} is surface water quality, SQ_{E5} is air quality and SQ_{E6}

is food quality. The advantage of this method is that soil functions can be evaluated based on the specific performance criteria for each element.

$$SQ = (K_1SQ_{E1})\ (K_2SQ_{E2})\ (K_3SQ_{E3})\ (K_4SQ_{E4})\ (K_5SQ_{E5})\ (K_6SQ_{E6})$$

where, K is the weighting coefficients whose relative weight was determined by the geographical and societal concerns and economical constraints.

Andrews *et al.* (2002) suggested indexing soil quality through of three steps, i) selection of the relevant indicators to form a minimum data set (MDS), ii) scoring of the indicators on the basis of performance of soil functions, and iii) combine the scores of indicators to a comparative index of soil quality.

2.4.3.1. Minimum data set

Larson and Pierce, (1991) suggested that, the identification of the most critical attributes that are sensitive to the functions in soil allows the minimum data set establishment. Andrews *et al.* (2002) stated that not all, but, a few carefully selected indicators can provide the information adequate for the decision making. Indicator selection can be done based on expert opinion, purely statistical procedures or the combination of both to set up a minimum data set (MDS).

The earlier proposed minimum data sets were relied on the expert judgements (Doran and Parkin, 1994). Various statistical data reduction techniques like principal component analysis (PCA), redundancy analysis (RDA) (Andrews and Carroll, 2001; Schipper and Sparling, 2000; Lima *et al.,* 2013), factor analysis, discriminant analysis and multiple regression analysis (Shukla *et al.,* 2006) have become more common too.

Initially reduced data is further subjected to single or multiple correlation analysis (Andrews and Carroll, 2001), or refined on the expert judgement for picking one among the highly correlated parameters (Sparling and Schipper, 2002) to limit the number of indicators to usual range of six to eight. Properties that are highly critical for the soil functioning, but fail to exhibit variation in the given study will not be opted for the MDS. Setting up a MDS is an inevitable step in assessment of quality of a soil due to financial and time limitations and to avoid colinearity (Bunemann *et al.,* 2018).

In a study conducted by Khormali *et al.* (2009), attributes like soil organic matter (SOM), water stable aggregates (WSA), mean weight diameter (MWD), available phosphorus and calcium carbonate equivalent (CCE) explained most part of the total variance.

Joseph (2014) while studying the quality of pokkali soils under different land uses used a MDS of 13 attributes, *viz.* available water, pH, fine sand per cent, silt percent, aggregate stability, bulk density, available Mg, available S, microbial biomass carbon, available Mn, base saturation, organic carbon and EC.

2.4.3.2. Principal component analysis (PCA)

Principal components (PC) are defined as the linear combination of variables in a set of data that shows maximum variation in the set by describing closest fit to the *n* observations in *p* dimensional space, subject to being orthogonal to one another (Andrews *et al.,* 2002).

PCs with Eigen value ≥ 1 is studied, since it is considered that those with high values represent the system at its best (Brejda *et al.,* 2001). PCA forms an efficient tool to create a subset from a large data. Within the PC, each variable has got a factor loading or weight that refers to the contribution of that particular variable to the PC. Only the highly weighted variables (i.e. within 10 per cent of the highest factor loading) were retained in the PC.

When more than one variable is present in the PC, linear correlations among them are worked and if the variables are seen to be highly correlated, the one with highest sum of correlation coefficient (absolute values) is chosen for the MDS. Whereas, if the variables are not correlated (coefficient value < 0.60), each one of them is retained in the MDS (Andrews and Carroll, 2001).

2.4.3.3. Transformation (scoring) of the indicators

Andrews *et al.* (2002) in his study compared two techniques of scoring of the indicators *viz.* linear and non-linear scoring. In the case of linear scoring (Liebig *et al.,* 2001) , each observations were ranked in ascending or descending order, with respect to the type of soil function, for which a higher value is considered “good” or “bad”.

For ‘more is better’ indicators, each observation is divided by the highest value, so that the higher value gets a score of 1. In case of ‘lower is better’ indicators, the lowest value is divided by each observation such that the lowest value received the score 1. Moreover, for indicators such as pH, P and Zn, observations were scored as ‘higher is better’ up to a threshold value and the scored as ‘lower is better’ above the threshold.

Non-linear scoring functions were made use in the second technique. It is done by construction of curves. The shape of the curve i.e. bell shaped, sigmoid with an upper asymptote (more is better) or sigmoid with a lower asymptote (less is better), was determined according to agronomic and environmental soil functions using data from undisturbed fields (natural ecosystem), literature values, and knowledge of experts.

2.4.4. Soil quality index calculations

2.4.4.1. Simple additive method

The soil parameters are given threshold values based on the literature review and expert opinion of the authors. The total SQI is then obtained by summing up the individual index values (Amacher *et al.,* 2007).

$\sum$SQI = $\sum$ individual soil parameter index values

2.4.4.2. Weighted additive method

The selected parameters are first assigned unit less scoring from 0 to 1 through the linear scoring functions. After normalizing soil parameters, the scores were integrated into a single index value for each soil using a weighted additive approach (Karlen and Stott, 1994) which was later modified by Fernandes *et al.* (2011).

Mukherjee and Lal (2014) used the method in their study and they assigned weights of 0.4, 0.2 and 0.4 to soil functions root development capacity (RDC), water storage capacity (WSC) and nutrient supply capacity (NSC) respectively. The lower weightage was given to that function which had lower number of representative indicators. The parameters selected for RDC were bulk density, penetration resistance, water stable aggregates and geometric mean diameter. WSC was represented by available water capacity and NSC was indicated by pH, EC, carbon stock and nitrogen stock. Sub weight values were given to indicators based on their relevance, and the values added up to 1 under each functional property.

SQI = [(Weight 1)* RDC] + [(Weight 2)*WSC] + [(Weight 3)*NSC]

Singh *et al.* (2017) assigned an appropriate weight to the parameters in the MDS, based on existing soil conditions, cropping patterns, and agro-climatic conditions.

2.4.4.3. Statistical model

Mukherjee and Lal (2014) applied a statistics based model to estimate SQI in their work, using principal component analysis (PCA). Minimum data set was set up to reduce the load in the model. The observations were scored using the linear function. Each principal component explained certain amount of variation in the dataset which was divided by the maximum total variance of all PCs to get the certain weightage value (Andrews *et al.*, 2002). The weighted additive SQI was computed.

$$SQI = \sum \text{Weight} * \text{Individual soil parameter score}$$

Joseph (2014) conducted a study on the quality assessment of Pokkali soils under different land uses and highest soil quality was observed in the paddy alone land use system (4.53).

Correlation is a statistical tool, which helps to study the strong relationships between two quantitative variables. High correlation explains the strong relation between the studied parameters while a weak correlation reveals that they are hardly related (Franzese and Iuliano, 2019).

In a study conducted by Cerri and Magalhaes (2012), the correlation of physical and chemical attributes of soil with the yield of sugarcane was analysed. It was observed that the attributes like carbon and nitrogen had positive influence on the yield and attributes like pH, $CaCl_2$, phosphorus had negative correlation with the yield.

2.5. SOIL NUTRIENT INDEX

The method of nutrient indexing was introduced by Parker *et al.* (1951) and was later modified by several researchers. This index is used to evaluate the fertility status of soils based on the samples in each of the three classes, i.e., low, medium and high.

The knowledge of the distribution of the soil properties at the field scale is a prerequisite for screening the agricultural management practices and their effect on the environment (Cambardella and Karlen, 1999). The comparison of soil fertility status of two different areas is possible when status of a particular nutrient is represented as a single value. Nutrient index value is the measure of capacity of soils to supply nutrients to the plants (Singh *et al.,* 2016).

Ravikumar and Somashekar (2014) calculated the soil nutrient indices for low, medium and high ratings of soil nutrients for west coast of Karnataka and reported that the NPK status of Karnataka was L-L-H. Using the nutrient indices approach, Kumar *et al.* (2013) reported that the NPK status was L-M-M in Uttar Pradesh.

2.6. LAND QUALITY INDEX

Erosion, salinity, water logging, and acidification cause degradation of land resulting in the reduced quality of land in the area. Land quality monitoring is a necessity for proper land resources management. Soil organic carbon (SOC) stocks are regarded the most reliable indicator for monitoring land degradation, primarily by soil erosion (Rajan *et al*., 2010).

Soil organic carbon is a distinct land quality indicator, as single or coupled with other parameters, for assessing extend land degradation, and thereby the land quality. Dense rubber plantation with the practice of allowing the litter to remain and decompose in situ, had less erosion loss and was found to possess the highest SOC stocks and improved land quality. The lowest land quality was found where the organic carbon status was low due to high erosion, steep slope and light soil texture (Anilkumar *et al.*, 2015).

Apart from the change in micro climate induced by land use change, reduced organic matter addition, increased erosion and enhanced oxidation due to tillage are the three principal mechanisms accounting for SOC stocks depletion, in a given agro-climatic condition, irrespective of climate or land use (Anilkumar and Shalimadevi, 2009).

2.7. GEOGRAPHIC INFORMATION SYSTEM AND SOIL MAPPING

According to Aronoff (1989), GIS is any computer based procedure to capture and manipulate geographically referenced data (spatial data). Star and Estes (1990) suggested that GIS is both a database system as well as a working systems dealing with spatially referenced data. A data input system, a data storage and retrieval system, a data processing and analysing system, and a data reporting system are the four features of GIS.

GIS technologies have higher potential in the soil stream and has paved novel possibilities developing soil statistic system. It offers accelerated, repetitive, spatial and temporal synoptic view and can be used to understand the landscape dynamics in a cost effective and more accurate manner. GIS enables effective and efficient manipulation of spatial and non-spatial data for scientific mapping and characterization of soils for the benefit of local people (Star *et al*., 1997).

Mapping of the different soil properties is very important as it has crucial role in providing knowledge about those properties and to discuss the sustainable usage of the soil. GIS put forward greater scopes of enhanced soil surveys as it is a high potential tool with greater capability of handling voluminous data and in supporting spatial statistical analysis (Denton *et al.,* 2017).

Geographic information system offers intuitive ways to handle and analyze spatial information and harness new insights that are hidden in the complex data. Moreover when information is analyzed spatially, subtle spatial variations become manifested and further allow us to take appropriate actions to sustainably manage our resources (Venugopal *et al.,* 2018)

3. MATERIALS AND METHODS

The study entitled "Assessment of soil quality in the post-flood scenario of AEU 3 in Alappuzha district of Kerala and generation of GIS maps" was conducted to determine the important physical, chemical and biological attributes of the soils of the flood affected areas of the Onattukara sandy plain (AEU 3), computing the soil quality index and further, mapping them accordingly. The study was carried out at the College of Agriculture, Vellayani from May 2019 to March 2020 in four phases.

Part -1: Survey, collection and characterization of soil samples.

Part -2: Setting up of a Minimum Data Set for assessment of soil quality.

Part -3: Formulation of Soil Quality Index.

Part -4: Generation of maps using Geographic Information System.

The materials used and methods adopted for the execution of the research work is presented in this chapter.

3.1. SURVEY, COLLECTION AND CHARACTERISATION OF SOIL.

3.1.1. Details of the study area

Onattukara sandy plain, that extends from the coastal line to the midlands forms a special agro-ecological unit of Kerala. It covers an area of 67.447 ha (1.74%) in the state, within Alappuzha and Kollam districts. The soils of the region are sandy, deep, well drained, strongly acidic, low cation exchange capacity with shallow water table and single grain structure. The grey colour of the soils is the evidence of organic matter content in the soil.

The climate is tropical humid monsoon type with a mean annual temperature of 27.6 °C and an annual rainfall of 2492 mm. The probability of moderate drought during north east monsoon period is twice in ten years and that of two consecutive weeks receiving more than 20 mm rainfall is high from April to November. The soil moisture is adequate for crops from 2nd week of April to 2nd week of December. Length of growing period of annual crops is 37 weeks and dry period, around four months.

3.1.2. Weather parameters of the study area

The monthly mean of the weather parameters like maximum temperature, minimum temperature, relative humidity and rainfall of the study area during May 2018 to May 2019 is given in figure 1 (Appendix-I).

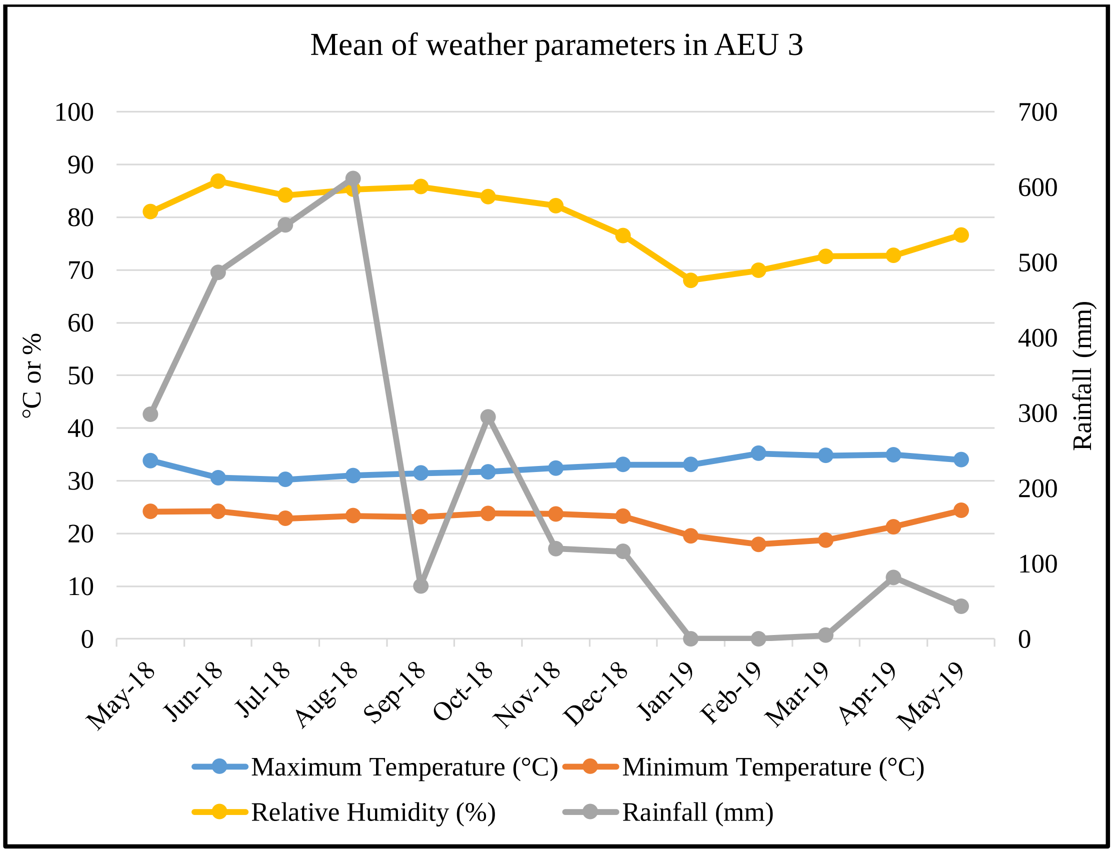


Fig.1. Monthly mean of weather parameters in AEU 3 (May 2018 to May 2019)

Table 1. Deviation in average monthly rainfall during 2018 from the average monthly rainfall over the last ten years

Month	Average rainfall (mm) (2008 – 2017)	Rainfall (mm) during 2018	Deviation in rainfall (mm)	Deviation in rainfall (%)	Average no. of rainy days (2008 – 2017)	No. of rainy days during 2018	Deviation in no. of rainy days
January	23.6	3.4	-20.2	- 85.6	0.7	1	+0.3
February	42.3	9.4	- 32.9	- 77.7	2	2	0
March	61.5	58.6	-2.86	- 4.65	3.6	5	+1.4
April	141.6	95.1	- 46.5	- 32.8	7.7	8	+0.3
May	240.2	298.3	+58.1	+ 24.2	10.5	18	+7.5
June	454.1	487	+32.9	+ 7.2	20.7	27	+6.3
July	380.1	549.6	+169.5	+ 44.5	20.3	22	+1.7
August	248.7	611.5	+362.8	+145.8	15.3	21	+5.7
September	246.2	70.4	-175.8	- 71.4	14.6	4	-10.6
October	275.4	295	+19.6	+ 7.11	11.5	13	+1.5
November	172.1	119.9	-52.2	- 30.3	10.2	11	+0.8
December	73.5	116	+ 42.5	+ 57.8	3.3	3	- 0.3
Total	2359.3	2714.2	+ 354.9	+ 150.4	120.4	135	+14.6

On comparison of the average rainfall of the previous ten years (2008 - 2017) with that of the year 2018, a positive deviation was observed during the May, June, July, August, October and December months (Table 1). 44.5 per cent and 57.8 per cent increase in average rainfall occurred in July and December respectively. On the other hand, the average rainfall of August 2018, the month of catastrophic flood in Kerala, was more than double (a positive deviation of 145.8 per cent) the average rainfall of previous ten years. Also, a positive deviation was observed in the number of rainy days in the months of January, March, April, May, June, July, August, October and November 2018 from that of the average number of rainy days of the previous ten years.

3.1.3. Survey

A Survey was conducted to identify the flood affected areas of AEU 3 in Alappuzha district and details including nutrient management practices of different crops were collected based on a pre-designed questionnaire (Appendix-II). The major flood affected areas in the AEU were seven panchayaths *viz.* Chunakkara, Nooranadu, Palamel, Chennithala, Chettikulangara, Pathiyoor and Veeyapuram of the Mavelikkara and Bharanikaavu block panchayaths. The detailed questionnaire and the outcome of the survey are given in the Appendix-II.

3.1.4. Collection of soil samples

Sampling locations were selected within the seven panchayaths *viz.* Chunakkara, Nooranadu, Palamel, Chennithala, Chettikulangara, Pathiyoor and Veeyapuram in such a way that it included the prominent land uses (rice, coconut, vegetables and banana) of the Onattukara region (Plate 1,2,3 and 4). During May 2019, composite soil samples were collected from each site. The samples were collected using V-shaped sampling method at the depth of 0-15 cm. In order to facilitate the study of certain physical properties, one core sample was also collected from each location. The core samples were stored undisturbed in polythene sample bags.

Ten samples were collected from each panchayath, which makes a total of 70 composite samples and 70 core samples were also collected from the entire AEU. The geographical co-ordinates of the sampling locations were recorded using the GPS. The details of the sampling sites and the corresponding land use are given in Table 2. Fig. 1 details the locations of the collected samples.

Table 2: The details of the sampling location and corresponding land use.

Sample No.	Location	No. of samples	Sample ID.	Latitude	Longitude	Land Use
1	Chunakkara	10	C1	9.179507 N	76.602995 E	Rice
2			C2	9.203568 N	76.608274 E	Rice
3			C3	9.187582 N	76.579424 E	Rice
4			C4	9.180467 N	76.586465 E	Coconut
5			C5	9.213206 N	76.591993 E	Rice
6			C6	9.204131 N	76.592620 E	Rice
7			C7	9.171844 N	76.592798 E	Rice
8			C8	9.185712 N	76.594559 E	Coconut
9			C9	9.196149 N	76.599072 E	Coconut
10			C10	9.190971 N	76.607494 E	Rice
11	Veeyapuram	10	V1	9.321661 N	76.475345 E	Rice
12			V2	9.314981 N	76.458542 E	Rice
13			V3	9.324563 N	76.457679 E	Rice
14			V4	9.302883 N	76.460303 E	Rice
15			V5	9.311715 N	76.464653 E	Rice
16			V6	9.323061 N	76.466143 E	Rice
17			V7	9.321661 N	76.475345 E	Rice
18			V8	9.317463 N	76.482740 E	Rice
19			V9	9.311015 N	76.488333 E	Rice
20			V10	9.324092 N	76.484252 E	Rice
21	Palamel	10	P1	9.175232 N	76.684048 E	Vegetables
22			P2	9.183317 N	76.654092 E	Banana
23			P3	9.196415 N	76.657601 E	Vegetables
24			P4	9.159330 N	76.665590 E	Banana
25			P5	9.160921 N	76.650109 E	Vegetables
26			P6	9.179551 N	76.643339 E	Vegetables
27			P7	9.172278 N	76.661630 E	Vegetables
28			P8	9.185881 N	76.667727 E	Vegetables
29			P9	9.169690 N	76.644426 E	Banana
30			P10	9.154730 N	76.636215 E	Banana
31			T1	9.246974 N	76.510280 E	Rice

32	Chettikulangara	10	T2	9.233410 N	76.510063 E	Banana
33			T3	9.223169 N	76.517412 E	Rice
34			T4	9.257593 N	76.515259 E	Banana
35			T5	9.247910 N	76.520497 E	Rice
36			T6	9.217149 N	76.526429 E	Banana
37			T7	9.205997 N	76.520461 E	Rice
38			T8	9.198149 N	76.527409 E	Banana
39			T9	9.220401 N	76.507597 E	Rice
40			T10	9.234760 N	76.521336 E	Banana
41	Nooranadu	10	N1	9.215236 N	76.625334 E	Vegetables
42			N2	9.190941 N	76.628700 E	Vegetables
43			N3	9.228176 N	76.632791 E	Vegetables
44			N4	9.220994 N	76.637938 E	Vegetables
45			N5	9.208674 N	76.636326 E	Banana
46			N6	9.178743 N	76.626965 E	Banana
47			N7	9.190972 N	76.619918 E	Banana
48			N8	9.182176 N	76.616162 E	Banana
49			N9	9.201660 N	76.626501 E	Vegetables
50			N10	9.196310 N	76.640240 E	Banana
51	Pathiyoor	10	A1	9.222969 N	76.476764 E	Coconut
52			A2	9.200884 N	76.505217 E	Vegetables
53			A3	9.198316 N	76.492282 E	Coconut
54			A4	9.197104 N	76.482472 E	Vegetables
55			A5	9.205702 N	76.481052 E	Vegetables
56			A6	9.206066 N	76.493122 E	Vegetables
57			A7	9.209338 N	76.507819 E	Coconut
58			A8	9.215681 N	76.482652 E	Coconut
59			A9	9.224198 N	76.491497 E	Vegetables
60			A10	9.214451 N	76.492893 E	Coconut
61	Chennithala	10	H1	9.288129 N	76.517228 E	Rice
62			H2	9.275649 N	76.539736 E	Vegetables
63			H3	9.298564 N	76.526087 E	Rice
64			H4	9.295680 N	76.511832 E	Rice
65			H5	9.299518 N	76.498958 E	Vegetables
66			H6	9.285598 N	76.529809 E	Banana
67			H7	9.275814 N	76.520009 E	Banana
68			H8	9.273976 N	76.506823 E	Banana

69			H9	9.265251 N	76.525959 E	Vegetables
70			H10	9.262455 N	76.538432 E	Vegetables

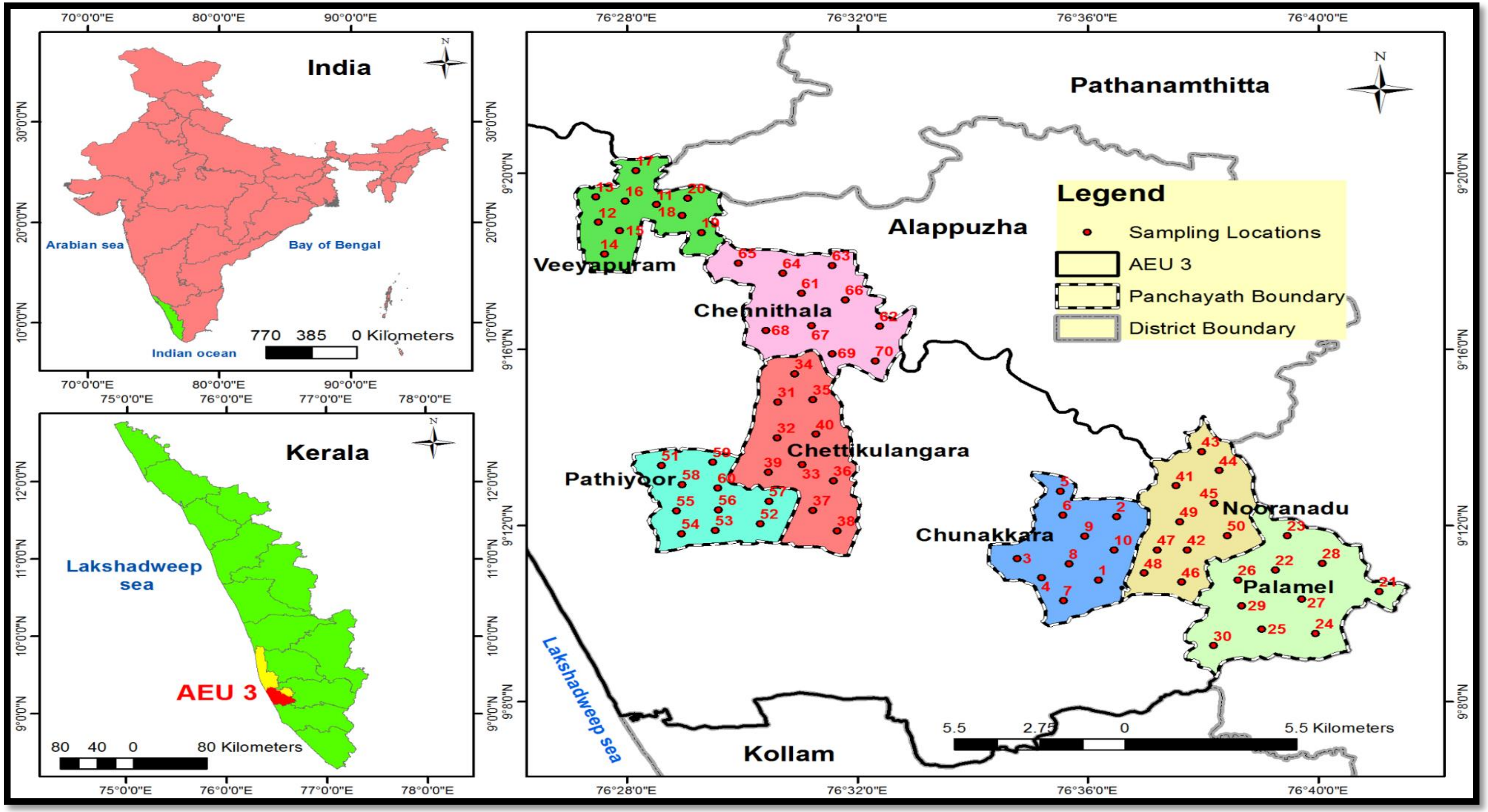


Fig.2. Sampling locations in the flood affected areas of AEU 3

Plate 1. Rice land use

Plate 2. Coconut land use

Plate 3. Vegetables land use

Plate 4. Banana land use

3.1.5. Characterisation of soil

The collected surface samples were brought to the laboratory, air dried, ground, passed through 2 mm sieve and stored. These were further subjected to the various physical, chemical and biological analyses.

Table 3. Analytical methods followed in physical, chemical and biological analysis of the soil.

Sl. No.	Parameter	Method	Reference
1.	Bulk density	Undisturbed core samples	Blake and Hartge (1986)
2.	Particle density	Pycnometer method	Vadyunina and Korchagina (1986)
3.	Porosity	Calculation using bulk density and particle density	Danielson and Sutherland (1986)
4.	Soil texture	Bouyoucos hydrometer method	Bouyoucos (1936)
5.	Aggregate analysis	Yoder's wet sieving method	Bavel (1949)
6.	Soil moisture	Gravimetric method	Gupta and Dakshinamurthy (1980)
7.	Water holding capacity	Core method	Gupta and Dakshinamurthy (1980)
8.	Soil pH	pH meter (1:2.5 soil water ratio)	Jackson (1973)
9.	Electrical conductivity	Conductivity meter (1:2.5 soil water ratio)	Jackson (1973)
10.	Organic carbon	Walkley and Black method	Walkley and Black (1934)
11.	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
12.	Available P	Bray No.1 extraction and estimation using spectrophotometer	Watanabe and Olsen (1965)
13.	Available K	Neutral normal ammonium acetate extraction and estimation using flame photometry	Jackson (1973)
14.	Available Ca and Mg	Neutral normal ammonium acetate extraction and estimation using atomic absorption spectrophotometer	Hesse (1971)
15.	Available S	$CaCl_2$ extraction and estimation using spectrophotometer	Massoumi and Cornfield (1963)
16.	Available Fe, Mn, Cu and Zn	0.1 N HCl extraction and estimation using atomic absorption spectrophotometer	Sims and Johnson (1991)

17.	Available B	Hot water extraction and estimation using spectrophotometer (Azomethane H method)	Gupta (1972)
18.	Available heavy metals (Pb, Cd, Ni, Cr)	0.1 N HCl extraction and estimation using atomic absorption spectrophotometer	Jackson (1973)
19.	Acid phosphatase activity	Colorimetric estimation of PNP released g^{-1} of soil h^{-1}	Eivazi and Tabatabai (1977)
20.	Dehydrogenase activity	Colorimetric estimation of TPF hydrolysed g^{-1} of soil 24^{-1} hrs	Casida (1977)

3.2. SETTING UP OF A MINIMUM DATA SET FOR ASSESSMENT OF SOIL QUALITY

Minimum data set (MDS) for the assessment of soil quality was set up after carrying out the Principal component analysis (Andrews and Carroll, 2001). Since it is based on the assumption that the principal components (PCs) receiving the higher values can best represent the system attributes, only the PCs with Eigen values greater than one was examined. The contribution of each variable to the PC is represented by the weight or factor loading it received. Only the highly weighted variables (within the 10% of the highest factor loading) from each PC were retained. When more than one variable was retained in the PC, their linear correlation were calculated to determine the whether the variable to be considered redundant. Among the well correlated variables in the PC, the variables with highest sum of correlation coefficients were chosen for the MDS (Andrews *et al.*, 2002).

3.3. FORMULATION OF SOIL QUALITY INDEX

The soil quality evaluation was done as per the procedure described by Larson and Pierce (1994).

The attributes in the MDS were assigned an appropriate weight based on existing soil conditions, cropping patterns, and agro-climatic conditions (Singh *et al.*, 2017). The status of each attribute was categorised into four classes *viz*. Class-I (very good status), Class-II (good status), Class-III (poor status) and Class-IV (very poor status) and marks of 4, 3, 2 and 1 were assigned to the classes respectively (Kundu *et al.*, 2012; Mukherjee and Lal, 2014) with slight modifications based on the soil fertility ratings for secondary and micronutrients for Kerala soil. Soil quality index (SQI) was calculated by the equation,

$SQI = \sum W_i \times M_i$

Where W_i is weight of the indicators and M_i is the marks of the indicator classes.

The change of soil quality was measured by computing the relative soil quality index (RSQI) using the concept of Karlen and Stott, 1994.

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

Where SQI is the computed soil quality index and SQI_m is the theoretical maximum. Then each sampling location were rated based on the RSQI value as poor (RSQI < 50%), medium (RSQI 50 – 70%) and good (RSQI > 70%) (Kundu *et al.*, 2012).

3.3.1. Soil nutrient index

To facilitate the comparison of the fertility of one area to that of the other, a single value for each nutrient was required. The calculation and categorisation of soil nutrient index was done according to the following method, (Parker *et al.*, 1951).

Nutrient index = $\{(1 \times A) + (2 \times B) + (3 \times C)\}/ TNS$

Where, A = Number of samples in low category

B = Number of samples in medium category

C = Number of samples in high category

TNS = Total number of samples

Nutrient index	Value
Low	<1.67
Medium	1.67 – 2.33
High	>2.33

(Ramamoorthy and Bajaj, 1969)

3.3.2. Land quality index

Soil organic carbon stock was calculated using the following equation (Batjes, 1996) and was expressed in Mg ha^{-1}

Soil organic carbon stock = soil organic carbon (%) × bulk density (Mgm^{-3}) ×

soil depth (m) × 100

The land quality index was calculated based on the soil organic carbon stock (value expressed in kg m^{-2}) and was classified as per criteria suggested by Shalimadevi (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

3.4. GENERATION OF MAPS USING GEOGRAPHIC INFORMATION SYSTEM

GIS based thematic maps were generated using ArcGIS 10.5.1 software through interpolation. Mapping was done to illustrate the sampling locations and soil parameters that showed large variation throughout the AEU *viz.* texture, soil pH, organic carbon, available N, P, K, Ca, Zn, the nutrient index for available OC, N, P, K, the land quality index and the RSQI of the flood affected areas of the AEU 3.

Inverse Distance Weighted (IDW) method, a spatial analyst tool in ArcGIS software was used for the interpolation. Interpolation cell values by averaging the values of sample points in the vicinity of each cell. It is assumed that, the influence of value of the variable being mapped at a sampling point reduces with increase in distance from the sampling point (ESRI, 2001). The values at unknown locations are determined using a weighting value and values at known locations. Weights are calculated using an equation based on the distance between the known and unknown locations and the total number of sampling points (Ogbozige *et al.*, 2018).

The soil analysis data along with the respective geo coordinates were entered in MS excel, converted into a CSV (Comma Separated Values) file and imported to ArcGIS mapping software. The shape file with the boundaries of sampled panchayaths in AEU 3 of Alappuzha district *viz.* Chunakkara, Nooranadu, Palamel, Chennithala, Chettikulangara, Pathiyoor and Veeyapuram was also imported into the mapping software. IDW was selected from the spatial analyst tool. Longitude, latitude and soil attribute values were selected as x, y and z respectively and boundaries of the panchayaths were taken as the processing extent in the IDW dialog box. The number of sampling points was also entered and the data was interpolated. The output map obtained for each parameter was classified manually based on the standard ratings and different colours were allocated for each class.

3.5. STATISTICAL ANALYSIS

To study the relationships between the analysed parameters, Pearson's correlations ($p < 0.05$ and $p < 0.01$) among them were worked out using the statistical software package WASP 2.0 (Panse and Sukhatme, 1954).

4. RESULT

The results of various analyses carried out to realize the objectives of the investigation are presented in this chapter.

4.1. SURVEY AND COLLECTION OF SOIL SAMPLES

4.1.1. Survey

A Survey was conducted to identify the flood affected areas of AEU 3 in Alappuzha district and details including nutrient management practices of different crops were collected based on a predesigned questionnaire (Appendix II). Survey data revealed that in AEU 3, only seven panchayaths were severely affected by flood. There was no much damage due to flood in other panchayaths and municipalities of AEU 3. The affected panchayaths were Chunakkara, Veeyapuram, Palamel, Chettikulangara, Nooranadu, Pathiyoor and Chennithala. The major crops cultivated in these areas were rice, coconut, banana and vegetables. Rice based cropping system is prevalent in lowland and coconut based cropping system is the major cropping system in upland. Majority of the farmers were marginal farmers and the rest of them were small farmers (Table 4). The details of survey are given in Appendix II.

Details of nutrient management practices of various crops were collected and the data revealed that majority of the crops were under fertilized with respect to potash, magnesium and boron. The major fertilizers used were urea, Factamfos, rock phosphate and 18-18-18. Farmers following organic practices mainly applied cowdung, green manure, compost, vermicompost, bone meal, neem cake and ash. Some of the organic farmers used biocontrol agents like *Pseudomonas* and *Beauveria* also.

Deficiency symptoms of potassium, magnesium and boron were prevalent in banana, coconut and vegetables. For vegetables, most of the farmers follow mainly organic nutrient management practices but not meeting the crop requirement and some farmers undertaking large scale cultivation use fertilizers. For rice, in general nitrogen and potassium were applied less than the required quantity but phosphorous application was in excess. Majority of the farmers use complex fertilizers for rice and banana.

Some farmers follow soil test based fertilizer recommendations and recommendations from Krishibhavans for their cultivation. Liming was not sufficient in all the crops.

Table 4. Details of the field survey conducted in the AEU 3.

Particulars	Number of farmers	Percentage
Crops		
1. Rice	25	35.7
2. Coconut	8	11.4
3. Vegetables	20	28.6
4. Banana	17	24.3
Nutrient management		
1. Organic	20	28.6
2. INM	25	35.7
3. Inorganic	25	35.7
Size of holding		
1. Marginal	64	91.5
2. Small	6	8.5
3. Medium	0	0

4.1.2. Collection of soil samples

Seventy representative geo referenced surface soil samples were collected from the flood affected areas of the AEU 3 under major land uses *viz.* paddy, coconut, banana and vegetables.

4.2. SOIL QUALITY ANALYSIS

The soil samples collected were characterized for important physical, chemical and biological properties to assess the soil quality.

4.2.1. Physical attributes

The collected soil samples were subjected to analysis of various physical properties like bulk density, particle density, porosity, texture, depth of silt/clay/sand deposition, aggregate analysis, soil moisture content and water holding capacity.

4.2.1.1. Bulk density

The bulk density of soil samples ranged from 0.76 Mg m^{-3} to 1.76 Mg m^{-3} in the post-flood soils of AEU 3 (Table 5). The mean value of bulk density observed was 1.29 Mg m^{-3}. The highest mean value was observed in the Nooranadu panchayath (1.43 Mgm^{-3}) and the lowest mean value in Veeyapuram panchayath (0.87 Mg m^{-3}).

A notable difference was observed in the bulk density of the rice land use of the Veeyapuram panchayath in comparison with the other flood affected areas of the AEU 3. Banana land use had the highest mean value of bulk density (1.47 Mg m^{-3}) and rice land use had the lowest mean value (1.09 Mg m^{-3}) (Table 6).

4.2.1.2. Particle density

The value of particle density in the flooded regions of AEU 3 ranged from 1.23 Mg m^{-3} to 2.47 Mgm^{-3} with a mean value of 2.08 Mg m^{-3}. The highest mean value (2.29 Mg m^{-3}) was observed in Nooranadu panchayath and the lowest mean value (1.43 Mg m^{-3}) in Veeyapuram panchayath (Table 5).

The lowest mean value was observed in the rice land use (1.78 Mg m^{-3}) and the highest mean value was observed in the banana land use (2.25 Mg m^{-3}) among the land uses (Table 6).

4.2.1.3. Porosity

The values of porosity per cent of the samples in the post-flood soils of AEU 3 varied between 24.4 and 49.3 per cent with a mean value of 37.8 per cent. Soils of Pathiyoor panchayath was found to have the highest mean value of porosity (40.9 per cent) and those of Chunakkara panchayath had the lowest mean value (35.9 per cent) (Table 5).

Among various land uses, soils of vegetables land use had the highest mean porosity value (29.6 per cent) and soils of banana land use had the lowest mean value (24.2 per cent) (Table 6).

Table 5. Bulk density, particle density and porosity of the post-flood soils of AEU 3

Parameters →	Bulk density (Mg m^{-3})		Particle density (Mg m^{-3})		Porosity (%)	
Panchayath↓	Mean ± SD	Range	Mean± SD	Range	Mean ± SD	Range
Chunakkara	1.39 ± 0.14	1.18 - 1.56	2.16 ± 0.18	1.88 - 2.38	35.9 ± 4.1	30.4 - 43.5
Veeyapuram	0.87 ± 0.09	0.76 - 1.12	1.43 ± 0.18	1.33 - 1.91	39.6 ± 4.1	34.1 - 49.3
Palamel	1.42 ± 0.15	1.22 - 1.76	2.27 ± 0.19	1.99 - 2.47	36.2 ± 7.3	25 - 44.6
Chettikulangara	1.34 ± 0.18	1.07 - 1.59	2.13 ± 0.23	1.76 - 2.39	37.1 ± 6.1	24.4 - 44.2
Nooranadu	1.43 ± 0.09	1.22 - 1.51	2.29 ± 0.12	2.05 - 2.46	37.6 ± 3.7	33.6 - 43.9
Pathiyoor	1.30 ± 0.06	1.24 - 1.37	2.21 ± 0.20	1.83 - 2.49	40.9 ± 4.5	32.2 - 47.3
Chennithala	1.29 ± 0.20	1.07 - 1.62	2.04 ± 0.24	1.68 - 2.38	36.9 ± 3.6	31.9 - 43.1
AEU 3	1.29 ± 0.23	0.76 – 1.76	2.08 ± 0.33	1.23 - 2.47	37.8 ± 5.1	24.4 - 49.3

Table 6. Bulk density, particle density and porosity of the post-flood soils of AEU 3 (Land use wise)

Parameters →	Bulk density (Mgm^{-3})		Particle density (Mgm^{-3})		Porosity (%)	
Land Use↓	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Rice	1.09 ± 0.22	0.76 - 1.49	1.78 ± 0.34	1.33 - 2.39	25.8 ± 5.9	15.2 – 36.7
Coconut	1.37 ± 0.13	1.16 - 1.56	2.22 ± 0.24	1.83 - 2.50	28.3 ± 6.8	18.9 – 40.2
Vegetables	1.36 ± 0.11	1.07 - 1.50	2.24 ± 0.15	1.88 - 2.48	29.6 ± 5.7	15.4 – 39.4
Banana	1.47 ± 0.14	1.07 - 1.76	2.25 ± 0.20	1.68 - 2.47	24.2 ± 6.7	11.1 – 36.5

4.2.1.4. Particle size distribution and Soil texture

The particle size distribution of soils from the various sampling locations were examined and the texture was determined based on the percentage of sand, silt and clay fractions (Table 7).

The sand content in the post-flood soils of AEU 3 ranged from 27.4 to 87.4 per cent. The highest mean value of sand content was observed in Pathiyoor (82.8 per cent) and the lowest value was observed in Veeyapuram panchayath (41.8 per cent) (Table 7). Vegetables land use had high mean sand content (81.8 per cent) whereas, rice land use had the lowest (63.5 per cent) (Table 8).

The silt content in the soil samples ranged from 6 to 40 per cent. The highest mean value of silt content (28.9 per cent) was recorded in Veeyapuram and the lowest value (9.56 per cent) in Chunakkara (Table 7). High silt content was observed in soils of rice land use (17.5 per cent) and soils of coconut and vegetables land use had lower content (10.7 per cent) of silt (Table 8).

Table 7. Sand, silt and clay content of the post-flood soils of AEU 3

Parameters→	% Sand		% Silt		% Clay	
Panchayath↓	Mean ± SD	Range	Mean± SD	Range	Mean ± SD	Range
Chunakkara	74.9 ± 6.31	62.4 - 83.4	9.56 ± 2.6	5 - 13.6	15.5 ± 5.97	5.6 - 27.6
Veeyapuram	41.8 ± 7.19	36.2 - 57.4	28.9 ± 6.83	15 - 40	29.2 ± 3.83	22.6 - 33.4
Palamel	81.7 ± 5.39	67.4 - 87.4	10.1 ± 2.46	5.4 - 12.4	8.16 ± 5.25	5.2 - 22.6
Chettikulangara	78.6 ± 10.8	48.0 - 83.5	12.9 ± 6.99	6 - 32	8.48 ± 4.28	5.6 – 20
Nooranadu	80.8 ± 3.15	74.8 - 84.5	10.8 ± 1.96	6 - 12.8	8.39 ± 3.13	5.6 – 14
Pathiyoor	82.8 ± 2.26	79.6 - 87.4	10.2 ± 2.65	6 - 14.6	6.99 ± 1.34	5.8 - 10.6
Chennithala	77.5 ± 17.7	27.4 - 87.4	12.3 ± 6.79	6 - 30	10.2 ± 11.5	4.4 - 42.6
AEU 3	74.0 ± 15.9	27.4 - 87.4	13.6 ± 7.92	6 - 40	12.4 ± 9.26	4.4 - 42.6

Table 8. Sand, silt and clay content of the post-flood soils of AEU 3 (Land use wise)

Parameters→	% Sand		% Silt		% Clay	
Land Use↓	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Rice	63.5 ± 19.2	36.2 - 83.4	17.5 ± 10.7	5 - 40	18.9 ± 10.2	5 - 33.4
Coconut	81.4 ± 3.79	75.6 - 87.4	10.7 ± 2.36	6.4 - 14.6	7.94 ± 3.15	5.60 - 13.4
Vegetables	81.8 ± 3.60	67.4 - 84.5	10.7 ± 2.12	6 - 14.2	7.56 ± 3.86	4.40 - 22.6
Banana	76.8 ± 15.5	27.4 - 87.4	12.6 ± 7.28	5.4 - 32	10.6 ± 9.07	5.60 - 42.6

The clay content in the post-flood soils of the AEU 3 varied from 4.4 to 42.6 per cent. The mean clay content was observed to be the highest (29.2 per cent) in Veeyapuram and to be lowest (6.99 per cent) in Pathiyoor panchayath (Table 7). Rice land use had highest (18.9 per cent) clay content and the vegetables land use had the lowest (7.56 per cent) (Table 8).

The predominant textural class in the Onattukara region was loamy sand. Other textural classes like sandy loam, sandy clay loam, clay loam, loam and clay were also identified (Appendix-III).

Majority of the samples (70 per cent) in Chunakkara were sandy loam in texture, along with 20 per cent sandy clay loam and 10 per cent loamy sand. Veeyapuram panchayath with predominantly rice land use had clay loam texture (60 per cent). Palamel and Chettikulangara had loamy sand as the major texture. Eighty per cent of Nooranadu samples were loamy sand and the rest were sandy loam. The samples of Pathiyoor panchayath were exclusively loamy sand. Samples from Chennithala were loamy sand except one, which was clay in texture. Loam texture was found in two samples, one each from Veeyapuram and Chettikulangara panchayath (Appendix -III).

4.2.1.5. Depth of silt/clay/sand deposition

Significant deposition of sand/silt/clay was not found all over the AEU 3, but only found as light coating in some of the areas. Prominent silt deposition was found in sampling location H6 (2 cm thickness) and H8 (5 cm thickness) of Chennithala panchayath. Silt deposition was mainly found near the river banks.

4.2.1.6. Aggregate analysis

Aggregate stability of the soil samples was measured by estimating the Mean Weight Diameter (MWD) and the percentage of Water Stable Aggregates (WSA) (Table 9).

The highest value of mean weight diameter in the post-flood soils observed was 3.74 mm and the lowest value was 0.284 mm. Soil samples of Veeyapuram panchayath had the highest mean value (2.92 mm) of MWD and that of Chettikulangara had the lowest value (0.64 mm) (Table 9). Among land use, rice had highest MWD (1.80 mm) and vegetables had the lowest mean value (0.821 mm) (Table 10).

Table 9. MWD and per cent WSA of the post-flood soils of AEU 3

Parameters→	MWD (mm)		WSA (%)	
Panchayath↓	Mean ± SD	Range	Mean± SD	Range
Chunakkara	1.34 ± 0.73	0.441 - 2.88	71.6 ± 7.74	58.8 - 78.9
Veeyapuram	2.92 ± 0.44	2.361 - 3.74	79.2 ± 5.17	68.0 - 87.4
Palamel	0.83 ± 0.41	0.324 - 1.86	66.7 ± 4.99	58.4 - 75.3
Chettikulangara	0.64 ± 0.40	0.324 - 1.56	63.4 ± 6.14	51.1 - 69.9
Nooranadu	1.08 ± 0.65	0.382 - 2.54	68.9 ± 7.96	56.2 - 78.9
Pathiyoor	0.79 ± 0.46	0.301 - 1.48	65.9 ± 5.17	57.2 - 72.3
Chennithala	0.95 ± 0.80	0.284 - 1.61	65.9 ± 11.7	49.6 - 84.2
AEU 3	1.22 ± 0.91	0.284 – 3.74	68.9 ± 8.56	49.6 – 87.4

Table 10. MWD and per cent WSA in the post-flood soils of AEU 3 (Land use wise)

Parameters→	MWD (mm)		WSA (%)	
Land Use↓	Mean ± SD	Range	Mean ± SD	Range
Rice	1.80 ± 1.09	0.324 - 3.74	73.5 ± 7.61	58.8 - 87.3
Coconut	1.01 ± 0.44	0.667 - 1.76	68.1 ± 5.77	58.9 - 77.8
Vegetables	0.821 ± 0.47	0.294 - 1.86	65.9 ± 6.87	52.6 - 78.7
Banana	0.942 ± 0.77	0.284 - 2.54	65.6 ± 10.17	49.6 - 84.2

The per cent of water stable aggregates values in the post-flood soils of AEU 3 ranged from 49.6 to 87.4. Highest mean value of WSA (73.5 per cent) was observed in Veeyapuram and the lowest (63.4 per cent) in Chettikulangara. Per cent of WSA was observed to be highest (73.5 per cent) in the rice land use and lowest (65.6 per cent) in banana land use (Table 10). Noticeable variations were observed in the aggregate stability within the panchayaths and land uses.

4.2.1.7. Soil moisture

Soil moisture content in the post-flood samples of AEU 3 varied from 5.03 per cent to 48.42 per cent with a mean value of 18.4 per cent. Highest mean value of soil moisture content (27.2 per cent) was observed in the Veeyapuram panchayath and the lowest mean value (13.9 per cent) in the Palamel panchayath (Table 11).

Soils of rice land use had highest mean soil moisture content (28.8 per cent) and soils of banana land use had the lowest soil moisture content (13.3 per cent) (Table 12).

Table 11. Soil moisture and water holding capacity of the post-flood soils of AEU 3

Parameters→ Panchayath↓	Soil moisture (%)		Water holding capacity (%)	
	Mean ± SD	Range	Mean ± SD	Range
Chunakkara	17.4 ± 6.78	6.19 - 24.87	29.6 ± 6.19	17.7 - 39.3
Veeyapuram	27.2 ± 10.3	18.2 - 48.42	58.9 ± 7.26	51.8 - 71.7
Palamel	13.9 ± 5.40	5.52 - 20.35	28.6 ± 7.43	12.2 - 35.1
Chettikulangara	16.4 ± 7.76	5.03 - 25.14	32.4 ± 11.9	11.6 - 57.7
Nooranadu	18.1 ± 4.66	10.7 - 24.47	30.3 ± 3.89	23.8 - 36.2
Pathiyoor	16.5 ± 6.88	11.1 - 30.28	33.1 ± 8.19	26.4 - 51.3
Chennithala	19.5 ± 8.68	10.6 - 35.14	36.6 ± 8.86	26.6 - 50.8
AEU 3	18.4 ± 8.11	5.03 - 48.42	35.6 ± 12.5	11.6 - 71.7

Table 12. Soil moisture and water holding capacity of the post-flood soils of AEU 3 (Land use wise).

Parameters→ Land Use↓	Soil moisture (%)		Water holding capacity (%)	
	Mean ± SD	Range	Mean ± SD	Range
Rice	28.8 ± 10.07	6.19 - 48.4	44.2 ± 13.9	23.4 - 71.7
Coconut	25.5 ± 6.80	12.1 - 36.3	32.4 ± 10.7	17.7 - 51.3
Vegetables	16.6 ± 5.10	9.28 - 30.4	31.1 ± 4.2	23.7 - 41.9
Banana	13.3 ± 6.54	5.03 - 27.5	29.9 ± 11.3	11.6 - 57.7

4.2.1.8. Water holding capacity

The water holding capacity of post-flood soils in AEU 3 varied widely from 11.62 per cent to 71.7 per cent with a mean value of 35.6 per cent (Table 11). Average water holding capacity was found to be highest (58.9 per cent) in soils of Veeyapuram and lowest in soils of Palamel panchayath (28.6 per cent) (Table 11).

Among land use, soils of rice land use had highest mean water holding capacity (44.2 per cent) and banana had lowest mean value (29.9 per cent) (Table 12).

4.2.2. Chemical attributes

Geo-referenced soil samples were analysed for the fertility parameters like pH, electrical conductivity, organic carbon, available primary nutrients *viz.* N, P and K, secondary nutrients *viz.* Ca, Mg and S and micronutrients *viz.* Fe, Mn, Cu, Zn and B. The level of heavy metals like Pb, Cd, Ni and Cr were also analyzed in the samples.

4.2.2.1. Soil pH

The pH of the flood affected areas of Onattukara sandy plain fell exclusively in the acidic range with a mean value of 4.57. Majority (57.1 per cent) samples were under the very strongly acidic class (4.51- 5.0) (Appendix-III). The lowest pH recorded was 3.52 and the highest was 5.37. Among the panchayaths, the highest mean value was observed in Pathiyoor (4.72) and the lowest mean value in Veeyapuram panchayath (4.44) (Table 13).

The lowest mean value of pH (4.51) was seen in rice land use and the highest mean value (4.67) in the vegetables land use (Table 14).

4.2.2.2. Electrical conductivity (EC)

The results show that all the samples were with very low conductivity and were in the non-saline category. The value of electrical conductivity varied from 0.02 dSm^{-1} to 0.97 dSm^{-1} in the post flood soils of AEU. The mean value observed was 0.28 dSm^{-1}. The lowest mean value of EC (0.11 dSm^{-1}) was observed in the Chunakkara and the highest mean value (0.57 dSm^{-1}) was observed in the Nooranadu panchayath (Table 13).

Table 13. Soil pH, EC and OC status of the post-flood soils of AEU 3

Parameters→ Panchayath↓	pH		EC (dSm^{-1})		OC (%)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Chunakkara	4.61 ± 0.29	4.04 - 4.92	0.11 ± 0.06	0.04 - 0.20	0.96 ± 0.38	0.33 - 1.44
Veeyapuram	4.44 ± 0.46	3.52 - 4.96	0.28 ± 0.24	0.12 - 0.81	1.43 ± 0.39	0.72 - 1.98
Palamel	4.57 ± 0.34	4.02 - 4.98	0.22 ± 0.23	0.06- 0.71	0.72 ± 0.22	0.21 - 0.90
Chettikulangara	4.59 ± 0.31	3.98 - 4.98	0.26 ± 0.13	0.09 - 0.48	0.52 ± 0.31	0.12 - 0.88
Nooranadu	4.52 ± 0.29	4.05 - 4.97	0.57 ± 0.26	0.19 - 0.94	0.99 ± 0.53	0.24 - 1.90
Pathiyoor	4.72 ± 0.39	4.23 - 5.37	0.27 ± 0.31	0.02 - 0.97	0.76 ± 0.49	0.15 - 1.47
Chennithala	4.62 ± 0.32	4.02 - 5.11	0.24 ± 0.13	0.04 - 0.52	0.73 ± 0.58	0.03 - 1.42
AEU 3	4.57 ± 0.34	3.52 -5.37	0.28 ± 0.24	0.02 - 0.97	0.87 ± 0.50	0.03 - 1.98

Table 14. Soil pH, EC and OC status of the post-flood soils of AEU 3 (Land use wise)

Parameters→ Land Use↓	pH		EC (dSm^{-1})		OC (%)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Rice	4.51 ± 0.36	3.52 - 4.98	0.24 ± 0.19	0.04 - 0.81	1.07 ± 0.48	0.21 - 1.98
Coconut	4.61 ± 0.28	4.23 - 4.92	0.21 ± 0.31	0.02 - 0.97	0.92 ± 0.38	0.60 - 1.44
Vegetables	4.67 ± 0.39	4.02 - 5.37	0.37 ± 0.32	0.04 - 0.94	0.73 ± 0.45	0.12 - 1.60
Banana	4.57 ± 0.29	4.02 - 4.98	0.27 ± 0.15	0.06 - 0.54	0.72 ± 0.54	0.03 - 1.9

Among the land use, the lowest mean value of EC (0.21 dSm^{-1}) was observed in the coconut land use and the highest mean value (0.37 dSm^{-1}) was observed in the vegetables land use (Table 14).

4.2.2.3. Organic carbon

Organic carbon content ranged from 0.03 to 1.98 per cent in the post-flood soils of AEU, with a mean value of 0.87 per cent. The highest mean value of organic carbon content (1.43 per cent) among the panchayath was in Veeyapuram panchayath and the lowest mean value (0.52 per cent) was in Chettikulangara (Table 13). Half of the samples had organic carbon content between 0.3 and 0.9 per cent i.e. medium class (Appendix-III).

Rice land use recorded highest mean organic carbon content (1.07 per cent) and the lowest mean content (0.72 per cent) was recorded in banana (Table 14).

4.2.2.4. Available Nitrogen

The available N content of the samples ranged from 38 kg ha^{-1} to 414 kg ha^{-1} in the flooded parts of AEU 3 with a mean value of 221 kg ha^{-1}. The highest mean availability of N (335 kg ha^{-1}) was seen in Veeyapuram and the lowest (86 kg ha^{-1}) in Chennithala panchayath (Table 15). Majority (71.4 per cent) of the soils were low (< 280 kg ha^{-1}) in available nitrogen (Appendix-III).

Among the land uses, highest mean value of available N was observed in rice (278 kg ha^{-1}) and the lowest mean value in banana (170 kg ha^{-1}) (Table 16).

4.2.2.5. Available Phosphorus

The available P content in the post-flood soils of AEU 3 ranged from 10.1 kg ha^{-1} to 185 kg ha^{-1} with a mean value of 60.1 kg ha^{-1}. Among the panchayath, Nooranadu recorded the highest mean value of available P content (132 kg ha^{-1}) and Chennithala had the lowest value (22.7 kg ha^{-1}) (Table 15). 71.4 per cent of the soil samples analyzed were high (> 24 kg ha^{-1}) in the available phosphorus content (Appendix-III)

Rice land use showed the lowest mean value (32.4 kg ha^{-1}) of P availability and banana showed the highest mean value (94.42 kg ha^{-1}) (Table 16).

4.2.2.6 Available Potassium

Potassium availability in the post-flood soils of AEU 3 varied largely between the lowest value of 12.8 kg ha^{-1} and the highest value of 258 kg ha^{-1} with a mean value of 108 kg ha^{-1} (Table 15). 62.9 per cent of the samples were under the low class (< 115 kg ha^{-1}) of K availability (Appendix-III).

The mean value for available K of Chunakkara panchayath was the lowest (40.9 kg ha^{-1}) and that of Nooranadu was the highest (200 kg ha^{-1}). Coconut land use had the lowest mean value for available K (52.7 kg ha^{-1}) and the banana land use had the highest mean value (125) kg ha^{-1} (Table 16).

Table 15. Available N, P and K status of the post-flood soils of the AEU 3.

Parameters→ Panchayath↓	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Chunakkara	316 ± 44.9	263 - 414	50.2 ± 39.3	12.5 – 119	40.9 ± 21.8	12.8 - 92.2
Veeyapuram	335 ± 40.9	251 - 401	29.1 ± 20.8	12.5 - 64.4	133 ± 59.7	52.6 – 250
Palamel	201 ± 66.9	88 - 289	54.4 ± 29.8	25.6 – 108	116 ± 75.5	38.1 – 258
Chettikulangara	183 ± 70.8	100 - 251	69.9 ± 45.4	14.2 – 134	96.6 ± 89.4	25.3 – 247
Nooranadu	221 ± 56.8	100 - 301	132 ± 44.3	65.9 – 182	200 ± 62.1	44.1 – 254
Pathiyoor	203 ± 73.6	75 - 301	62.5 ± 51.3	10.9 – 135	73.3 ± 50.5	21.8 – 174
Chennithala	86 ± 33.48	38 - 125	22.7 ± 9.65	10.1 - 35.2	97.1 ± 55.1	47.5 – 225
AEU 3	221 ± 95.5	38 - 414	60.1 ± 48.7	10.1 – 185	108 ± 75.7	12.8 – 258

Table 16. Available N, P and K status of the post-flood soils of the AEU 3 (Land use wise).

Parameters→ Land Use↓	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Rice	278 ± 98.3	75.3 - 414	32.4 ± 23.8	10.1 - 98.2	101 ± 77.8	12.8 – 250
Coconut	205 ± 86.7	75.3 - 301	50.9 ± 43.8	10.9 - 120	52.7 ± 25.6	21.2 - 92.2
Vegetables	199 ± 73.7	62.7 - 301	69.1 ± 44.7	16.6 - 139	124 ± 75.9	38.1 – 254
Banana	170 ± 81.4	38 - 276	94.4 ± 59.8	14.2 - 182	125 ± 79.2	38.9 – 258

4.2.2.7. Available Calcium

A wide variation was seen in the availability of the Ca in post-flood soils of the AEU 3. Majority (72.9 per cent) of the samples were deficient in available Ca (Appendix-III). The values ranged from 14.7 mg kg^{-1} to 441 mg kg^{-1}. The mean value of the available Ca was 191 mg kg^{-1}. Highest mean value of available Ca content (256 mg kg^{-1}) among the panchayath was recorded in Nooranad and the lowest mean value (108 mg kg^{-1}) in Chennithala (Table 17).

Among the land uses, the mean value of available Ca varied from 160 mg kg^{-1} in vegetables to 249 mg kg^{-1} in the banana (Table 18).

Table 17. Available Ca, Mg and S status of the post-flood soils of the AEU 3

Parameters→ Panchayath↓	Ca (mg kg^{-1})		Mg (mg kg^{-1})		S (mg kg^{-1})	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Chunakkara	173 ± 98.7	83.7 - 322	14.1 ± 0.41	13.5 - 14.9	0.51 ± 0.19	0.18 - 0.82
Veeyapuram	252 ± 63.3	181 - 355	15.1 ± 0.22	14.6 - 15.4	2.75 ± 1.53	0.39 - 4.51
Palamel	162 ± 147	27.2 - 441	13.8 ± 0.64	12.5 - 14.7	0.20 ± 0.15	0.06 - 0.54
Chettikulangara	162 ± 87.5	67.5 - 310	14.1 ± 0.74	12.5 - 14.9	0.41 ± 0.38	0.09 - 0.63
Nooranadu	256 ± 95.5	124 - 430	14.4 ± 0.55	13.1 - 14.9	0.29 ± 0.15	0.13 - 0.55
Pathiyoor	221 ± 103	69.5 - 363	14.6 ± 0.79	13.6 - 15.7	1.13 ± 0.82	0.28 – 3
Chennithala	108 ± 106	14.7 - 304	15.5 ± 0.51	14.7 - 16.1	1.62 ± 1.24	0.52 - 4.21
AEU 3	191 ± 110	14.7 - 441	14.5 ± 0.80	12.5 - 16.1	0.99 ± 1.17	0.06 - 4.51

Table 18. Available Ca, Mg and S status of the post-flood soils of the AEU 3 (Land use wise).

Parameters→ Land Use↓	Ca (mg kg^{-1})		Mg (mg kg^{-1})		S (mg kg^{-1})	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Rice	180 ± 95.1	14.7 – 355	14.6 ± 0.76	12.5 - 15.7	1.57 ± 1.49	0.11 - 4.51
Coconut	176 ± 97.1	69.5 – 322	14.4 ± 0.76	13.6 - 15.6	0.99 ± 0.94	0.18 – 3
Vegetables	160 ± 118	27.2 – 363	14.3 ± 0.97	12.5 - 15.9	0.66 ± 0.93	0.06 - 4.21
Banana	249 ± 114	67.5 – 441	14.5 ± 0.70	13.4 - 16.1	0.51 ± 0.54	0.09 - 1.95

4.2.2.8. Available Magnesium

The results revealed severe deficiency of available Mg throughout the post-flood soils of AEU 3, irrespective of panchayath and land uses (Appendix-III). Mg availability ranged from 12.5 mg kg^{-1} to 16.1 mg kg^{-1} with a mean value of 14.49 mg kg^{-1} which was far below the critical limit 120 mg kg^{-1}. Highest mean value among panchayath was seen in Chennithala (15.5 mg kg^{-1}) and lowest in Palamel (13.8 mg kg^{-1}) (Table 17).

The mean value of available Mg did not show much variation between the various land uses and it varied from lowest value of 14.3 mg kg^{-1} in vegetable land use to highest value of 14.6 mg kg^{-1} in rice land use. (Table 18).

4.2.2.9. Available Sulphur

Available S was deficient (< 5 mg kg^{-1}) in the entire flood affected areas of AEU 3 (Appendix III). The lowest value recorded was 0.06 mg kg^{-1} and the highest value was 4.51 mg kg^{-1} in the samples. The mean value of available S in the AEU was 0.99 mg kg^{-1}.The mean values of different panchayaths showed large variation from the mean value of the AEU. Veeyapuram had the highest mean value (2.75 mg kg^{-1}) and Palamel panchayath had the lowest value (0.20 mg kg^{-1}) (Table 17).

The highest mean value of available S among the various land uses was recorded in rice (1.57 mg kg^{-1}) and the lowest (0.51 mg kg^{-1}) in banana (Table 18).

4.2.2.10. Available Iron

The results revealed that the entire samples were sufficient (>5 mg kg^{-1}) in available Fe (Appendix-III) and the values ranged from 171 $mgkg^{-1}$ to 978 mg kg^{-1} with a mean value of 704.09 mg kg^{-1}. Among the panchayaths, Veeyapuram recorded the highest mean value (911 mg kg^{-1}) and Chennithala had the lowest mean value (267 mg kg^{-1}) of Fe availability (Table 19).

In the case of land uses, rice recorded the highest mean value (747 mg kg^{-1}) and the lowest (650 mg kg^{-1}) value was recorded in banana (Table 20).

4.2.2.11. Available Manganese

The entire flood affected areas of the AEU 3 was sufficient (>1 mg kg^{-1}) in available Mn (Appendix-III). The values varied from 1.31 mg kg^{-1} to 38.5 mg kg^{-1}. The mean value was 11.3 mg kg^{-1}. Panchayaths like Chunakkara, Palamel, Chettikulangara and Pathiyoor had considerably lower values of the available Mn in comparison with the mean value. Chunakkara panchayath had the least mean value (2.12 mg kg^{-1}) of Mn availability and Veeyapuram had the highest (25.5 mg kg^{-1}) (Table 19).

Rice land use had the highest mean value (14.2 mg kg^{-1}) and coconut land use had the lowest mean value (4.63 mg kg^{-1}) of the available nutrient (Table 20).

4.2.2.12. Available Copper

The results showed the deficiency of available Cu (<1 mg kg^{-1}) throughout the flooded area of Onattukara (Appendix-III). The values varied between 0.03 mg kg^{-1} and 0.98 mg kg^{-1} in the AEU 3 with a mean value of 0.47 mg kg^{-1}. Veeyapuram had the lowest mean value (0.23 mg kg^{-1}) of the available Cu, among the panchayaths whereas, Pathiyoor had the highest mean value (0.56 mg kg^{-1}) (Table 19).

Among land uses, coconut had the highest mean availability (0.61 mg kg^{-1}) of the Cu and rice had the lowest value (0.38 mg kg^{-1}) (Table 20).

4.2.2.13. Available Zinc

Although the availability of Zn showed both sufficiency and deficiency status, only 14.28 per cent of the samples (Appendix-III) were under deficient class (<1 mg kg^{-1}). The lowest value observed was 0.38 mg kg^{-1} and the highest was 4.26 mg kg^{-1}. The mean value of the post-flood soils of AEU 3 was 2.03 mg kg^{-1}. The smallest mean value among panchayaths was observed in Veeyapuram (1.55 mg kg^{-1}) and the highest (2.38 mg kg^{-1}) in Pathiyoor (Table 19).

Rice land use had the lowest mean value of Zn availability (1.95 mg kg^{-1}) and coconut land use had the highest mean value (2.12 mg kg^{-1}) (Table 20).

4.2.2.14. Available Boron

The results revealed that the flood affected regions of the AEU 3 was completely deficient (<0.5 mg kg^{-1}) in the availability of B (appendix III). The lowest value observed was 0.01 mg kg^{-1} and the highest value was 0.26 mg kg^{-1}. The mean value of the B availability in AEU 3 was 0.12 mg kg^{-1}. Chennithala had the lowest mean B availability (0.07 mg kg^{-1}) and Palamel the highest (0.15 mg kg^{-1}) (Table 19).

Among land uses, vegetables had the lowest (0.11 mg kg^{-1}) and coconut had the highest value (0.14 mg kg^{-1}) (Table 20).

Table 19. Available micronutrients (Fe, Mn, Cu, Zn and B) status of the post-flood soils of AEU 3.

Parameters→ Panchayath↓	Fe ($mg\ kg^{-1}$)		Mn ($mg\ kg^{-1}$)		Cu ($mg\ kg^{-1}$)		Zn ($mg\ kg^{-1}$)		B ($mg\ kg^{-1}$)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Chunakkara	814 ± 59.1	741 – 932	2.12 ± 0.15	1.91 - 2.48	0.43 ± 0.10	0.26 - 0.55	2.36 ± 0.84	1.17 – 3.33	0.13 ± 0.04	0.05 - 0.18
Veeyapuram	911 ± 73.2	745 – 975	25.5 ± 7.54	14.6 - 38.5	0.23 ± 0.15	0.03 - 0.47	1.55 ± 0.62	0.82 – 2.71	0.14 ± 0.05	0.12 - 0.18
Palamel	705 ± 194	355 – 907	4.42 ± 3.90	1.18 - 12.8	0.25 ± 0.06	0.44 - 0.63	1.91 ± 0.91	0.96 - 3.50	0.15 ± 0.04	0.05 - 0.19
Chettikulangara	655 ± 225	302 – 910	4.50 ± 2.30	2.05 - 8.6	0.55 ± 0.09	0.39 - 0.64	1.66 ± 1.00	0.38 - 3.96	0.14 ± 0.04	0.05 - 0.18
Nooranadu	813 ± 114	623 – 978	12.1 ± 7.38	5.3 - 16.6	0.42 ± 0.15	0.1 - 0.61	2.03 ± 0.73	0.89 - 3.15	0.11 ± 0.08	0.01 - 0.26
Pathiyoor	734 ± 214	350 – 973	5.53 ± 2.51	2.13 - 9.45	0.56 ± 0.24	0.28 - 0.97	2.38 ± 0.79	1.14 - 3.50	0.13 ± 0.04	0.05 - 0.17
Chennithala	267 ± 178	171 – 340	25.1 ± 12.1	9.79 - 38.5	0.54 ± 0.36	0.02 - 0.98	2.33 ± 1.24	0.94 - 4.26	0.07 ± 0.04	0.01 - 0.14
AEU 3	704 ± 252	171 – 978	11.3 ± 11.2	1.31 - 38.5	0.47 ± 0.21	0.03 - 0.98	2.03 ± 0.91	0.38 - 4.26	0.12 ± 0.05	0.01 - 0.26

Table 20. Available micronutrients (Fe, Mn, Cu, Zn and B) status of the post-flood soils of AEU 3 (Land use wise).

Parameters→ Land Use↓	Fe ($mg\ kg^{-1}$)		Mn ($mg\ kg^{-1}$)		Cu ($mg\ kg^{-1}$)		Zn ($mg\ kg^{-1}$)		B ($mg\ kg^{-1}$)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Rice	748 ± 248	171 – 975	14.2 ± 12.8	2.06 - 38.5	0.38 ± 0.22	0.02 - 0.98	1.95 ± 0.86	0.66 - 4.26	0.13 ± 0.05	0.02 - 0.18
Coconut	735 ± 231	350 – 932	4.63 ± 3.13	1.91 - 9.45	0.61 ± 0.24	0.34 - 0.97	2.12 ± 0.88	1.14 - 3.25	0.14 ± 0.04	0.05 - 0.17
Vegetables	683 ± 255	184 – 978	10.3 ± 12.1	1.18 - 37.5	0.52 ± 0.18	0.07 - 0.83	2.05 ± 0.88	0.89 - 3.50	0.11 ± 0.05	0.01 - 0.19
Banana	650 ± 272	171 – 927	11.5 ± 8.87	2.05 - 31.1	0.47 ± 0.18	0.1 - 0.91	2.09 ± 1.10	0.38 - 4.23	0.12 ± 0.07	0.01 - 0.26

4.2.2.15. Heavy metals

The soil samples collected from the flood affected areas of the AEU 3 were analysed for heavy metals like Pb, Cd, Ni and Cr. Pb and Cr were detected in all the samples irrespective of the area and land use. Cd was not detected in any of the samples. Ni was present in 61.43 per cent of the samples and was not detected in rest of the samples (Appendix-III).

The highest content of Lead observed was 0.795 mg kg^{-1} and the lowest content observed was 0.026 mg kg^{-1}. The mean value of the Pb content was 0.248 mg kg^{-1}. Among the panchayaths, Veeyapuram had the highest mean value of Pb content (0.414 mg kg^{-1}), and Chettikulangara had the lowest mean value (0.093 mg kg^{-1}) (Table 21). Rice land use had the maximum mean value of Pb content (0.325 mg kg^{-1}) and the minimum mean value (0.181 mg kg^{-1}) was noticed in vegetables land use (Table 22).

Chromium content in the samples ranged from 0.115 mg kg^{-1} to 0.326 mg kg^{-1}, with a mean value of 0.179 mg kg^{-1}. Pathiyoor panchayath had the least mean value (0.132 mg kg^{-1}) of Cr content, whereas, Veeyapuram had the maximum mean value (0.232 mg kg^{-1}) (Table 21). Among land uses, rice had maximum content (0.190 mg kg^{-1}) and coconut had the least content (0.162 mg kg^{-1}) of the metal (Table 22).

Even though Nickel was not detected in 38.57 per cent of the samples, its content in the remaining samples varied from 0.015 mg kg^{-1} to 0.763 mg kg^{-1}. The metal was below the detectable level in Chettikulangara panchayath (Table 21).

Rice land use was found to have high mean content (0.219 mg kg^{-1}) of Ni and coconut land use had the least content (0.027 mg kg^{-1}) (Table 22). It is clear from the data that the samples of Veeyapuram panchayath and those of rice land use were found to have more content of both the prominent heavy metals, Pb and Cr.

Even though the presence of the heavy metals were detected in the soil samples, the content of all of them were far below the critical limits for the soil.

Table 21. Heavy metal (Pb, Cd, Ni and Cr) status of the post-flood soils of AEU 3.

Parameters→ Panchayath↓	Pb (mg kg^{-1})		Cd (mg kg^{-1})		Ni (mg kg^{-1})		Cr (mg kg^{-1})	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Chunakkara	0.359 ± 0.149	0.135 - 0.644	ND	ND	0.023 ± 0.013	0.012 - 0.047	0.184 ± 0.023	0.154 - 0.229
Veeyapuram	0.414 ± 0.172	0.259 - 0.795	ND	ND	0.378 ± 0.126	0.215 - 0.615	0.232 ± 0.020	0.201 - 0.264
Palamel	0.214 ± 0.081	0.153 - 0.328	ND	ND	0.214 ± 0.238	0.022 - 0.763	0.189 ± 0.117	0.129 - 0.513
Chettikulangara	0.093 ± 0.127	0.026 - 0.283	ND	ND	ND	ND	0.136 ± 0.023	0.115 - 0.172
Nooranadu	0.242 ± 0.082	0.070 - 0.400	ND	ND	0.087 ± 0.054	0.008 - 0.179	0.219 ± 0.055	0.146 - 0.326
Pathiyoor	0.258 ± 0.155	0.170 - 0.697	ND	ND	0.029 ± 0.018	0.015 - 0.043	0.132 ± 0.014	0.119 - 0.169
Chennithala	0.153 ± 0.079	0.073 - 0.312	ND	ND	0.161 ± 0.095	0.042 - 0.209	0.160 ± 0.020	0.135 - 0.184
AEU 3	0.248 ± 0.159	0.026 - 0.795	ND	ND	0.158 ± 0.161	0.015 - 0.763	0.179 ± 0.061	0.115 - 0.326

Table 22. Heavy metal (Pb, Cd, Ni and Cr) status of the post-flood soils of AEU 3 (Land use wise).

Parameters→ Land Use↓	Pb (mg kg^{-1})		Cd (mg kg^{-1})		Ni (mg kg^{-1})		Cr (mg kg^{-1})	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Rice	0.325 ± 0.193	0.028 - 0.795	ND	ND	0.219 ± 0.193	0.012 - 0.615	0.190 ± 0.043	0.125 - 0.264
Coconut	0.286 ± 0.184	0.135 - 0.697	ND	ND	0.027 ± 0.017	0.015 - 0.043	0.162 ± 0.033	0.127 - 0.207
Vegetables	0.181 ± 0.083	0.070 - 0.400	ND	ND	0.043 ± 0.022	0.008 - 0.074	0.167 ± 0.053	0.119 - 0.326
Banana	0.194 ± 0.107	0.026 - 0.379	ND	ND	0.169 ± 0.181	0.022 - 0.763	0.185 ± 0.096	0.115 - 0.513

4.2.3. Biological attributes

4.2.3.1. Acid phosphatase activity

Activity of acid phosphatase enzyme in the post-flood soils of the AEU 3 ranged from 2.72 µg p-nitrophenol released g^{-1} soil hr^{-1} to 89.3 µg p-nitrophenol released g^{-1} soil hr^{-1}. The mean value observed was 32.6 µg p-nitrophenol released g^{-1} soil hr^{-1}. The lowest mean value among panchayath (22.2 µg p-nitrophenol released g^{-1} soil hr^{-1}) was recorded in Pathiyoor and the highest mean value (53.2 µg p-nitrophenol released g^{-1} soil hr^{-1}) in Veeyapuram (Table 23). 82.9 per cent of the soil were observed to have the enzyme activity less than 50 µg p-nitrophenol released g^{-1} soil hr^{-1} (Appendix-III).

Rice had the highest mean value (38.2 µg p-nitrophenol released g^{-1} soil hr^{-1}) and coconut had the lowest (26.8 µg p-nitrophenol released g^{-1} soil hr^{-1}) acid phosphatase activity among the land uses (Table 24).

4.2.3.2. Dehydrogenase activity

Dehydrogenase activity in soils of flood affected areas of AEU 3 varied between 5.75 µg TPF hydrolysed g^{-1} soil 24 hr^{-1} to 93.5 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}. The mean value was 32.4 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}. 97.1 per cent of the samples had enzyme activity less than 75 µg TPF hydrolysed g^{-1} soil 24 hr^{-1} (Appendix III). Among the panchayath, Chennithala had the lowest mean activity of the enzyme (24.3 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) and Veeyapuram had the highest (39.3 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) (Table 23).

Banana land use had the lowest mean value (29.9 µg TPF hydrolysed g^{-1} soil 24 hr^{-}1) and rice land use had the highest mean value (35.2 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) (Table 24).

Table 23. Acid phosphatse and Dehydrogenase activity in the post-flood soils of AEU 3

Parameters→ Panchayath↓	Acid phospahatase (µg p-nitrophenol released g^{-1} soil hr^{-1})		Dehydrogenase (µg TPF hydrolysed g^{-1} soil 24 hr^{-1})	
	Mean ± SD	Range	Mean ± SD	Range
Chunakkara	26.5 ± 10.5	10.4 - 39.8	37.2 ± 18.1	6.91 - 70.4
Veeyapuram	53.2 ± 25.1	17.5 - 89.3	39.3 ± 19.8	9.40 - 69.7
Palamel	32.9 ± 13.9	15.6 - 57.4	31.5 ± 14.6	21.3 - 61.9
Chettikulangara	29.3 ± 14.1	14.6 - 53.9	30.9 ± 16.9	16.3 - 72.2
Nooranadu	32.7 ± 13.6	14.1 - 59.9	37.1 ± 26.7	12.5 - 93.5
Pathiyoor	22.2 ± 8.12	11.2 - 33.8	26.7 ± 19.2	6.1 - 58.2
Chennithala	31.1 ± 20.9	2.72 - 62.9	24.3 ± 13.4	5.75 - 45.3
AEU 3	32.6 ± 17.9	2.72 - 89.3	32.4 ± 18.7	5.75 – 93.5

Table 24. Acid phosphatase and Dehydrogenase activity in the post-flood soils of AEU 3 (Land use wise).

Parameters→ Land Use↓	Acid phospahatase (µg p-nitrophenol released g^{-1} soil hr^{-1})		Dehydrogenase (µg TPF hydrolysed g^{-1} soil 24 hr^{-1})	
	Mean ± SD	Range	Mean ± SD	Range
Rice	38.2 ± 22.7	2.72 - 89.3	35.2 ± 19.9	5.75 - 72.2
Coconut	26.8 ± 8.88	14.2 - 39.8	35.0 ± 19.5	6.14 - 58.2
Vegetables	29.9 ± 14.5	10.2 - 49.2	30.7 ± 16.9	11.9 - 77.9
Banana	31.5 ± 15.3	7.18 - 59.9	29.9 ± 19.9	12.4 - 93.5

4.3. FORMULATION OF MINIMUM DATA SET AND SOIL QUALITY INDEX

4.3.1. Formulation of Minimum data set (MDS)

Principal Component Analysis (PCA) was used for setting up the minimum data set. All the analysed soil characteristics (26) except heavy metals were considered as vectors for the PCA. The PCA resulted in seven principal components (PCs), which had Eigen value more than 1, which was selected for the MDS. The PCs explained 34.46

per cent, 11.34 per cent, 8.14 per cent, 8.07 per cent, 6.70 per cent, 4.54 per cent and 4.11 per cent variance respectively (Table 25).

The factor loading of a variable under particular PC gives the contribution of that variable to the PC. Only the highly weighted variables (within 10 per cent of the factor loading) with in each PC were retained (Wander and Bollero, 1999).

Table 25. Result of principal component analysis (PCA)

Particulars	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigen value	8.96	2.95	2.12	2.10	1.74	1.18	1.07
% variance	34.46	11.34	8.14	8.07	6.70	4.54	4.11
Cumulative variance	34.46	45.80	53.93	62.00	68.70	73.24	77.35
Eigen vectors							
Sand %	**0.936**	-0.036	0.128	0.127	0.256	0.152	0.052
Silt %	0.818	-0.05	-0.027	0.01	-0.378	-0.151	-0.1
Clay %	0.841	0.104	-0.198	-0.228	-0.117	-0.134	-0.003
MWD	-0.894	0.191	-0.004	-0.101	0.132	-0.109	-0.056
WSA %	0.745	0.243	0.038	-0.095	**0.585**	-0.142	-0.12
B.D.	-0.822	0.251	0.135	**0.799**	0.068	-0.163	-0.129
P.D.	-0.87	0.274	0.03	0.117	0.114	0.03	-0.061
Porosity	-0.282	0.067	-0.194	0.624	0.235	-0.105	0.091
Soil moisture	0.548	-0.264	-0.111	0.334	0.281	0.357	-0.362
WHC	0.849	-0.229	-0.082	0.255	-0.085	0.155	-0.029
pH	-0.206	0.128	0.366	-0.36	0.17	0.373	-0.022
EC	-0.04	0.203	0.051	-0.157	-0.22	-0.157	0.047
OC	0.737	0.266	0.17	0	0.444	**0.403**	-0.137
N	0.482	0.478	-0.401	-0.268	0.135	0.108	-0.169
P	-0.358	**0.710**	0.169	0.143	-0.049	-0.249	0.03
K	0.109	0.4	0.446	0.403	-0.234	0.074	0.062
Ca	0.188	**0.741**	0.319	-0.159	-0.192	0.02	0.217
Mg	0.523	-0.165	**0.703**	-0.019	0.001	0.101	0.024
S	0.613	-0.187	0.14	-0.008	-0.367	0.365	0.129
Fe	0.256	0.665	-0.506	0.086	-0.13	0.133	0.037
Mn	0.615	-0.194	0.558	0.164	-0.1	-0.139	0.085
Cu	-0.328	-0.451	0.242	0.018	0.334	-0.35	-0.183
Zn	-0.219	0.308	0.364	-0.41	0.004	**0.423**	-0.156
B	0.159	-0.278	-0.176	-0.263	0.238	0.032	**0.780**
Acid phosphatase	0.672	0.109	0.141	0.168	0.366	0.034	0.066
Dehydrogenase	0.313	0.27	0.046	0.237	0.39	-0.068	0.281

When more than one variable was retained in a PC, the correlation between them was worked out and if they are significantly correlated ($r > 0.6$), the one with highest loading factor was retained for the MDS and the rest excluded. On the other hand, the non-correlated variables under the PC were retained, considering them important (Andrews and Carroll, 2001).

Table 26. Minimum data set (MDS) for the assessment of soil quality

PC1	PC2	PC3	PC4	PC5	PC6	PC7
Sand per cent	Available P	Available Mg	Bulk density	Per cent of water stable aggregates	Organic carbon	Available B
	Available Ca				Available Zn	

4.3.2. Formulation of soil quality index (SQI)

4.3.2.1. Scoring of the parameters

In order to formulate the soil quality index of the analysed soil samples, the parameters in the minimum data set was assigned with appropriate weights based on existing soil conditions, cropping patterns, and agro-climatic conditions (Singh *et al.*, 2017) and each class with proper score according to the procedure by Kundu *et al.* (2012); Mukherjee and Lal (2014) with slight modifications based on the soil fertility ratings for secondary and micronutrients for Kerala soil (Table 27).

Table 27. Scoring of the parameters for the computation of soil quality index

Soil quality indicators	Weights	Class I with score 4	Class II with score 3	Class III with score 2	Class IV with score 1
WSA%	15	>90	70 – 90	50 – 70	< 50

B D (Mg m^{-3})	10	1.3 – 1.4	1.2 – 1.3 or 1.4 – 1.5	1.1 – 1.2 or 1.5 – 1.6	< 1.1/ > 1.6
Texture (sand %)	10	Loam	Clay loam/ Sandy loam	Sand/Clay	Grit
OC (%)	15	>1	0.75 - 1	0.5 - 0.75	< 0.5
Available P (kg ha^{-1})	10	>24	15 – 24	10 - 15	< 10
Available Ca (mg kg^{-1})	10	>300	250 - 300	150 - 250	< 150
Available Mg (mg kg^{-1})	10	>120	90 - 120	60 - 90	< 60
Available Zn (mg kg^{-1})	10	>1.0	0.5 - 1.0	0.25 - 0.5	< 0.25
Available B (mg kg^{-1})	10	>0.5	0.25 - 0.5	0.1 - 0.25	< 0.1

4.3.2.2. Computation of SQI and Relative soil quality index (RSQI)

Soil quality index (SQI) of the soil samples was calculated by weighted additive method, using the equation (Table 28),

$SQI = \sum W_i \times M_i$

Where W_i is weight of the indicators and M_i is the marks of the indicator classes.

Relative soil quality index (RSQI) of the samples were calculated to study the change in soil quality of the samples (Table 28) and the samples were classified into different classes (Appendix-III).

The soil quality index of the samples varied between 175 and 295, with a mean value of 239. Mean value of SQI was found to be maximum (260) in the Nooranadu panchayath and minimum (217) in Chettikulangara panchayath (Table 28). Coconut land use recorded highest mean SQI (248) and rice land use recorded the least mean SQI (234) (Table 29).

The relative soil quality index of the samples in the post-flood scenario of AUE 3 ranged from 43.8 per cent to 78.8 per cent. The Nooranadu panchayath was observed to have the highest mean RSQI (64.9 per cent) and Chettikulangara was observed to have the lowest value (54.1 per cent) (Table 28).

Coconut land use had high mean RSQI (62.1 per cent) among the land uses, and rice had least value (58.6 per cent) (Table 29).

Table 28. SQI and RSQI of the post-flood soils of AEU 3.

Parameters→ Panchayath↓	Soil quality index		Relative soil quality index (%)	
	Mean ± SD	Range	Mean ± SD	Range
Chunakkara	250 ± 29.1	205 – 295	62.5 ± 7.26	52.5 - 73.8
Veeyapuram	240 ± 18.6	215 – 275	60.0 ± 4.64	53.8 - 68.8
Palamel	241 ± 23.1	200 – 270	60.3 ± 5.77	50.0 - 67.5
Chettikulangara	217 ± 39.9	170 – 295	54.1 ± 9.98	42.5 - 73.8
Nooranadu	260 ± 34.4	195 – 305	64.9 ± 8.59	48.8 - 76.3
Pathiyoor	256 ± 25.5	230 – 320	63.9 ± 6.39	57.5 - 80.0
Chennithala	220 ± 24.2	190 – 255	55.0 ± 6.04	47.5 - 63.8
AEU 3	239 ± 31.5	175 – 295	59.7 ± 7.87	43.8 - 78.8

Table 29. SQI and RSQI of the post-flood soils of AEU 3 (Land use wise).

Parameters→ Land Use↓	Soil quality index		Relative soil quality index	
	Mean ± SD	Range	Mean ± SD	Range
Rice	234 ± 30.1	175 – 285	58.6 ± 7.51	43.8 - 71.3
Coconut	248 ± 25.1	220 – 295	62.1 ± 6.26	55.0 - 73.8
Vegetables	239 ± 32.5	195 – 315	59.6 ± 8.12	48.8 - 78.8
Banana	241 ± 36.2	185 – 305	60.3 ± 9.04	46.3 - 76.3

4.3.3. Soil nutrient index

To facilitate the comparison of fertility of different areas, the nutrient index was computed. Single value was obtained to represent each nutrient and the regions were classified into fertility classes (Ramamoorthy and Bajaj, 1969).

Table 30. Nutrient indices values and classes of OC, N, P and K in the flood affected areas of AEU 3

Nutrient index→	NI of OC		NI of N		NI of P		NI of K	
Panchayath↓	Value	Class	Value	Class	Value	Class	Value	Class
Chunakkara	2.4	High	1.8	Medium	2.7	High	1	Low
Veeyapuram	3	High	1.9	Medium	2.4	High	1.5	Low
Palamel	1.9	Medium	1.1	Low	3	High	1.4	Low
Chettikulangara	1.6	Low	1	Low	2.9	High	1.3	Low
Nooranadu	2.1	Medium	1.1	Low	3	High	1.9	Medium
Pathiyoor	2.1	Medium	1.1	Low	2.6	High	1.2	Low
Chennithala	1.9	Medium	1	Low	2.3	High	1.3	Low

Most of the panchayath came under the medium nutrient index class of organic carbon. Chunakkara and Veeyapuram panchayath had high nutrient index of organic carbon and only Chettikulanagara had low index of organic carbon. Nutrient index for nitrogen in the majority of panchayaths were under class low, except Chunakkara and Veeyapuram. Phosphorus had exclusively high nutrient index value in the AEU. In case of potassium, Nooranadu alone came under the medium nutrient index class and rest of them in the low nutrient index class (Table 30).

4.3.4. Land quality index

Land quality index of the flooded area of the AEU 3 was determined based on the soil organic carbon (SOC) stock (Shalimadevi, 2006) and it was observed that the majority (91.4 per cent) of samples fell into very low class of land quality and the rest of them fell into the class low of land quality (Table 31).

Table 31. SOC stock and land quality index of the post-flood soils of AEU 3

Parameters→ Panchayath↓	Soil organic carbon stock (Mg ha^{-1})	Soil organic carbon stock (kg m^{-2})		LQI
	Range	Mean	Range	
Chunakkara	7.30 - 31.1	1.97 ± 0.75	0.73 - 3.11	Very low
Veeyapuram	8.90 - 25.2	1.85 ± 0.53	0.89 - 2.52	Very low
Palamel	4.30 - 21.4	1.55 ± 0.50	0.43 - 2.14	Very low
Chettikulangara	2.70 - 19.5	1.03 ± 0.61	0.27 - 1.95	Very low
Nooranadu	5.40 - 41.4	2.12 ± 1.13	0.54 - 4.14	Very low
Pathiyoor	3.10 - 30.9	1.47 ± 0.94	0.31 - 3.09	Very low
Chennithala	0.80 - 35.1	1.34 ± 1.12	0.08 - 3.51	Very low
AEU 3	0.80 - 41.4	1.62 ± 0.88	0.08 – 4.14	Very low

Table 32. SOC stock and land quality index of the post-flood soils of AEU 3 (Land use wise)

Parameters→ Land Use↓	Soil organic carbon stock (Mg ha^{-1})	Soil organic carbon stock (kg m^{-2})		LQI
	Range	Mean ± SD	Range	
Rice	3.40 - 26.8	1.68 ± 0.67	0.34 - 2.68	Very low
Coconut	8.30 - 31.1	1.87 ± 0.73	0.83 - 3.11	Very low
Vegetables	2.50 - 35.1	1.51 ± 0.94	0.25 - 3.51	Very low
Banana	0.80 - 41.4	1.55 ± 1.14	0.08 - 4.14	Very low

The SOC stock of the post-flood soils of AEU 3 ranged from 0.08 kg m^{-2} to 4.14 kg m^{-2} with a mean value of 1.62 kg m^{-2}. Nooranadu panchayath had the highest mean value of SOC stock (2.12 kg m^{-2}) and Chettikulangara panchayath had the lowest mean value (1.03 kg m^{-2}). All the panchayath were classified under very low quality with respect to land quality (Table 31).

Coconut land use had the highest mean value of SOC stock (1.86 kg m^{-2}) and vegetables land use had the lowest mean value (1.51 kg m^{-2}) (Table 32).

4.4. GENERATION OF MAPS USING GIS TECHNIQUE

Geo-referenced thematic maps of different soil characteristics like textural classes, soil pH, OC, available N, P, K, Ca and Zn, soil nutrient indices for OC, N, P and K, were prepared using the GIS technique (ArcGIS). Map of land quality index and relative soil quality index of the post flood soils of the AEU 3 was also prepared based on the data generated after the assessment of SQI.

4.5. CORRELATION ANALYSIS OF THE DATA

Pearson's Correlations were worked out among the analysed physical, chemical and biological parameters (Table 26). Positive correlations ($p<0.01$) were found between the sand per cent, bulk density and particle density. Clay per cent was seen to be highly positively correlated with the MWD, per cent of WSA and WHC (Table 33). Organic content in the soils was highly positively correlated ($p<0.01$) with the MWD, WSA per cent, soil moisture content and the WHC (Table 33).

Sand per cent in the samples were negatively correlated ($p<0.01$) with the MWD, WSA per cent, WHC. Negative correlations were found between silt per cent and the bulk density and particle density (Table 33).

In case of the chemical parameters, positive correlations were observed among OC and N, OC and Mg, OC and Mn, N and Fe, P and K, Mg and S, Mg and Mn, Mn and S, EC and K. ($p <0.01$). Also, OC and Fe, OC and S, were found to be positively correlated ($p <0.05$). Parameters like N and Cu, P and S, Fe and Cu were negatively correlated ($p <0.05$). (Table 34).

Table 33. Correlation analysis of physical parameters and organic carbon content

	Sand %	Silt %	Clay %	MWD	WSA %	BD	PD	Porosity %	Soil moisture%	WHC%	OC %
Sand %	1.000										
Silt %	**-0.916****	1.000									
Clay %	**-0.939****	**0.724****	1.000								
MWD	**-0.849****	**0.706****	**0.859****	1.000							
WSA %	**-0.582****	**0.431****	**0.634****	**0.833****	1.000						
BD	**0.694****	**-0.668****	-0.625**	**-0.659****	-0.525**	1.000					
PD	**0.781****	**-0.737****	-0.716**	**-0.738****	-0.552**	**0.884****	1.000				
Porosity %	0.364**	-0.354**	-0.325**	-0.307**	-0.169NS	0.017NS	0.438**	1.000			
Soilmoisture %	-0.325**	0.321**	**0.286***	0.437**	0.370**	-0.540**	-0.493**	0.115NS	1.000		
WHC%	**-0.766****	**0.776****	**0.657****	**0.690****	0.472**	**-0.849****	**-0.766****	0.010NS	**0.639****	1.000	
OC %	-0.516**	0.420**	0.529**	**0.854****	**0.856****	-0.452**	-0.492**	-0.172NS	**0.420****	**0.492****	1.000

**Significance at 1%   *Significance at 5%

Table 34. Correlation analysis of the chemical parameters.

	pH	EC	OC	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
pH	1.000													
EC	-0.257*	1.000												
OC	-0.064^{NS}	-0.019^{NS}	1.000											
N	-0.053^{NS}	-0.224^{NS}	**0.465****	1.000										
P	0.160^{NS}	0.290*	-0.074^{NS}	0.068^{NS}	1.000									
K	-0.044^{NS}	**0.364****	0.122^{NS}	0.014^{NS}	**0.322****	1.000								
Ca	0.195^{NS}	0.072^{NS}	0.254*	0.253*	0.471**	0.361**	1.000							
Mg	0.076^{NS}	-0.075^{NS}	**0.460****	-0.063^{NS}	-0.203^{NS}	0.263*	0.206^{NS}	1.000						
S	-0.131^{NS}	-0.066^{NS}	**0.251***	0.174^{NS}	**-0.350****	0.127^{NS}	0.084^{NS}	**0.478****	1.000					
Fe	-0.146^{NS}	0.172^{NS}	**0.251***	**0.562****	0.229^{NS}	0.138^{NS}	0.391**	-0.291*	0.081^{NS}	1.000				
Mn	-0.056^{NS}	0.122^{NS}	**0.467****	-0.082^{NS}	-0.220^{NS}	0.213^{NS}	0.149^{NS}	**0.699****	**0.493****	-0.210^{NS}	1.000			
Cu	0.070^{NS}	-0.068^{NS}	-0.114^{NS}	**-0.388****	-0.076^{NS}	-0.121^{NS}	-0.359**	-0.022^{NS}	-0.342**	**-0.501****	-0.052^{NS}	1.000		
Zn	0.335**	-0.175^{NS}	-0.016^{NS}	0.022^{NS}	0.106^{NS}	0.140^{NS}	0.321**	0.083^{NS}	-0.052^{NS}	-0.017^{NS}	-0.173^{NS}	-0.015^{NS}	1.000	
B	-0.047^{NS}	-0.249*	0.043^{NS}	0.025^{NS}	-0.306**	-0.192^{NS}	-0.078^{NS}	0.036^{NS}	0.110^{NS}	-0.050^{NS}	0.009^{NS}	0.045^{NS}	-0.097^{NS}	1.000

**Significance at 1%   *Significance at 5%

The biological attributes such as acid phosphatase (AP) activity and dehydrogenase (DH) activity were observed to be positively correlated with the amount of organic carbon in the soil sample (Table 35).

Table 35. Correlation analysis of biological parameters and organic carbon content

	OC	AP	DH
OC	1.000		
AP	**0.626****	1.000	
DH	**0.467****	**0.456****	1.000

**Significance at 1%

*Significance at 5%

5. DISCUSSION

A study was undertaken on the assessment of soil quality in the post-flood scenario of the AEU 3 in the Alappuzha district of Kerala and for generation of GIS maps. The study included the collection of soil samples from the flood affected areas of the AEU, characterisation of the samples for various physical, chemical and biological attributes, setting up a minimum data set (MDS) for the formulation of soil quality index (SQI) and mapping using GIS. The results of the study are discussed in this chapter.

5.1. SOIL QUALITY ANALYSIS

The results of the physical, chemical and biological attributes analysed and the attributes which were used to set up the MDS and computing the SQI, are discussed below.

5.1.1. Physical attributes

5.1.1.1. Bulk density

The bulk density of the post-flood soils of Onattukara varied from 0.76 Mg m^{-3} to 1.76 Mg m^{-3}. The mean value of bulk density observed was 1.29 Mg m^{-3} (Table 5). 37.1 per cent of the samples had bulk density values between 1.4 to 1.6 Mg m^{-3}, 31.4 per cent had values less than 1.2 Mg m^{-3}, 28.6 per cent had values between 1.2 to 1.4 Mg m^{-3} and only 2.9 per cent had values above 1.6 Mg m^{-3} (Fig. 3).

Onattukara region is characterised by the well-drained coarse textured soil. Bulk density of sandy soils generally range between 1.2 and 1.8 Mg m^{-3} (Aubertin and Kardos, 1965). Morisada *et al.* (2004) reported that though bulk density depends on several factors like compaction, consolidation and amount of soil organic carbon, it is highly correlated to organic carbon content.

The highest mean value of bulk density was observed in the Nooranadu panchayath (1.43 Mg m^{-3}) and the lowest mean value in Veeyapuram panchayath (0.87 Mg m^{-3}) (Table 5). The variation in the bulk density is due to the textural difference observed. Nooranad had mostly loamy sand texture that has higher sand per cent whereas, Veeyapuram had clay loam and sandy clay loam with comparatively lower content of sand. Chaudhary *et al.* (2003) reported that the influence of sand content on the bulk density outweighs the other parameters and hence, clayey soil tends to have lower bulk density and sandy soil have higher bulk density.

Banana land use had the highest mean value of bulk density (1.47 Mg m^{-3}) and rice land use had the lowest mean value (1.09 Mg m^{-3}) (Table 6). The lower bulk density of rice fields is due to high clay and organic matter content compared to other land uses.

5.1.1.2. Particle density

The value of particle density in the flooded regions of AEU 3 ranged from 1.33 Mg m^{-3} to 2.49 Mg m^{-3} with a mean value of 2.08 Mg m^{-3} (Table 5). 52.9 per cent of samples have values less than 2.2 Mg m^{-3}, 38.6 per cent had values between 2.2 and 2.4 Mg m^{-3} and 8.5 per cent samples had values from 2.4 to 2.6 Mg m^{-3} (Fig. 4). The highest mean value (2.29 Mg m^{-3}) was observed in Nooranadu panchayath and the lowest mean value (1.43 Mg m^{-3}) in Veeyapuram panchayath (Table 5).

Particle density of a soil is actually the weighted mean value of the various types of minerals and humus (Blake and Hartge, 1986). The variations in the observed particle densities in the soils can also be explained with the same reasons as in the case of bulk density.

The lowest mean value of particle density was observed in the rice land use (1.78 Mg m^{-3}) and the highest mean value was observed in the banana land use (2.25 Mg m^{-3}) (Table 6).

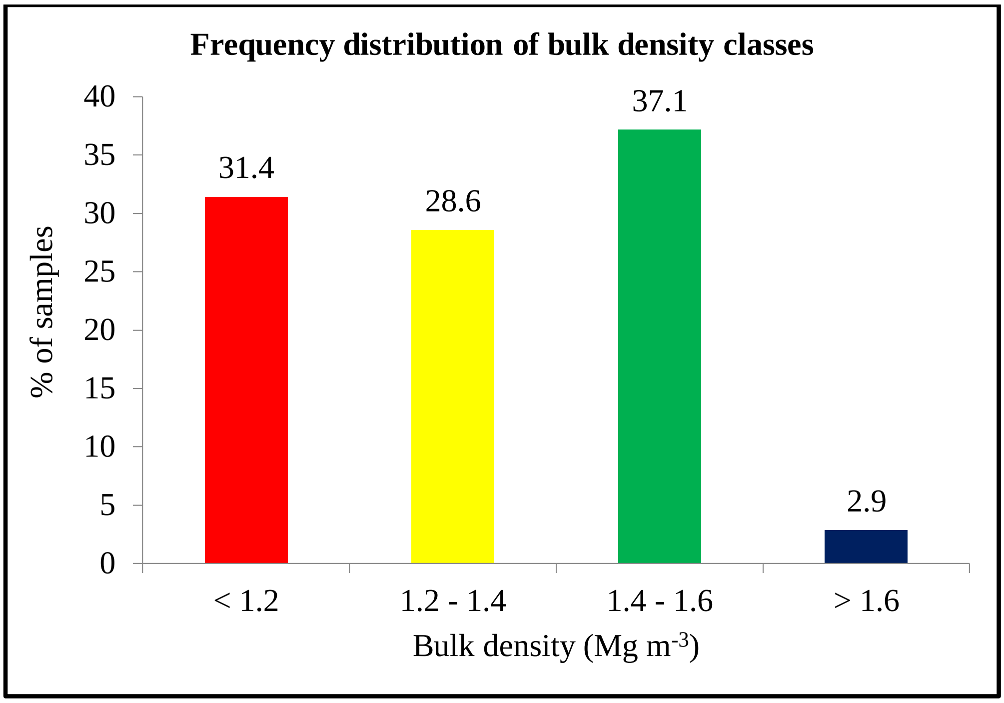


Fig. 3. Frequency distribution of classes of bulk density in the post-flood soils of AEU 3

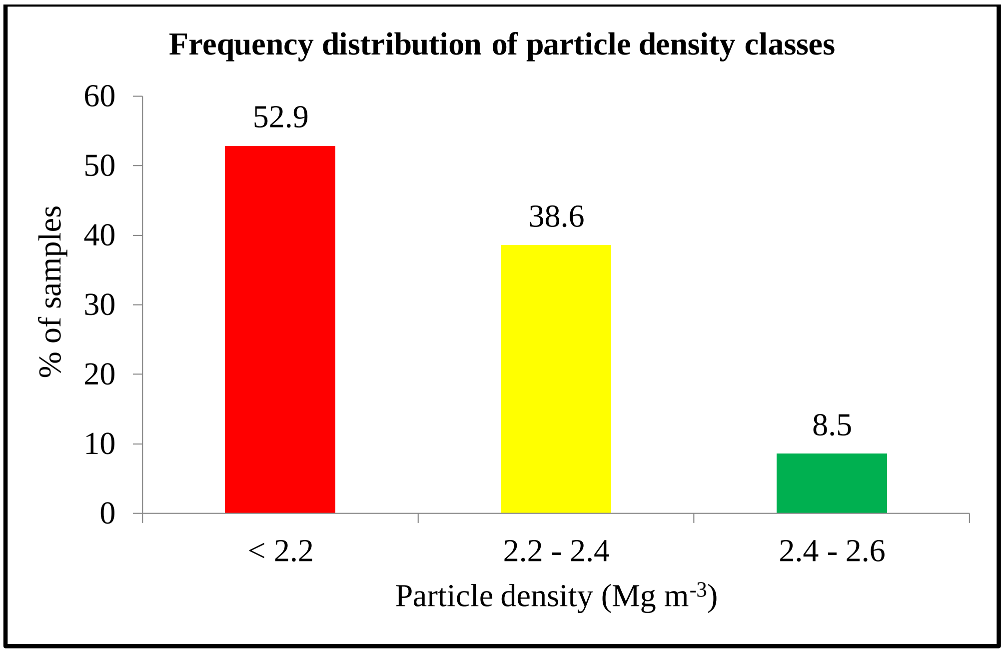


Fig. 4. Frequency distribution of classes of particle density in the post-flood soils of AEU 3

5.1.1.3. Porosity

The values of porosity per cent of the samples in the post-flood soils of AEU 3 varied between 24.4 and 49.3 per cent with a mean value of 37.8 per cent (Table 5). Majority of the samples (94.3 per cent) had porosity of 30 to 50 per cent. Only 5.7 per cent samples had the porosity less than 30 per cent (Fig. 5).

Sandy soils in tropics usually exhibit little changes in the porosity. Porosity ranges from 33 per cent to 47 per cent are generally recorded (Bruand *et al.,* 2005).

Among various land uses, soils of vegetables land use had the highest mean porosity value (29.6 per cent) and soils of banana land use had the lowest mean value (24.2 per cent) (Table 6). Soils from vegetables land use had comparatively higher porosity. Organic matter addition to the soil as a part of organic cultivation practices followed in the region is the possible reason. The above mentioned addition lacks in banana cultivation in the region, and hence the porosity of the soil remains less.

5.1.1.4. Soil texture

The predominant textural class in the Onattukara region was loamy sand. Other textural classes like sandy loam, sandy clay loam, clay loam, loam and clay were also identified (Fig.6 and 7).

The flood has caused depositions rich in sand, silt and clay that have brought in the textural changes observed in the surface soil. Based on the proportion of the sediments to the native soil, the texture might differ. As a result, changes in the soil properties like infiltration, water holding capacity, permeability and porosity may be observed (DSSSC, 2018).

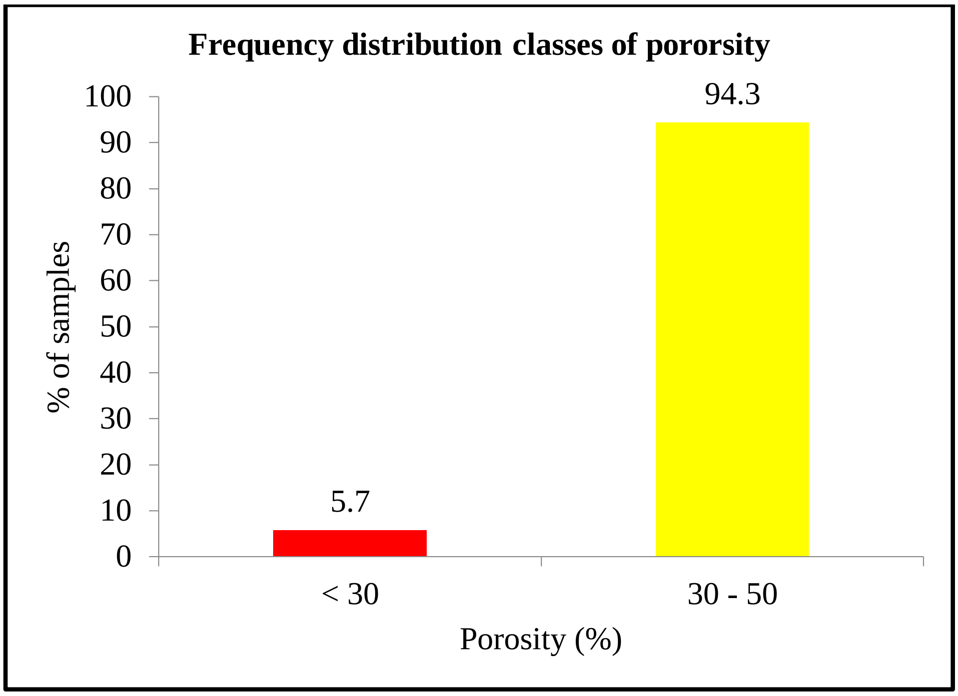


Fig. 5. Frequency distribution of classes of porosity in the post-flood soils of AEU 3

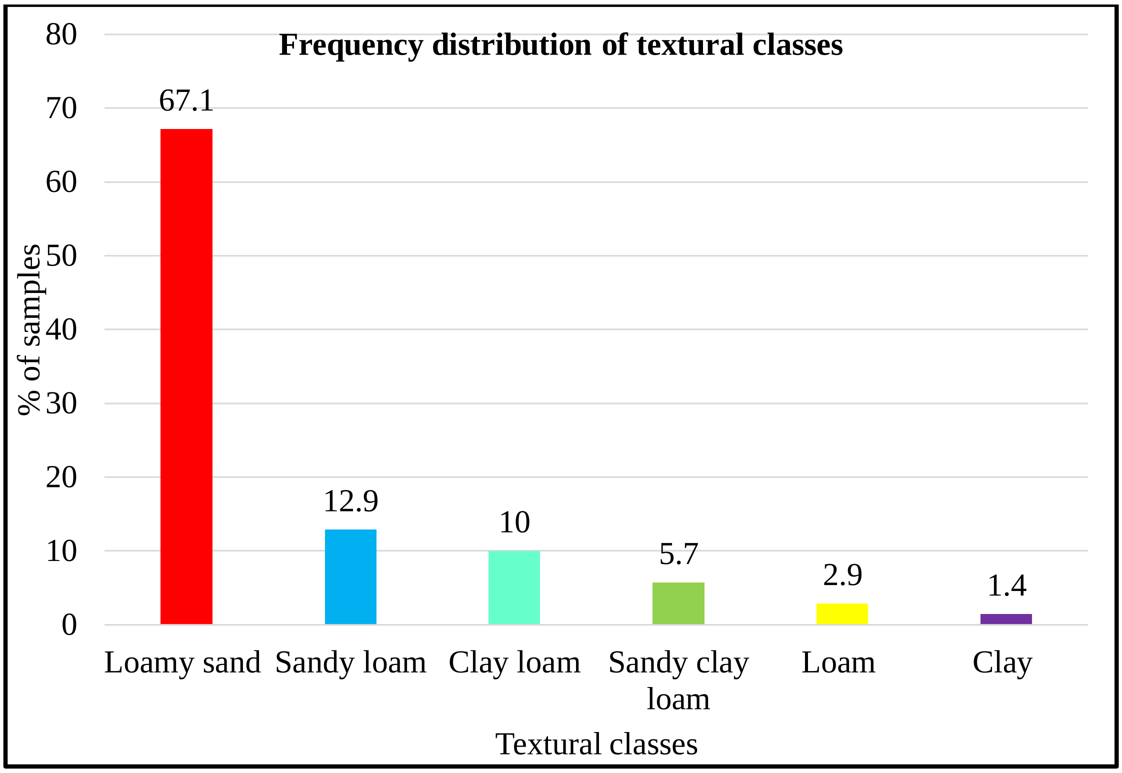


Fig. 6. Frequency distribution of textural classes in the post-flood soils of AEU 3

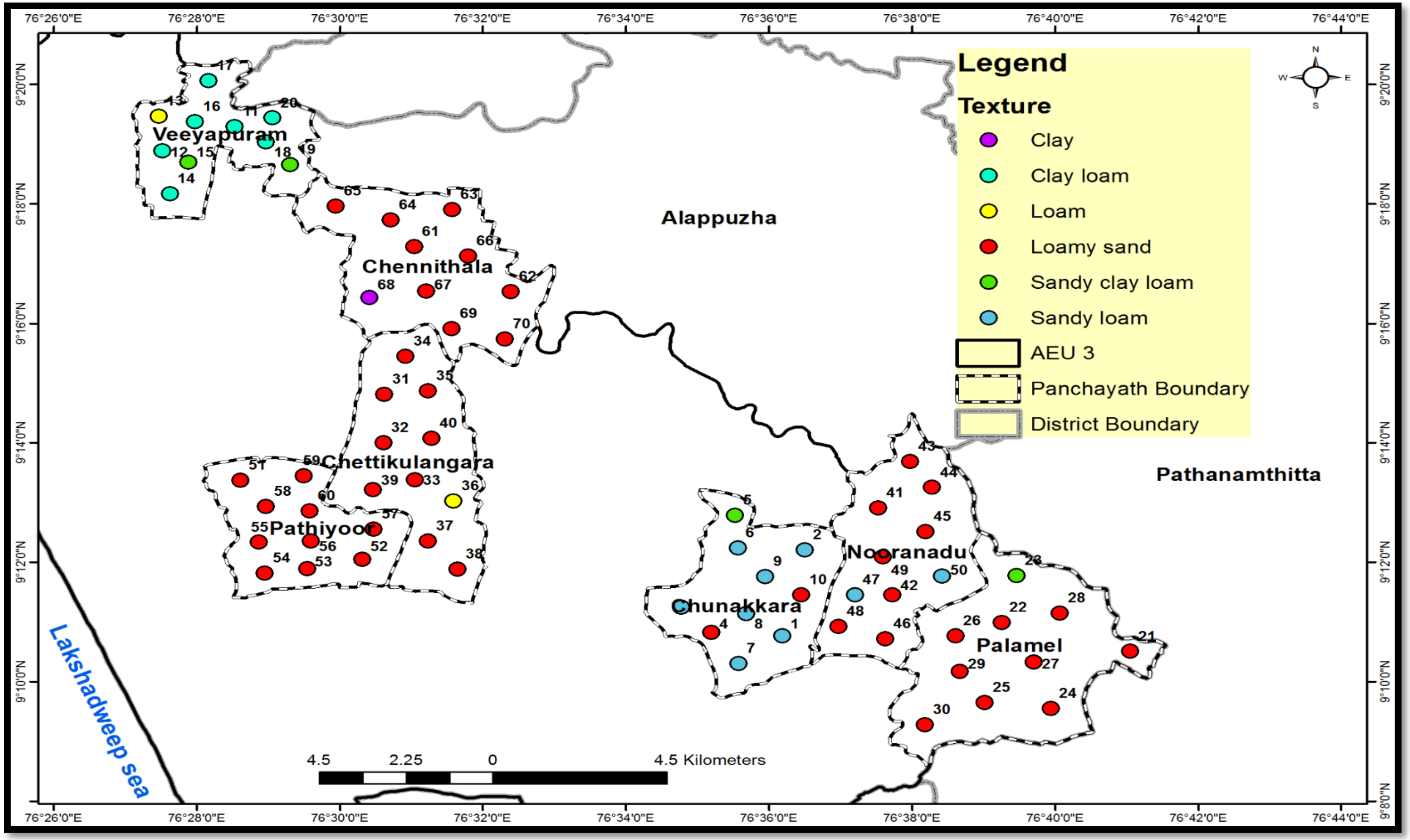


Fig. 7. Spatial distribution of textural classes in the flood affected areas of AEU 3

5.1.1.5. Depth of silt/clay/sand deposition

Prominent silt deposition was found in sampling location H6 (2 cm thickness) and H8 (5 cm thickness) of Chennithala panchayath. Significant deposition of sand/silt/clay was not found all over the region, rather a light coating of silt was found in some of the areas. The depositions were found on the banks of the river Achankovil, which drains the sandy plain of AEU 3. The main cause of flood in the AEU was the overflowing of the Achankovil river in the devastating rainfall during August, 2018.

5.1.1.6. Aggregate analysis

The highest value of mean weight diameter in the post-flood soils observed was 3.74 mm and the lowest value was 0.284 mm. Majority (61.4 per cent) of the samples had MWD less than 1 mm and 18.6 per cent samples had MWD above 2 mm.

The rest of the samples ranged between a MWD of 1 mm and 2 mm (Fig.8). Soil samples of Veeyapuram panchayath had the highest mean value (2.92 mm) of MWD and that of Chettikulangara had the lowest value (0.64 mm) (Table 9).

The per cent of water stable aggregates in the post-flood soils of AEU 3 ranged from 49.6 to 87.4. Majority of samples (60 per cent) had 50 to 70 per cent WSA and 38.6 per cent had above 70 per cent (Fig. 9). Highest mean value of WSA (79.2 per cent) was observed in Veeyapuram and the lowest (63.4 per cent) in Chettikulangara (Table 9).

Chaney and Swift (1984) reported that the soil organic matter was the major factor involved in the stabilization of the soil aggregates. Sullivan (1990) proposed that organic matter improve the air encapsulation within the soil that reduce water uptake rates and prevents slaking and breakdown of aggregates. Aggregate stability depends both on the forces that bind the particle together and the extent of disruptive stress (Beare and Bruce, 1993). Biotic, abiotic and environmental factors affect the stability of the aggregates (Chen *et al.*, 2015).

The influence of organic matter content in soil is evident in both MWD and the WSA per cent of the rice land use which had the highest value of both parameters in comparison with other land uses.

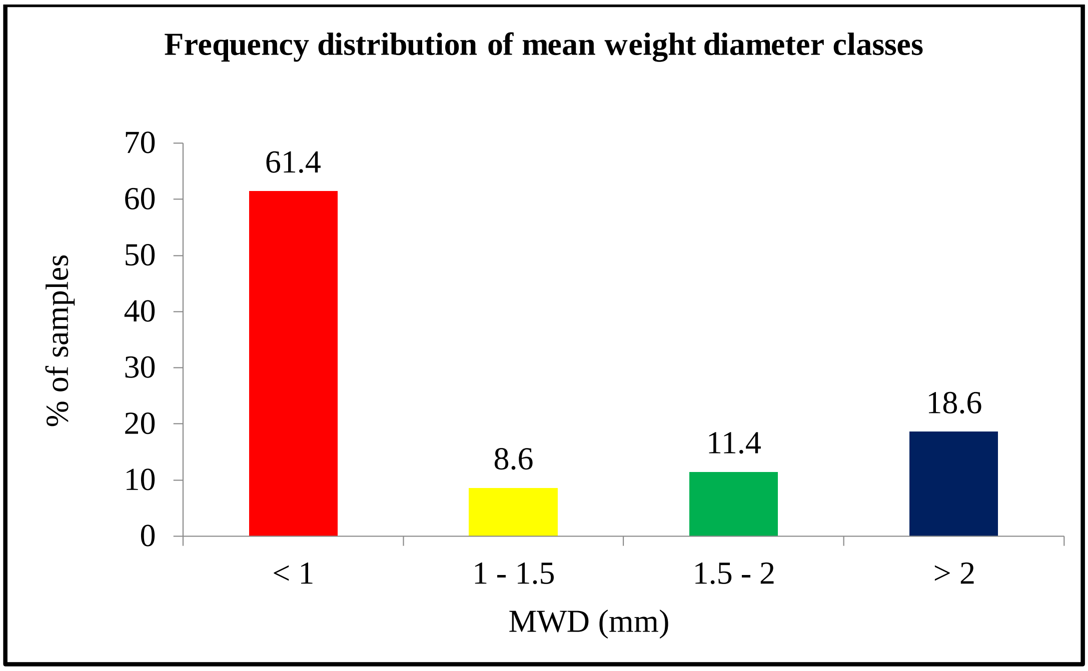


Fig. 8. Frequency distribution of classes of MWD in the post-flood soils of AEU 3

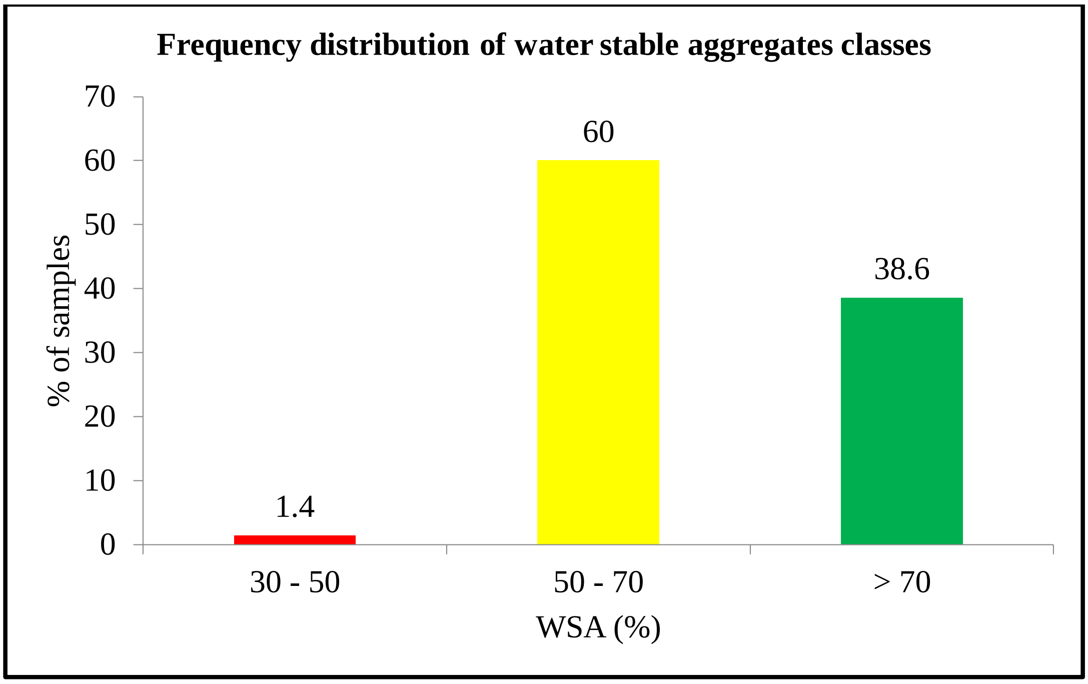


Fig. 9. Frequency distribution of classes of WSA in the post-flood soils of AEU 3

5.1.1.7. Soil moisture

Soil moisture content in the post-flood samples of AEU 3 varied from 5.03 per cent to 48.42 per cent with a mean value of 19.29 per cent (Table 11). 47.1 per sect samples had soil moisture content between 15 to 25 per cent and 30 per cent samples had 10 to 15 per cent moisture content (Fig.10). Highest mean value of soil moisture content (27.2 per cent) was observed in the Veeyapuram panchayath and the lowest mean value (13.9 per cent) in the Palamel panchayath.

Nair *et al.* (2018) reported that the structural aggregates, presence of coarse fragments, along with large porosity ensure rapid infiltration and permeability of water. In the structure less soils of Onattukara, rapid water transmission happens. This accounts for the lower moisture content of the soil of this region.

Bhaskaran *et al.* (2009) reported that, use of organic manures is the only way of improving soil structure in coarse textured soils. Addition of organic matter will result in better aggregation of soil particles, reduction of macropores with increase in micropores, thus reducing hydraulic conductivity and increasing water retention. Soils of rice land use had highest mean soil moisture content (28.8 per cent) due to the high organic matter and clay content whereas, soils of banana land use had the lowest soil moisture content (13.3 per cent) (Table 12).

5.1.1.8. Water holding capacity

The water holding capacity of post-flood soils in AEU 3 varied widely from 11.62 per cent to 71.7 per cent with a mean value of 35.6 per cent (Table 11). 48.6 per cent soils had WHC between 30 and 50 per cent. 33 per cent samples had less than 30 per cent WHC and 17 per cent had values between 50 and 70 per cent (Fig.11). Average water holding capacity was found to be highest (58.9 per cent) in soils of Veeyapuram and lowest in soils of Palamel (28.6 per cent) (Table 11).

The variation in the WHC can be explained by the same factors as in the case of soil moisture content. Among land uses, soils of rice land use had highest mean water holding capacity (44.2 per cent) and banana had lowest mean value (29.9 per cent) (Table 12).

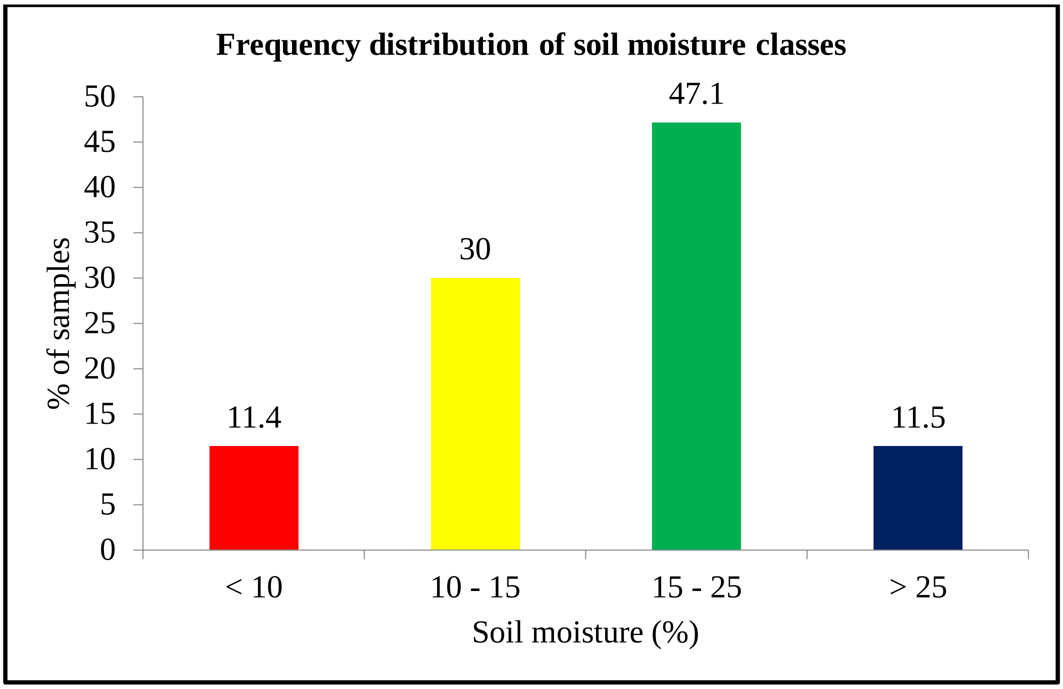


Fig. 10. Frequency distribution of classes of soil moisture in the post-flood soils of AEU 3

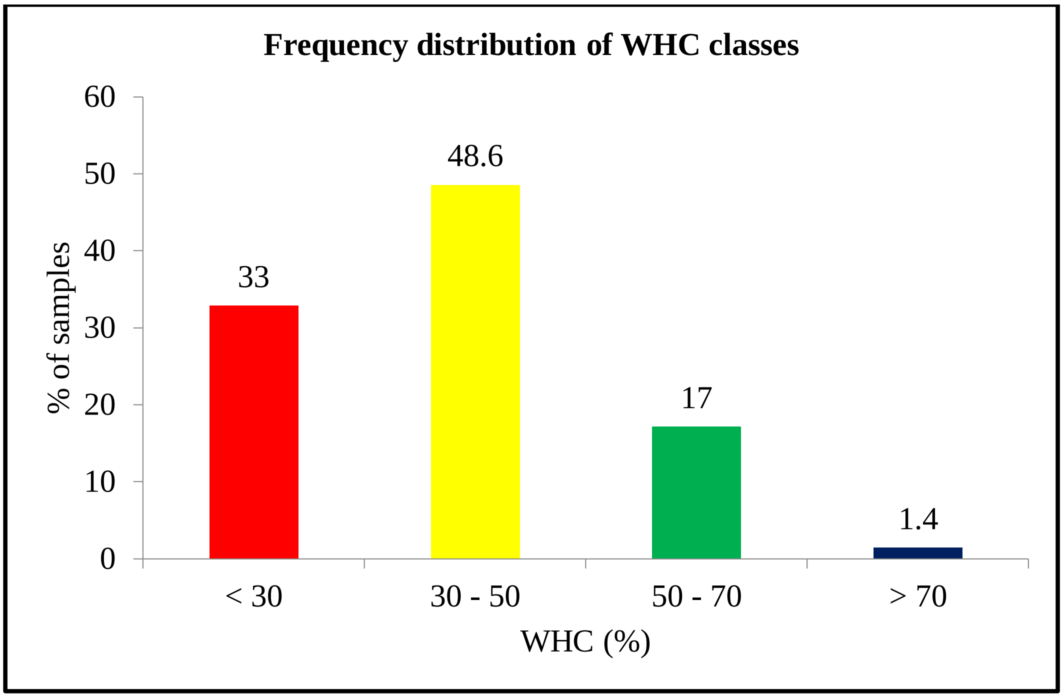


Fig. 11. Frequency distribution of classes of WHC in the post-flood soils of AEU 3

5.1.2. Chemical attributes

The results of the analysis of the chemical attributes of the post flood soils are discussed below.

5.1.2.1. Soil pH

The pH of the flood affected areas of the Onattukara sandy plain ranged from 3.52 to 5.37 with a mean value of 4.57 (Table 13). Among the total, 37.2 per cent of the samples comes under the extremely acidic class (pH 3.51- 4.5), 57.1 per cent under the very strongly acidic class (4.51- 5.0) and only 5.71 per cent in the strongly acidic (5.0 – 5.5) class (Fig. 12 and 13). Fig. 11 shows the various pH classes in the post flood soils of AEU 3.

Santhosh, (2013) also reported that pH of the majority of samples of Onattukara region were in the range of 4.51 - 5.0. Nair *et al.* (2018) reported that sandy soils of Onattukara are strongly acidic in surface and subsoil layers with a low base saturation. It is clear from the data that the acidity has been increased in the post flood soils of AEU 3 in comparison to pre flood condition. The Al saturation of the region is high with values ranging from 14 to 82 per cent with increase in depth.

The lowest mean value of pH was reported from the rice land use (4.51) (Table 14). The content of organic matter and available Fe were observed to be higher in the rice fields of the region which adds to the acidity (Table 18). Development of strong acid condition in the soil can also be due to application of fertilizers having residual acidity, without adequate and regular application of lime, thereby failing to neutralize the acidity generated (KSPB, 2013).

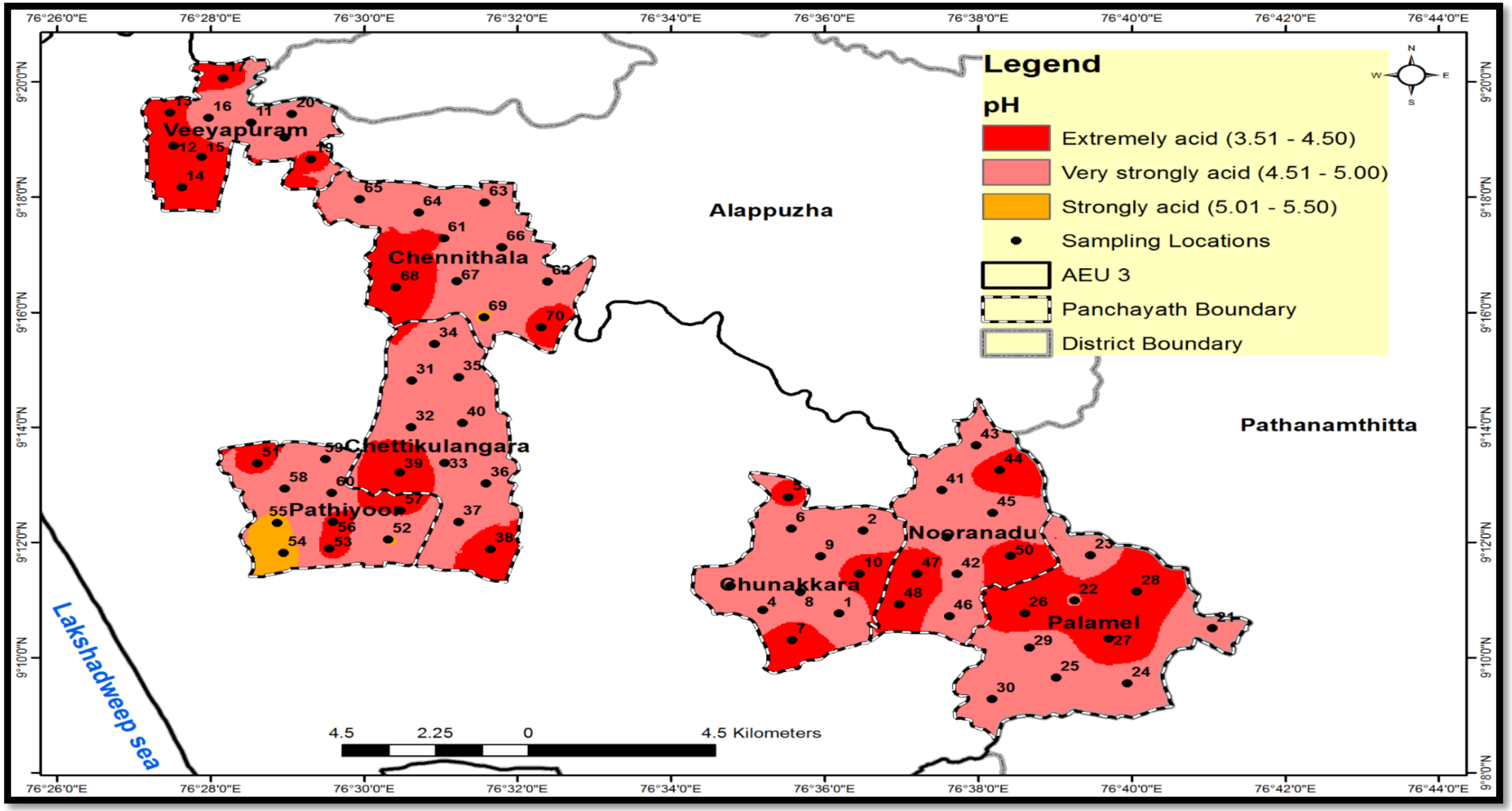


Fig. 12. Spatial distribution of classes of soil reaction in the post-flood soils of AEU 3

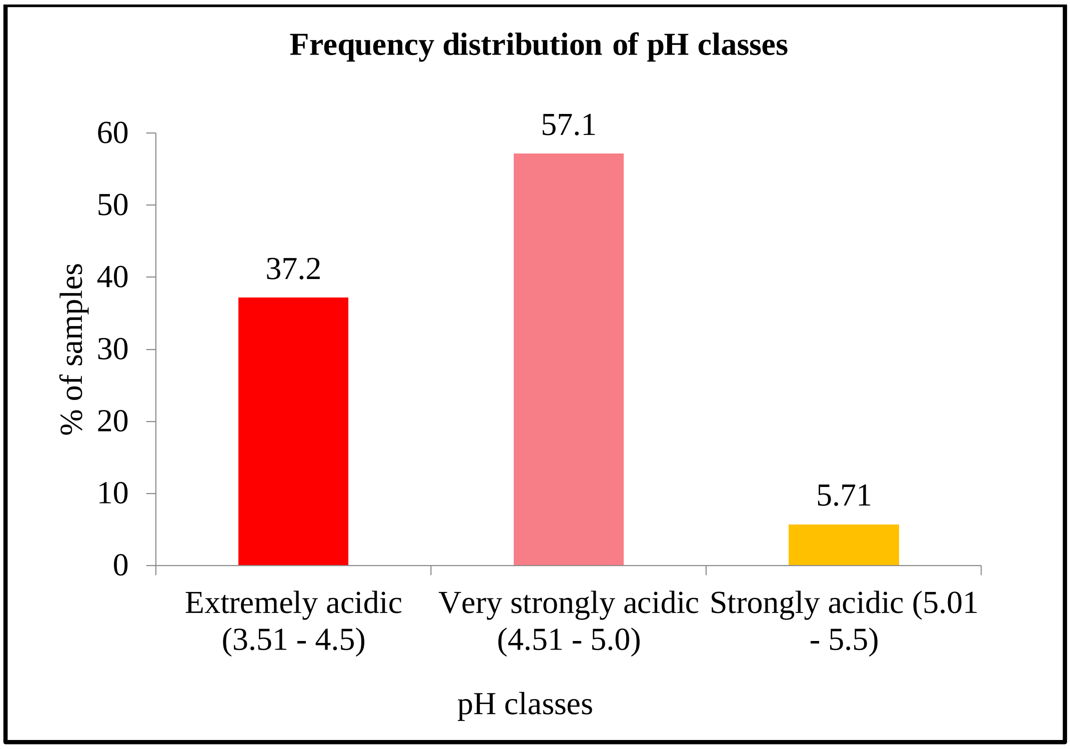


Fig 13. Frequency distribution of pH classes in the post-flood soils of AEU 3

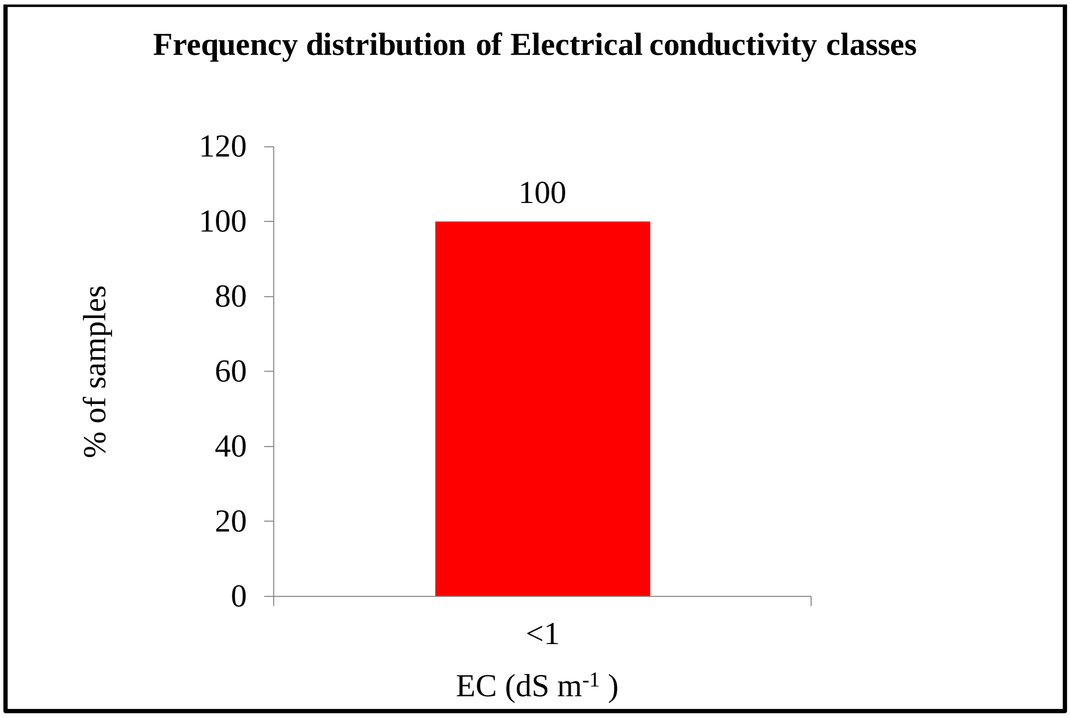


Fig 14. Frequency distribution of EC classes in the post-flood soils of AEU 3

5.1.2.2. Electrical conductivity

The value of electrical conductivity varied from 0.02 dS m^{-1} to 0.97 dS m^{-1} in the post-flood soils of AEU 3 (Fig. 14). The mean value observed was 0.28 dSm^{-1} (Table 13). The range is very low and explains that the soil belongs to non-saline category. The mineral salts present in the soil are lost due to the free drainage condition existing in the light textured soil of the region (Verma *et al.,* 2005). The humid climate and rainfall facilitate heavy leaching, responsible for the low salt content of the area (Nair *et al.,* 2018).

5.1.2.3. Organic carbon

The soil organic carbon in the flood affected area of the AEU 3 ranged from 0.03 to 1.98 per cent in the post flood soils of AEU, with a mean value of 0.87 per cent (Table 13). Half of the samples under study belonged to the medium class (0.3 – 0.9 per cent) of organic carbon, 30 per cent samples belonged to the high class (> 0.9 per cent) and 20 per cent to the low class (< 0.3 per cent) (Fig. 15 and 16). Samples from Veeyapuram, which were exclusively from the rice fields, had the highest mean value (Table 13).

Area under the rice land use had the maximum organic carbon content (Table 14). The incorporation of the crop stubbles and the slower pace of mineralization under the submerged condition might be the reason behind the higher organic carbon content (Mini, 2015). The lower organic carbon content in the banana land use may be due to the increasing inorganic cultivation practice in the crop that has declined the addition of organic matter to the soil.

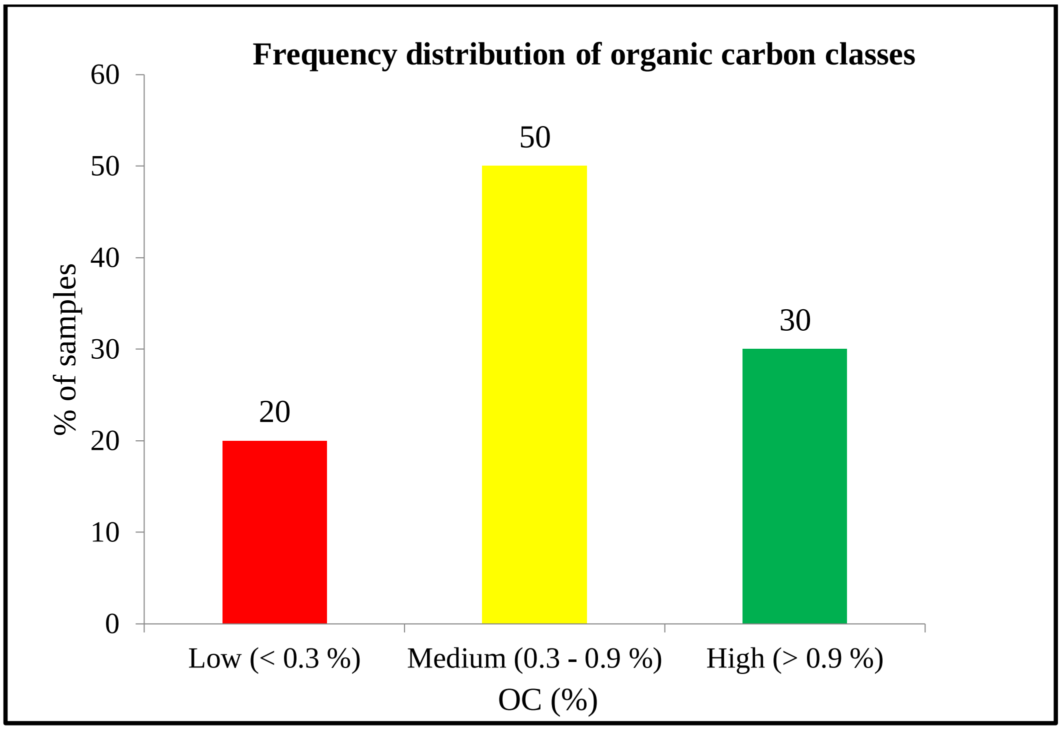


Fig 15. Frequency distribution of organic carbon classes in the post-flood soils of AEU 3

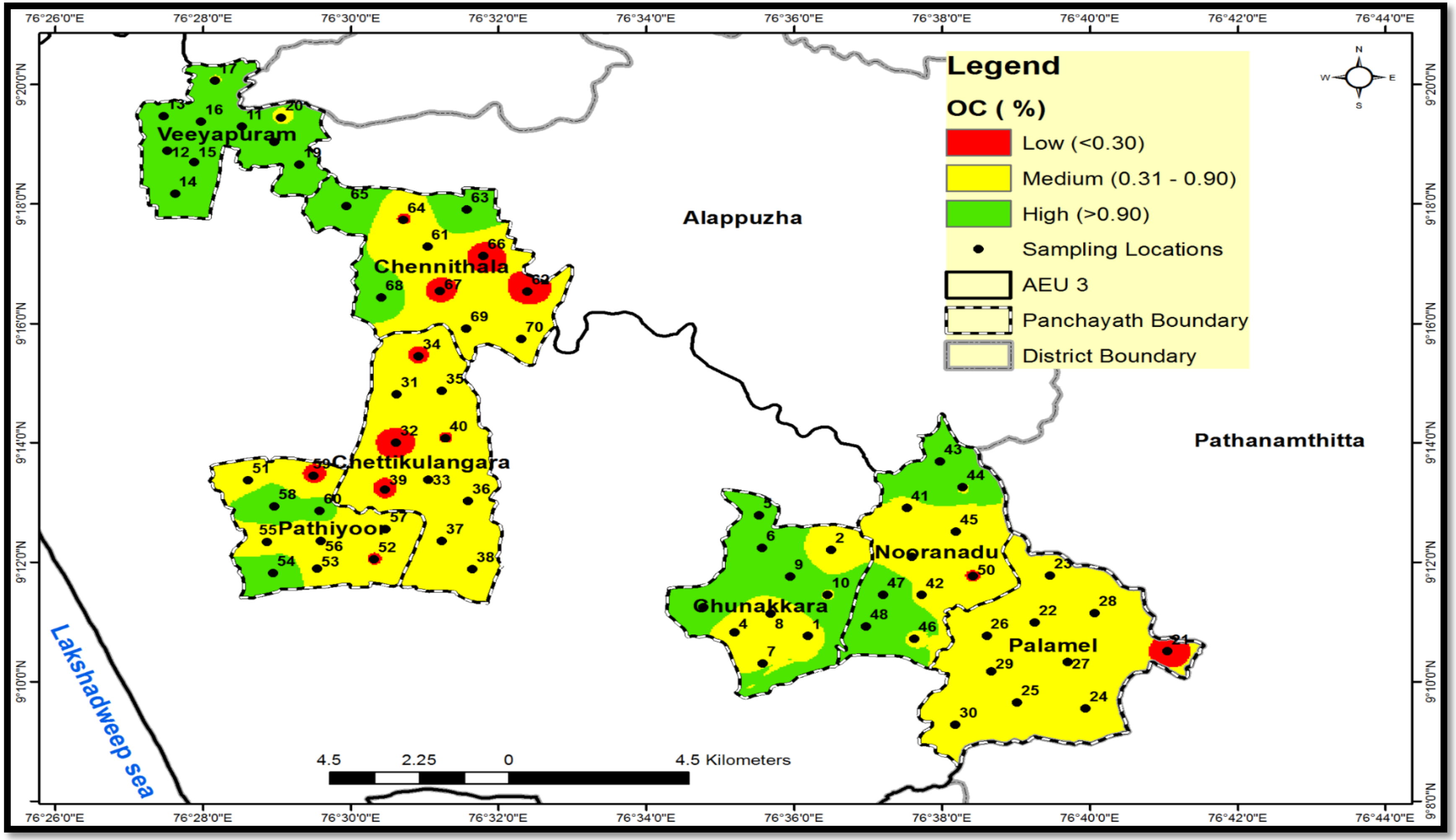


Fig. 16. Spatial distribution of classes of organic carbon in the post-flood soils of AEU 3

5.1.2.4. Available nitrogen

The available N content of the samples ranged from 38 kg ha^{-1} to 414 kg ha^{-1} in the flood affected areas of AEU 3, with a mean value of 221 kg ha^{-1} (Table 15). Majority (71.4 per cent) of the soils were low in available nitrogen and 28.6 per cent was medium in available nitrogen (Fig. 17 and 18). Although the content of organic carbon in the samples were seen to be mostly in the medium range, the status of available nitrogen in the region mostly came under low fertility class.

Usually nitrogen is observed to be under fertilized in the region. Moreover, the light textured soil facilitates the leaching losses of the nutrient ions. Split application of the nutrient that coincides with the plant requirement is advised in the region to avoid the leaching losses.

Rice land use had the highest mean content and banana land use had the lowest content of the nutrient (Table 16). Organic carbon content of the rice fields were high and hence they had higher availability of nitrogen.

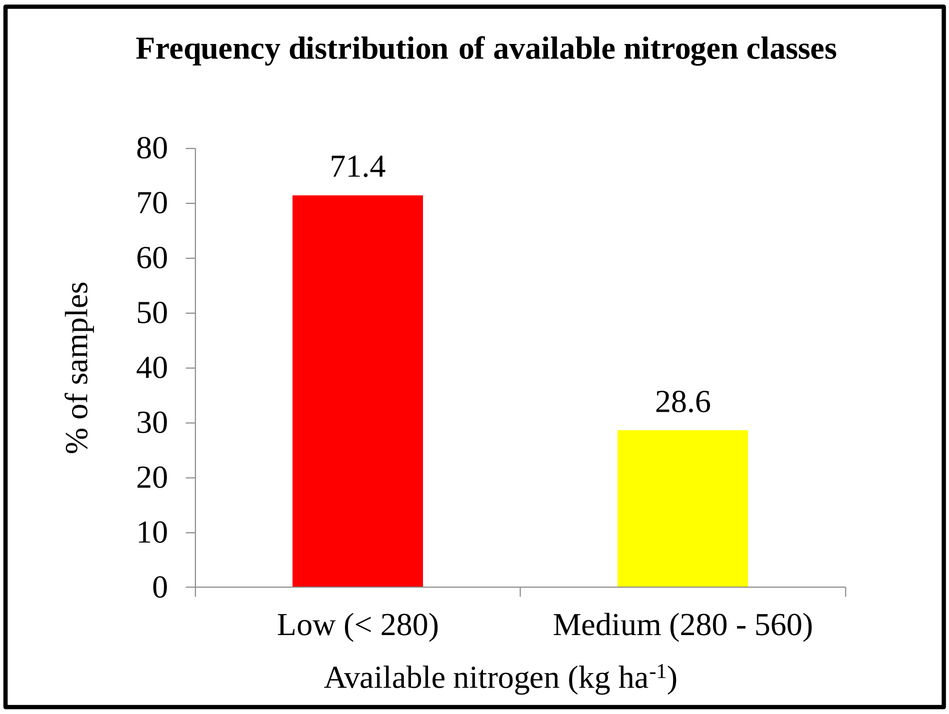


Fig. 17. Frequency distribution of classes of available N in the post-flood soils of AEU 3

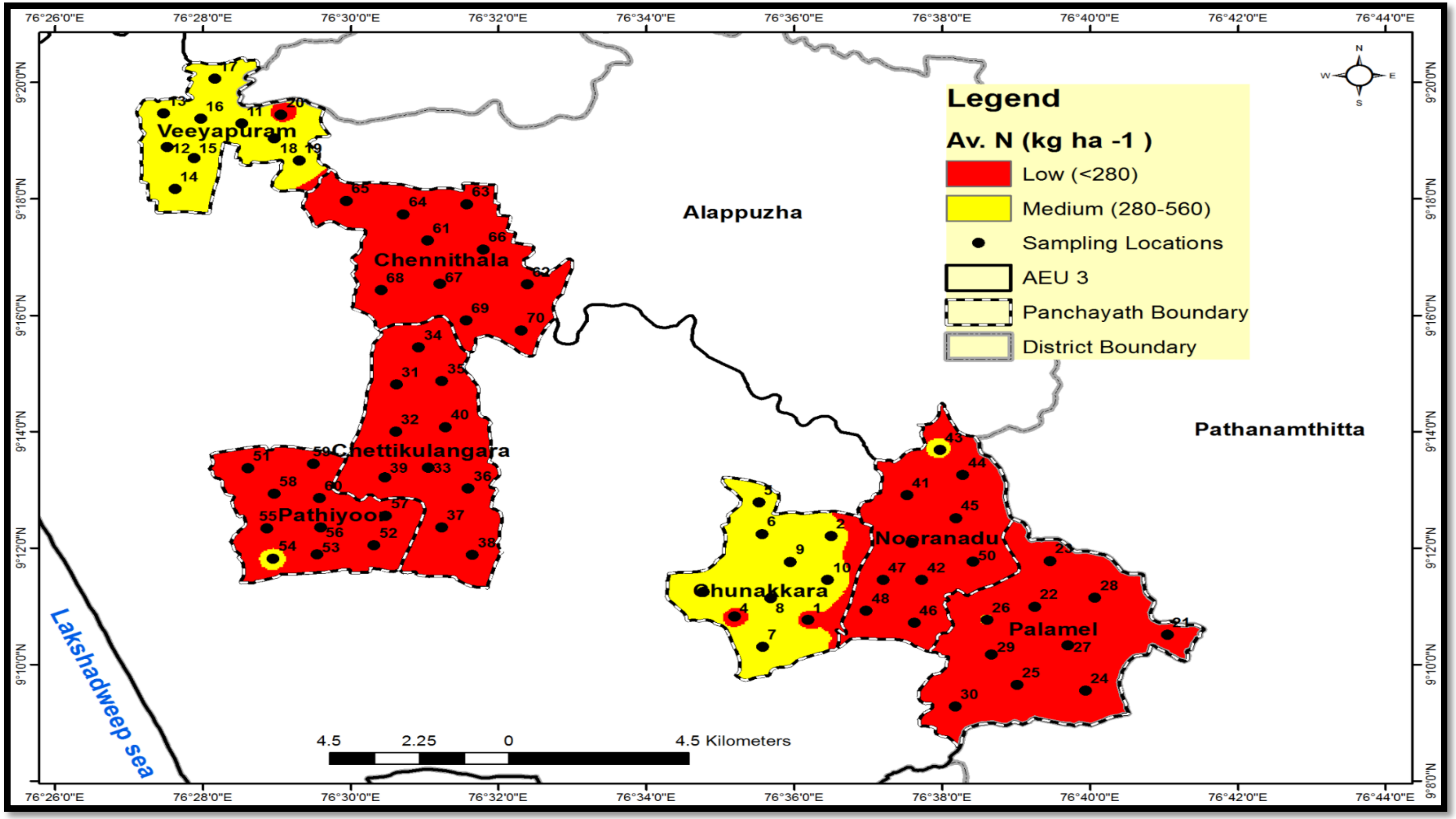


Fig. 18. Spatial distribution of fertility classes of available N in the post-flood soils of AEU 3

5.1.2.5. Available phosphorus

The available P content in the post-flood soils of AEU 3 ranged from 10.1 kg ha^{-1} to 185 kg ha^{-1} with a mean value of 60.1 kg ha^{-1} (Table 15). 71.4 per cent of the soil samples analysed were high in the available phosphorus content and 28.6 percent of them were in the medium class. No samples with low available phosphorus was found (Fig. 19 and 20). Mini and Mathew (2015) reported that the heavy input of the phosphatic fertilizers resulted in the very high amount of the available phosphorus in the Onattukara region.

Rice land use showed the lowest P availability and banana showed the highest value of the nutrient availability (Table 16). The lower availability of phosphorus in the rice land use may be attributed to the high Fe and Al content of the soils, which precipitates the phosphorus into insoluble forms (P fixation). The high available P content in the banana land use is due to the intensive cultivation with the regular application of acid soluble phosphatic fertilizers. The immobile nature of phosphate ions in soils must have caused the accumulation of P in soils.

High content of P in soils may induce the Zn deficiency in the region and hence it is important to follow soil test based recommendations (KAU, 2014).

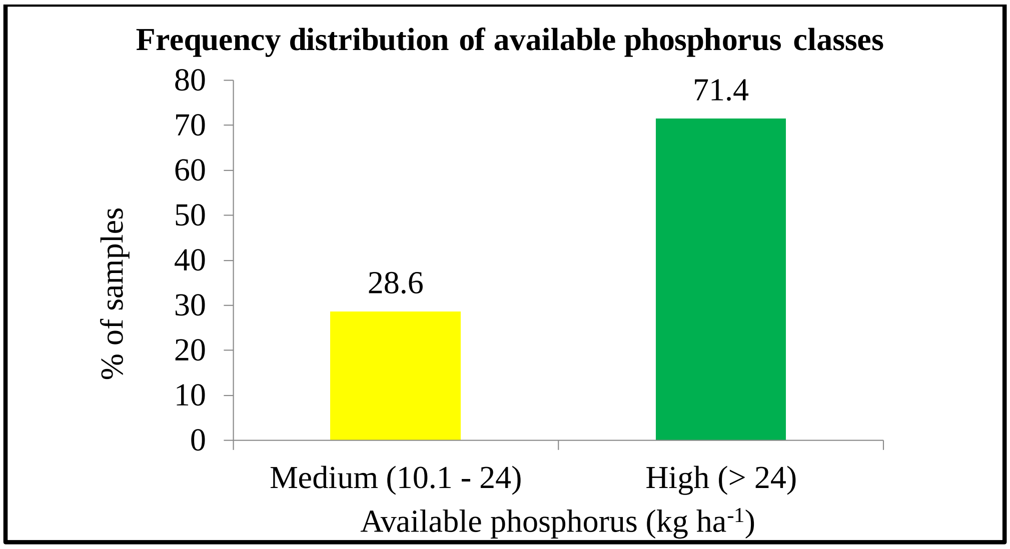


Fig. 19. Frequency distribution of classes of available P in the post-flood soils of AEU 3

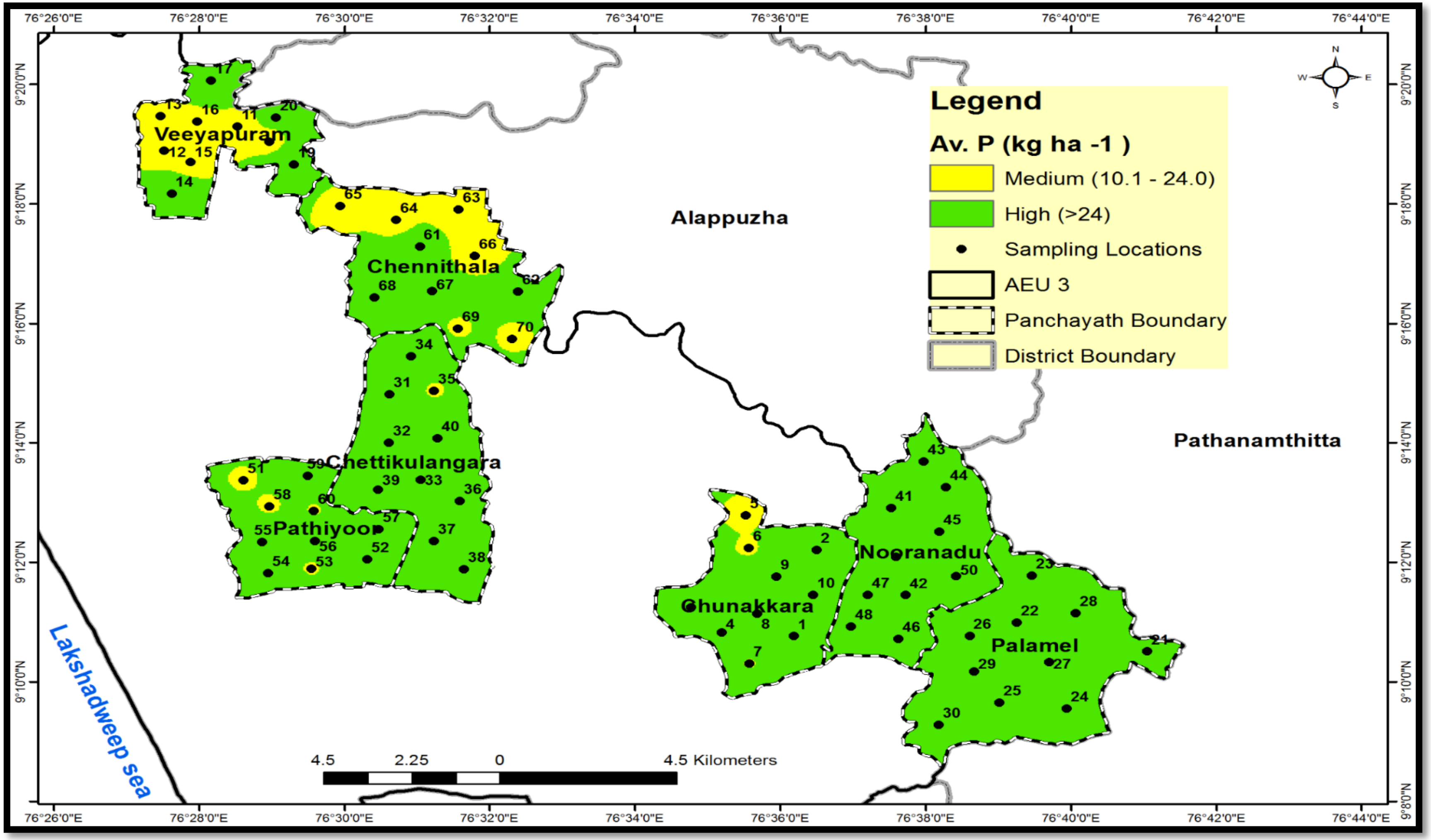


Fig. 20. Spatial distribution of fertility classes of available P in the post-flood soils of AEU 3

5.1.2.6. Available potassium

Potassium availability in the post-flood soils of AEU 3 varied largely between the lowest value of 12.8 kg ha^{-1} and the highest value of 258 kg ha^{-1} with a mean value of 108 kg ha^{-1} (Table 15). 62.9 per cent of the samples were under the low class of K availability and 37.1 per cent were medium in the availability of the nutrient (Fig. 21 and 22).

The reason behind the generally found lower status of potassium in Kerala soils can be the tropical climate and the abundance of the kaolinitic clay minerals with low K content. Moreover, the light textured soils of Onattukara coupled with low CEC do not support the retention of the nutrient, but rather promotes the leaching losses. Hence, it is advisable to apply the K fertilizers, in splits according to the need (Mini and Mathew, 2015).

Coconut land use had the lowest mean value of available K content and banana land use had the highest mean value (Table 16). Even though the K requirement of coconut is high compared to others, the availability of nutrient was low in the land use. This was due to lack of proper fertilizer application to replenish the nutrient content in the soil. In case of banana, K fertilization practiced might have contributed to the higher nutrient availability.

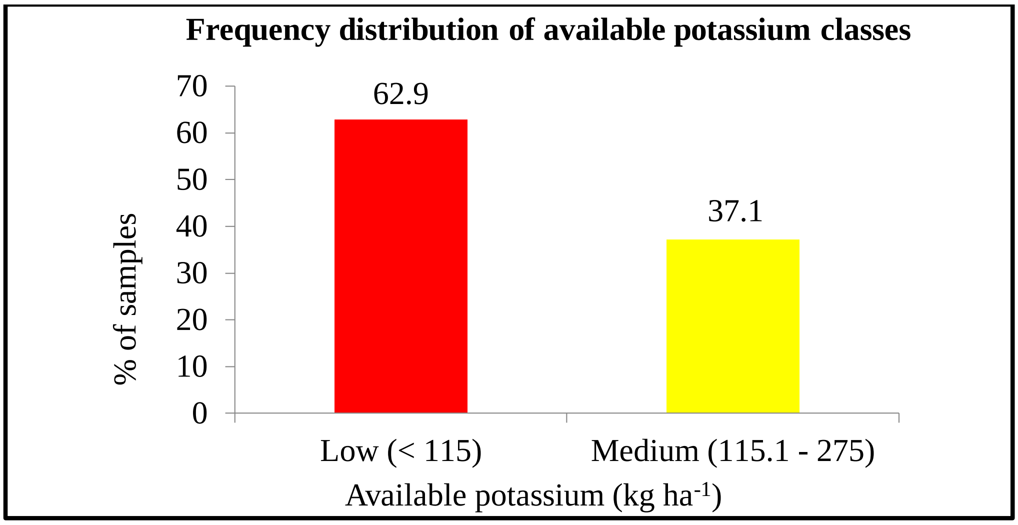


Fig. 21. Frequency distribution of classes of available K in the post-flood soils of AEU 3

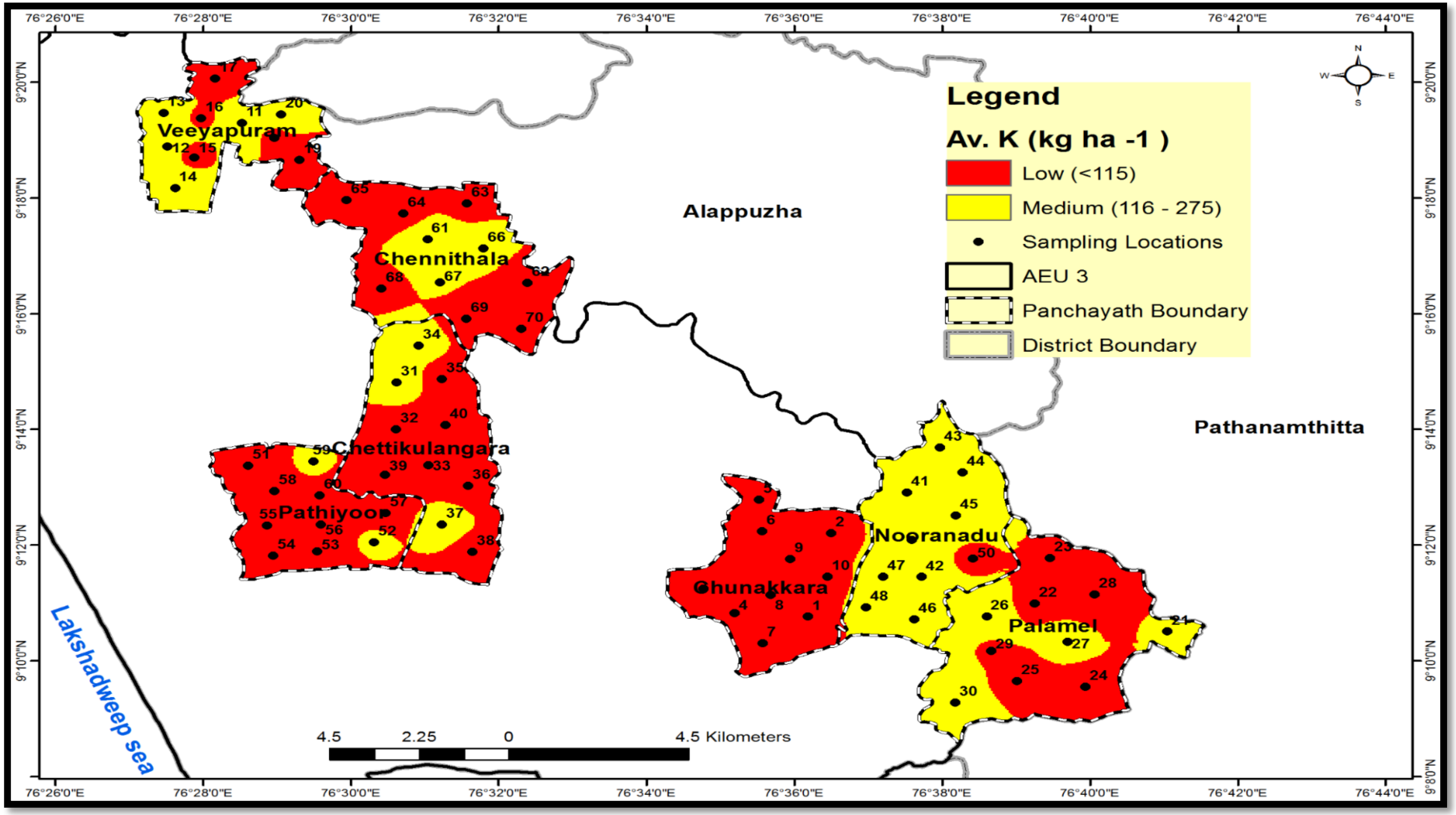


Fig. 22. Spatial distribution of fertility classes of available K in the post-flood soils of AEU 3

5.1.2.7. Available calcium

A wide variation was seen in the availability of the Ca in post-flood soils of the AEU 3 .The values ranged from 14.7 mg kg^{-1} to 441 mg kg^{-1}. The mean value of the available Ca was 191 mg kg^{-1} (Table 17). Majority (72.9 per cent) of the samples were deficient in available Ca (Fig. 23 and 24).

KSPB (2013) reported that the lack of minerals bearing the element as a reason for the reduced availability of the nutrient. The lower availability of Ca may be due to the increased addition of acidifying chemical fertilizers. There exist a direct relationship between pH and available Ca content (Chandrakala *et al.,* 2018). Thus, the application of liming materials in the adequate amount shall regulate the acidity and alleviate the deficiency of Ca in the region. Leaching losses of Ca in the light textured soil can also contribute to the deficiency.

Among the land uses, the mean value of available Ca varied from 160 mg kg^{-1} in vegetable land use to 249 mg kg^{-1} in the banana land use (Table 18). The lower availability of Ca in the vegetable land use is due to the lack of liming practice in vegetables in most of the areas.

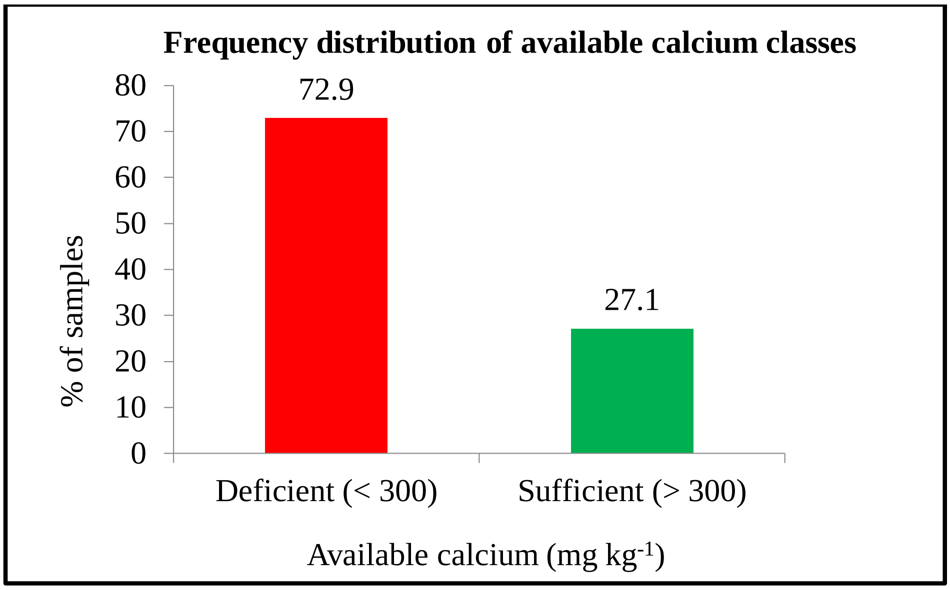


Fig. 23. Frequency distribution of classes of available Ca in the post-flood soils of AEU 3

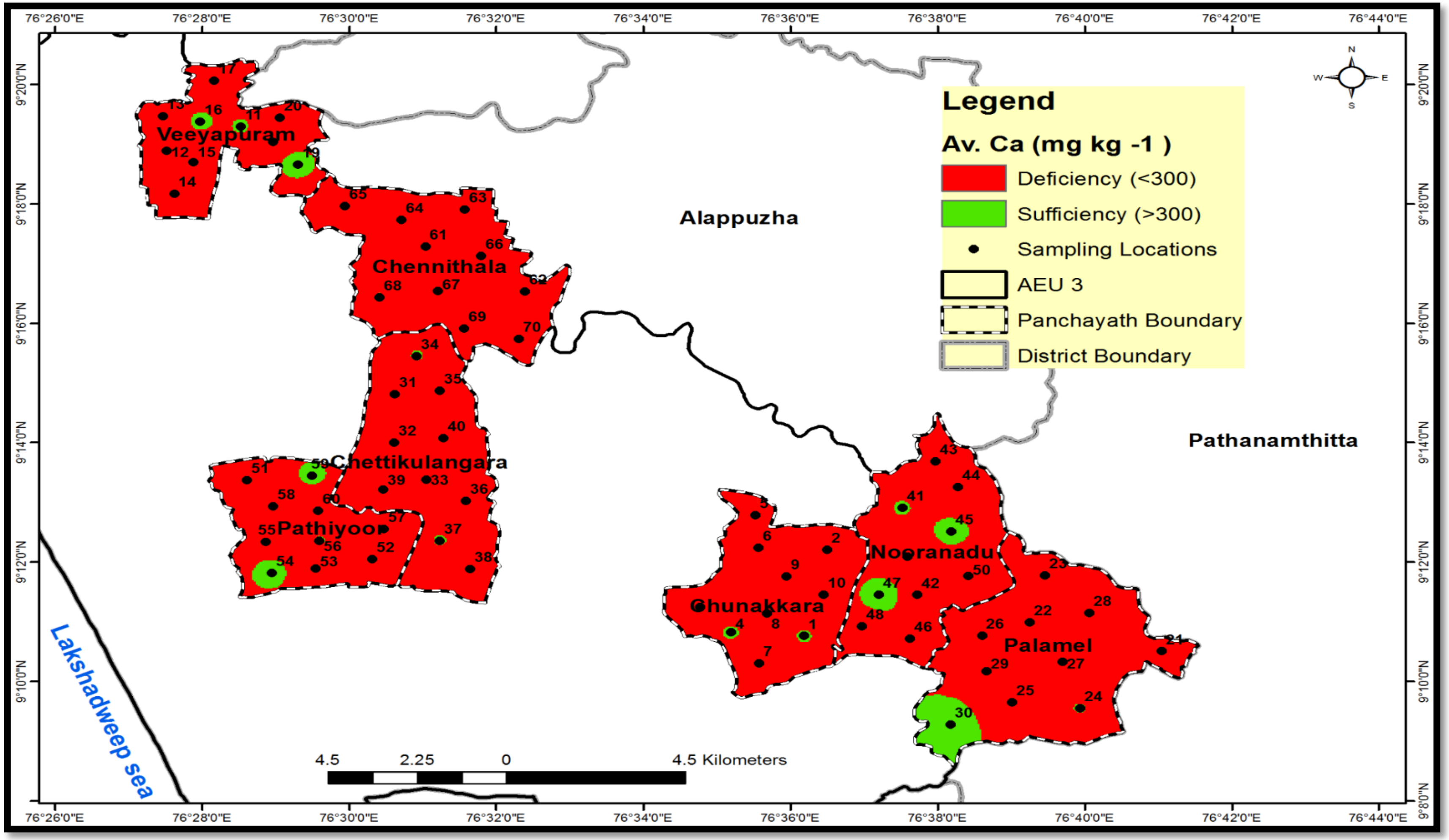


Fig. 24. Spatial distribution of fertility classes of available Ca in the post-flood soils of AEU 3

5.1.2.8. Available Magnesium

The results revealed the severe deficiency of the available Mg throughout the flood affected areas of Onattukara sandy plain (Fig. 25). Mg availability ranged from 12.5 mg kg^{-1} to 16.1 mg kg^{-1} with a mean value of 14.49 mg kg^{-1} which was far below the critical limit 120 mg kg^{-1} (Table 17).

Deficiency of available Mg can be due to the low Mg content in the parent material and the intensive leaching losses in the sandy soil of the region. Mini (2015) reported that the imbalanced fertilization practices along with the exclusion of magnesium fertilizers might have resulted in such situation. The reduction in the availability of Mg after the flood may be the result of the leaching and dilution, since flooding increases the solubility of the nutrients (DSSSC, 2018).

The mean value of available Mg did not show much variation between the various land uses (Table 18).

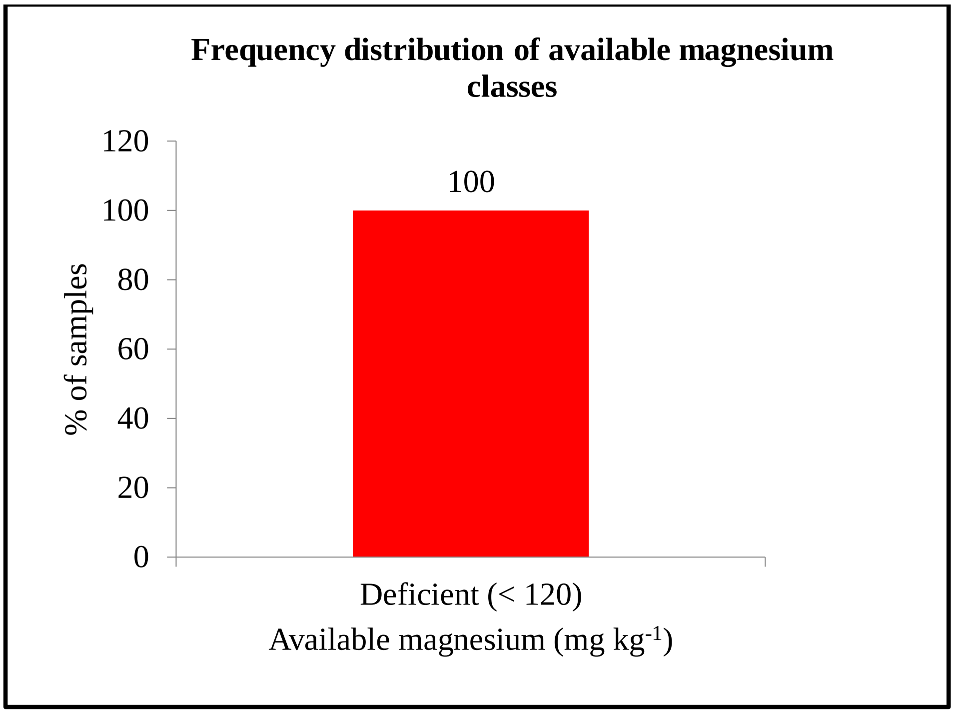


Fig. 25. Frequency distribution of fertility classes of available Mg in the post-flood soils of AEU

5.1.2.9. Available Sulphur

Available S was observed to be 100 per cent deficient in the flood affected areas of AEU 3 (Fig. 26). The lowest value recorded was 0.06 mgkg^{-1} and the highest value was 4.51 mg kg^{-1} in the samples. The mean value of available S in the AEU was 0.99 mg kg^{-1} (Table 17).

The deficiency of sulphur may be due to various reasons like low native sulphur content, coarse texture, inherent low organic matter content, and soil conditions that favour leaching losses of sulphur. The deficiency can be corrected by the addition of more organic inputs and use of sulphur containing fertilizers like ammonium sulphate and single super phosphate (DSSSC, 2018).

The highest mean value of available S among the various land uses was recorded in rice and the lowest in banana (Table 18). The high availability of the sulphur in the rice fields may be due to the extensive use of Factamfos, a complex N-P fertilizer. Deficiency of sulphur in the banana land use may be due to the lack of addition of organic inputs, amidst the intensive inorganic cultivation practices of the crop (Mini, 2015).

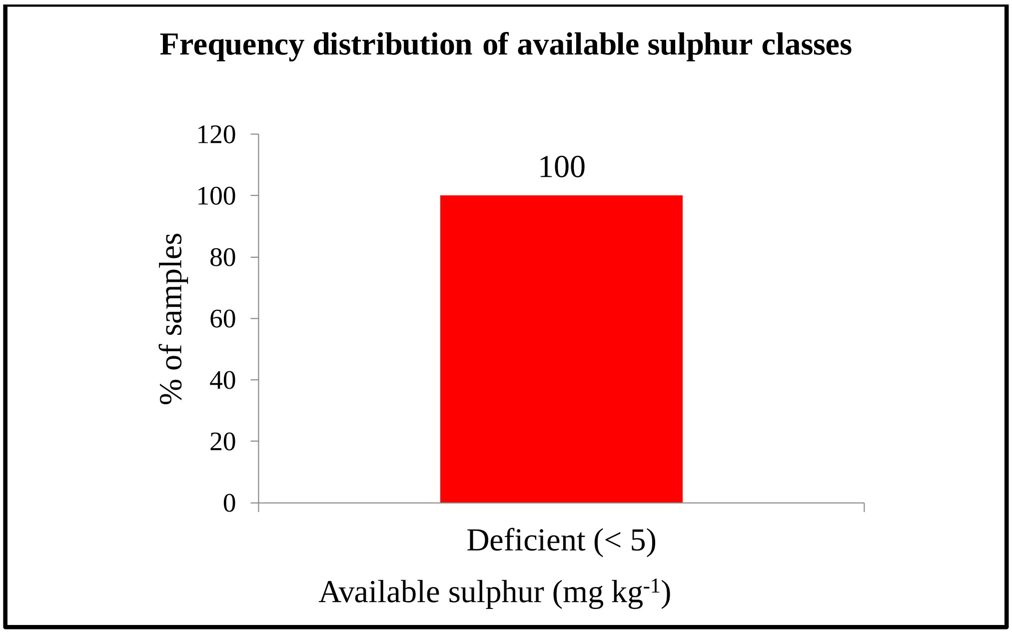


Fig. 26. Frequency distribution of fertility classes of available S in the post-flood soils of the AEU 3.

5.1.2.10. Available Iron

The results revealed that the entire samples were sufficient (> 5 mg kg^{-1}) in available Fe and the values ranged from 171 to 978 mg kg^{-1} with a mean value of 704.09 mg kg^{-1} (Fig. 27) (Table 19). George (2011) reported that soils of Kerala had high Fe content. Parent materials rich in iron and the leaching down of basic materials from the surface layers due to the heavy rainfall could be the reason for this.

In the case of land uses, rice recorded the highest mean value (747 mg kg^{-1}) and the lowest (650 mg kg^{-1}) value was recorded in banana (Table 20). The high availability of iron could be due to the increased acidity of the soil and also the rich Fe content of the parent material (Santhosh, 2013). Soil pH and organic carbon are the major soil factors that influence the availability of the Fe to the plants (Lindsay, 1979). Addition of organic matter to drained or waterlogged soil improve the Fe availability (Tisdale *et al.*, 1985) and these might be the reason for the higher Fe availability in rice and lower availability in banana land use.

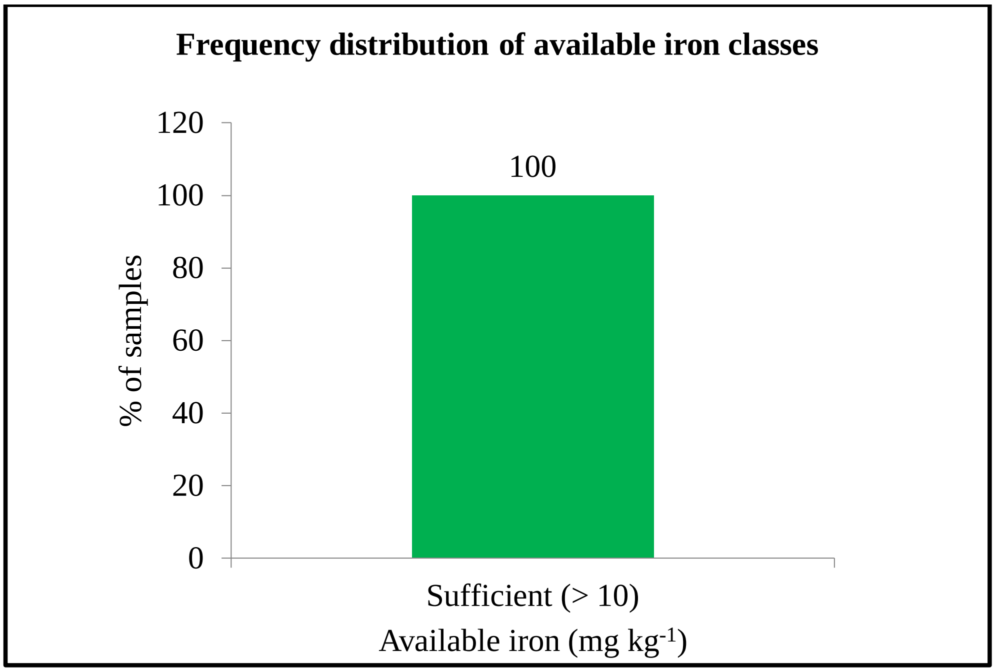


Fig. 27. Frequency distribution of classes of available Fe in the post-flood soils of the AEU 3

5.1.2.11. Available Manganese

The entire flood affected areas of the AEU 3 was sufficient (>1 mg kg^{-1}) in available Mn (Fig. 28). The values varied from 1.31 mg kg^{-1} to 38.5 mg kg^{-1}. The mean value was 11.317 mg kg^{-1} (Table 19).

Majority of the native manganese in the acid soils remains in water soluble and exchangeable forms. Randhawa *et al.* (1961) reported that the 16 per cent of total Mn in acid soils remains in water soluble and exchangeable forms. Availability of Mn is influenced by the same factors as that of availability of Fe. The increased availability of nutrients after the flooding may be due to the increased soil moisture and the favourable pH. Solubility of the nutrient and, thereby its availability increases under the high soil moisture and poor aeration (DSSSC, 2018).

Soil organic matter enhances the Mn availability to plants (Reisenauer, 1988). Rice land use with high content of organic matter and low pH had the highest mean value (14.2 mg kg^{-1}) of the available nutrient (Table 20). Coconut land use had the lowest mean value (4.63 mg kg^{-1}) which can be attributed to the comparatively higher pH of the land use.

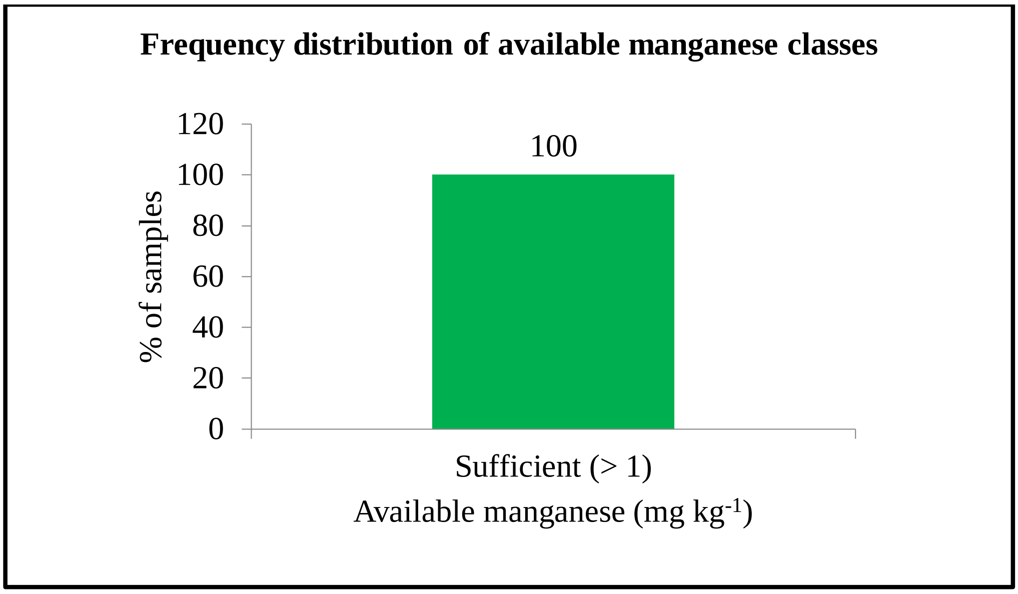


Fig. 28. Frequency distribution of classes of available Mn in the post-flood soils of the AEU 3

5.1.2.12. Available Copper

The results showed the 100 per cent deficiency of available Cu (<1 mg kg^{-1}) throughout the flooded region of Onattukara (Fig. 29). The values varied between 0.03 mg kg^{-1} and 0.98 mg kg^{-1} in the AEU 3 with a mean value of 0.47 mg kg^{-1} (Table 19). Sakal (2001) reported that among the various forms, only 10.8 per cent of the total Cu were found to be in the pools available to the plants and the rest were in unavailable forms. Moreover, in light textured soils, copper held by the exchange complexes in the soil is prone to leaching losses (Kanwar and Randhawa, 1974).

Antagonism between copper and phosphorus and formation of insoluble copper phosphate in soil may be another cause for low copper status in these soils (Wallace, 1984). Nair *et al.* (2018) reported that the use of other chemicals as prophylactic measures, instead of copper fungicides to control the fungal diseases, has declined the external addition of the element and caused deficiency in soil.

Among land uses, coconut had the highest mean availability (0.61 mg kg^{-1}) of the Cu and rice has the lowest value (0.38 mg kg^{-1}) (Table 20). Higher content of Cu in coconut land uses may be due to the addition of organic matter. The lower availability of Cu in rice fields, despite of the higher organic content may be due to the liming practice and the higher P fertilization. Nayyar *et al.* (1990) in reported that the availability of Cu increase with increase in organic matter content and decrease with increase in pH and $CaCO_3$ content of the soil.

5.1.2.13. Available Zinc

85.7 per cent of the samples were sufficient in zinc and 14.3 per cent of the samples were under deficient class (Fig. 30 and 31). The lowest value observed was 0.38 mg kg^{-1} and the highest was 4.26 mg kg^{-1}. The mean value of the post flood soils of AEU 3 was 2.03 mg kg^{-1} (Table 19). Sureshkumar (1993) reported the widespread deficiencies of Zn in the acid lateritic soils due to the excessive content of Fe and Mn.

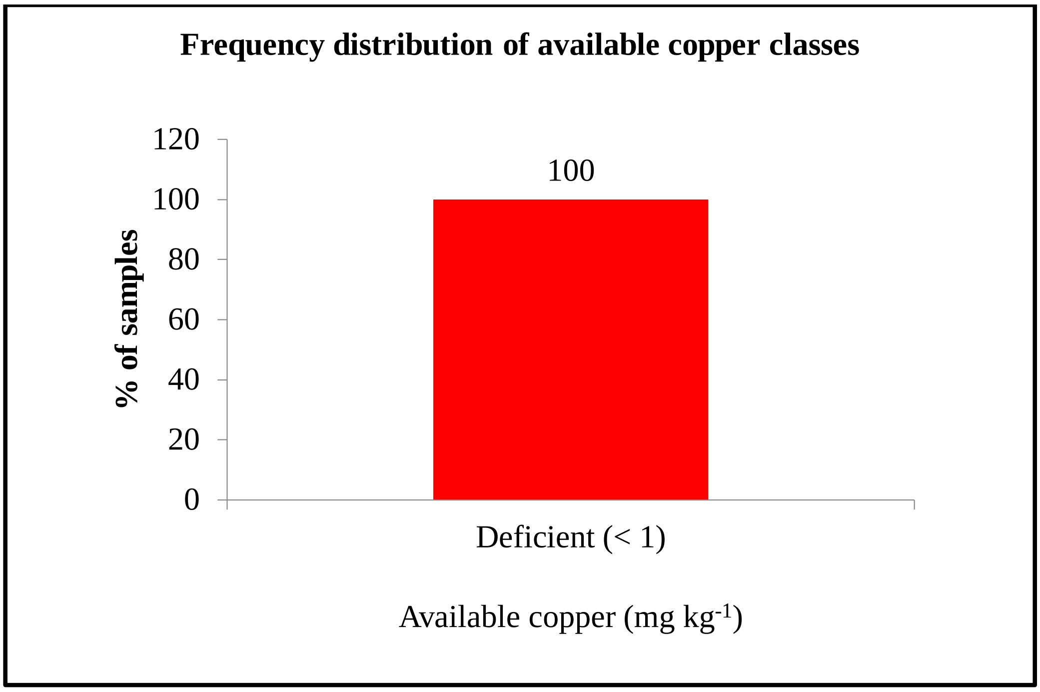


Fig. 29. Frequency distribution of classes of available Cu in the post-flood soils of the AEU 3

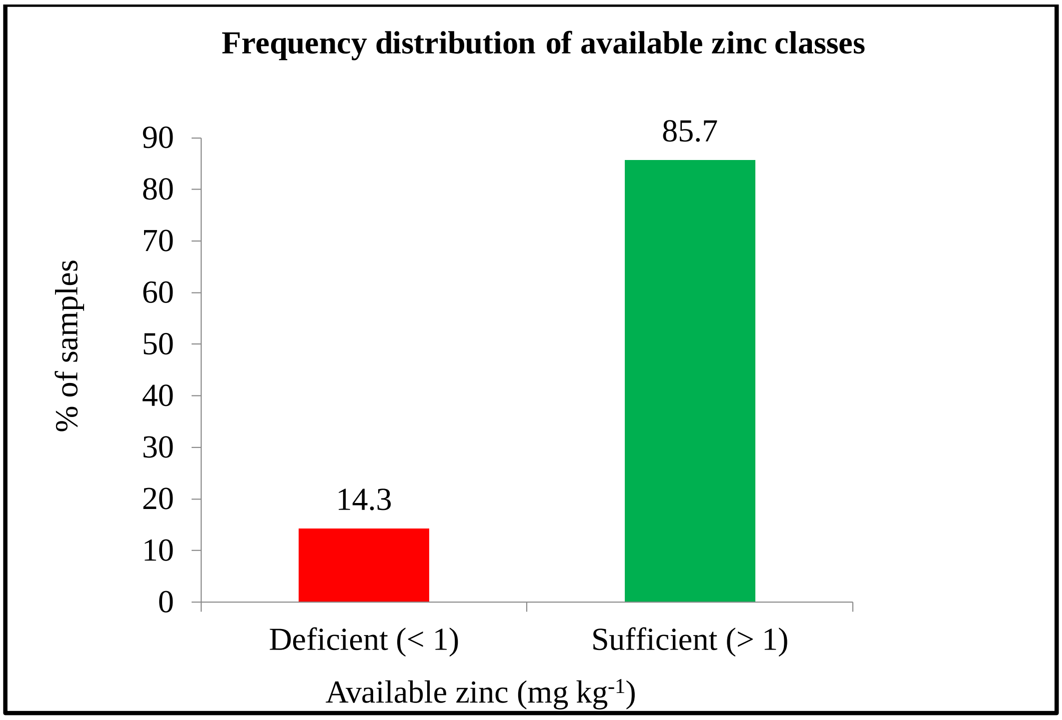


Fig. 30. Frequency distribution of classes of available Zn in the post-flood soils of the AEU

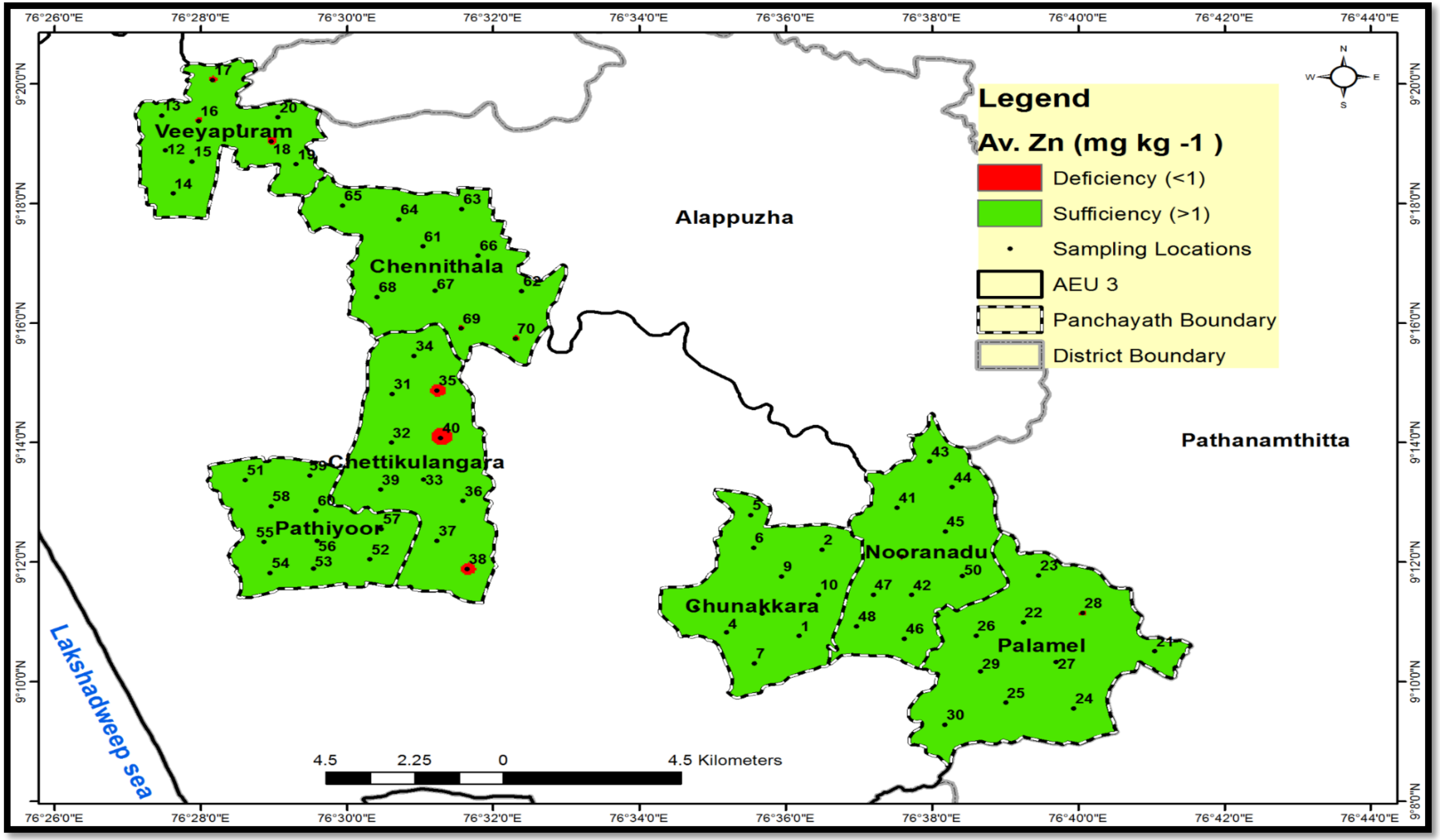


Fig. 31. Spatial distribution of fertility classes of available Zn in the post-flood soils of AEU 3

Acidic pH, leaching, excess P and unscientific use of high analysis fertilizers may be the reason for deficiency of Zn in Onattukara (Mini, 2015). Zinc deficiency may also occur in sandy soils, soils high in P and organic matter and those soils in which the subsoil have been exposed due to land levelling/erosion (DSSSC, 2018). High input of phosphatic fertilizers might have ensured adequate level of zinc in majority (85.7 per cent) of the soils (Nair *et al.,* 2013).

Rice land use had the lowest mean value of Zn availability (1.95 mg kg^{-1}) and the possible reason could be the high content of Fe and Mn in the soil. Coconut land use had the highest mean value (2.12 mg kg^{-1}) (Table 20).

5.1.2.14. Available Boron

The results revealed that the flood affected regions of the AEU 3 was completely deficient (<0.5 mg kg^{-1}) in the availability of B (Fig. 32). The lowest value observed was 0.01 mg kg^{-1} and the highest value was 0.26 mg kg^{-1}. The mean value of the B availability in AEU 3 was 0.12 mg kg^{-1} (Table 19). Gupta (1993) reported that B deficiency is common in acidic, coarse textured soils, low in organic matter.

Nair *et al.* (2018) reported that weathered soils in humid climatic region faces deficiency of the nutrient, due to the high water solubility of boron bearing minerals. Being highly mobile in soil, boron is prone to heavy leaching losses in the coarse textured soil especially in areas of high rainfall. Moreover, calcium acts to reduce the boron availability (DSSSC, 2018).

Mini (2015) reported the widespread deficiency of available B in Onattukara. Among land uses, vegetable had the lowest (0.11 mg kg^{-1}) and coconut had the highest value (0.14 mg kg^{-1}) (Table 20). The low availability of nutrient in the vegetables land use can be attributed to the under fertilization coupled with the leaching losses. The increased B availability in coconut is the result of application of borax which is a recommended practice for B nutrition in the region (KAU, 2014).

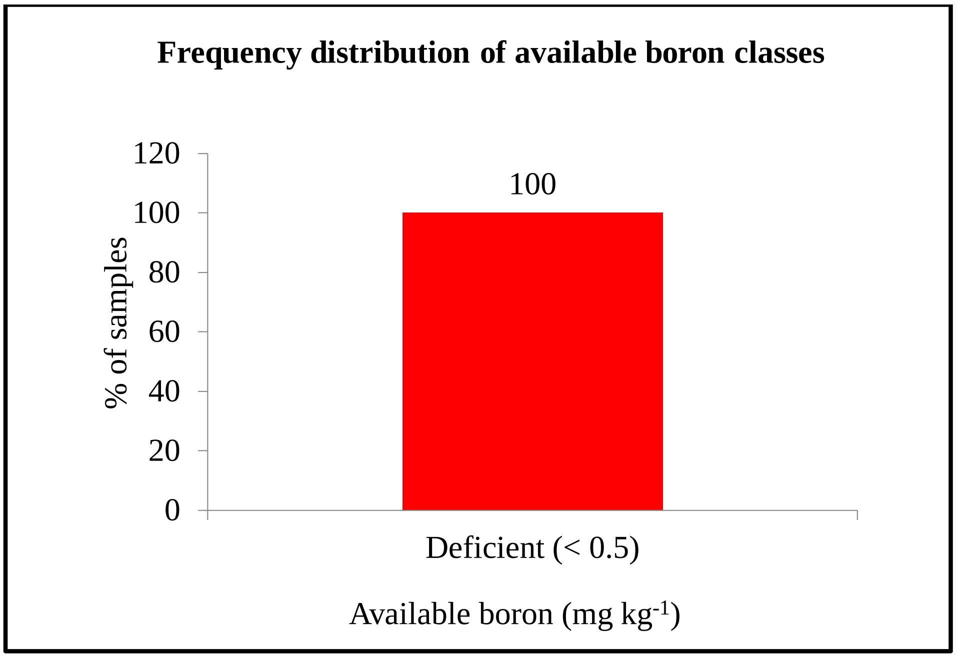


Fig. 32. Frequency distribution of classes of available B in the post-flood soils of the AEU 3

5.1.2.15. Heavy metals

The analysis of soil samples collected from the flood affected areas of the AEU 3 revealed the presence of Pb and Cr in all the samples irrespective of the area and land use. Cd was not detected in any of the samples (Table 21). Ni was present in 61.43 per cent of the samples and was not detected in rest of the samples (Appendix III). The samples of Veeyapuram panchayath and those of rice land use were found to have more content of both the prominent heavy metals, Pb and Cr (Table 22). Content of all the heavy metals were far below the critical limits in all the samples.

John and van Laerhoven (1972) reported that the Pb availability in soils were related to the soil pH, extractable Al, total Ni, than it was related with the organic matter. The amount of soil organic matter is very relevant in the studies of heavy metal retention by the soil, due to its influence on the CEC and tendency of transition metal cations to form stable complexes with organic ligands (Elliot *et al.*, 1986). The total Ni content was found to have positive correlation with the content of Mg, Fe and Al and the content of Cr was not influenced by the different chemical properties (Vijayan, 2015).

The high soil moisture content as the result of flood, have created favourable condition for the high availability of the heavy metals (DSSSC, 2018). Flooding combined with the organic matter content and favourable pH might be the possible reason for the heavy metal contents in the rice fields.

5.1.3. Biological attributes

5.1.3.1. Acid phosphatase activity

Activity of acid phosphatase enzyme in the post flood soils of the AEU 3 ranged from 2.72 µg p-nitrophenol released g^{-1} soil hr^{-1} to 89.3 µg p-nitrophenol released g^{-1} soil hr^{-1}. The mean value observed was 32.6 µg p-nitrophenol released g^{-1} soil hr^{-1} (Table 23). 44.3 per cent of the samples had enzyme activity between 25 to 50 µg p-nitrophenol released g^{-1} soil hr^{-1}. It is evident that the 82.9 per cent of the soil had enzyme activity less than 50 µg p-nitrophenol released g^{-1} soil hr^{-1} (Fig. 33). Organic matter determines the microbial and enzymatic activities in the sandy soils (Blanchart *et al.,* 2005). Low organic matter status of the Onattukara soils is reflected in the enzyme activity also. Plant roots or microbes such as fungi or bacteria are the source of phosphatase activity in the soils. Soils under organic management are ought to be more biologically active and possess higher ability to mobilize the native P (Bhat *et al.*, 2017).

Rice land use had the highest mean enzyme activity and coconut land use had the lowest mean enzyme activity (Table 24). The increased enzyme activity in rice fields could be because of the high organic additions. Also higher rate of fixation of P in the fields demands higher enzyme activity. Solubilisation and mobilization of the applied P to plants is mediated by such biological activities (Bhat *et al.*, 2017). The changes in the quantity and quality of soil phosphoryl substrates is indicated by the variations in the enzyme activity (Rao and Tarafdar, 1992). The overall lower enzymatic activity in the sandy soils may be due to the well-drained light texture, and lower organic matter content. The same reason can be attributed for the lower activity in coconut land use.

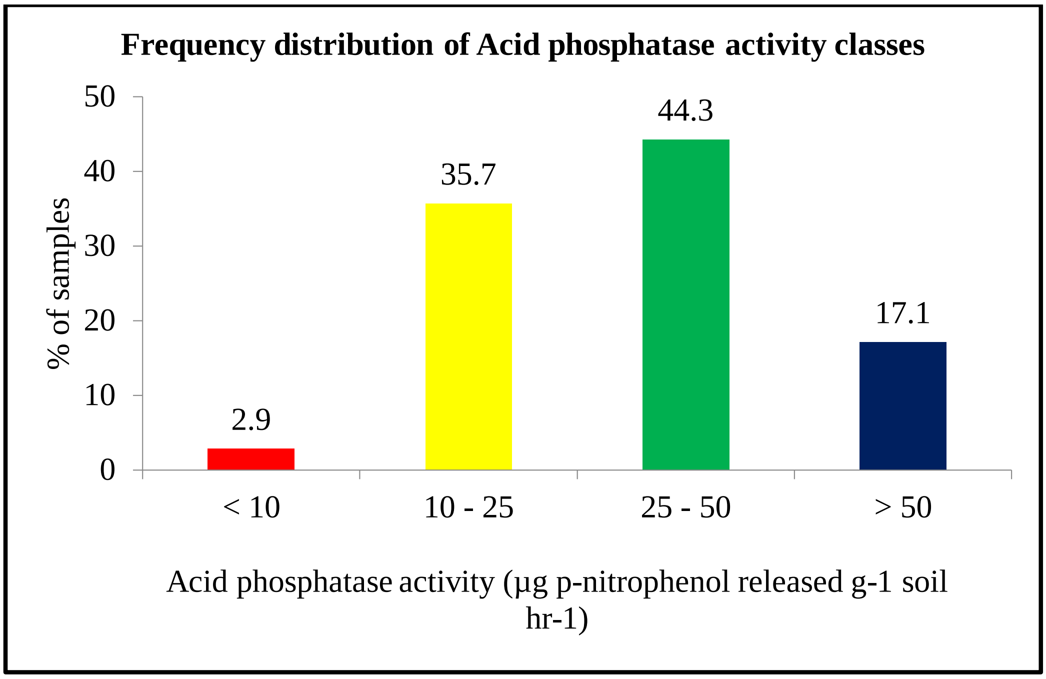


Fig. 33. Frequency distribution of acid phosphatase activity in post-flood soils of AEU 3

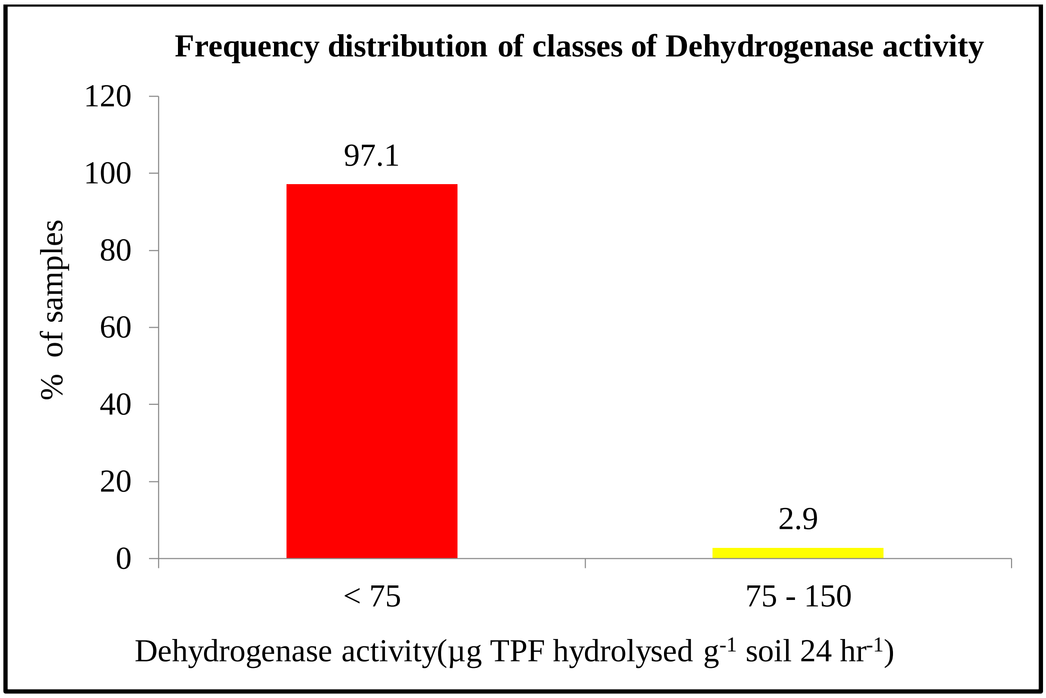


Fig. 34. Frequency distribution of dehydrogenase activity in post-flood soils of AEU 3

5.1.3.2. Dehydrogenase activity

Dehydrogenase activity in soils of flood affected areas of AEU 3 varied between 5.75 µg TPF hydrolysed g^{-1} soil 24 hr^{-1} to 93.5 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}. The mean value was 32.4 µg TPF hydrolysed g^{-1} soil 24 hr^{-1} (Table 23). 97.1 per cent of the samples had enzyme activity less than 75 µg TPF hydrolysed g^{-1} soil 24 hr^{-1} and only the remaining 2.9 per cent had an activity above the range (Fig. 34).

Dehydrogenase activity is referred as an indicator of biological activities in the soil (Burns, 1982). Amendments rich in microbial biomass not only impart a favourable environment for increased biological activity, but also contain intra and extra cellular enzymes, that accelerates the microbial activity in the soil (Liang *et al.*, 2005).

Banana land use had the lowest enzyme activity (29.9 µg TPF hydrolysed g^{-1} soil 24 hr^{-}1) and this may be due to lack of organic additions during the cultivation. Whereas, rice land use had the highest enzyme activity (35.2 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) because of the organic additions and the favourable moisture content in the soil (Table 24). Soil moisture content influence both microbial activity and the dehydrogenase enzyme activity in the soil (Kumar *et al.*, 2014).

5.2. SOIL QUALITY INDEX

The minimum data set (MDS) for soil quality assessment was prepared using PCA of the analysed parameters. The MDS included the attributes viz., sand per cent, available P, available Ca, available Mg, bulk density, per cent of water stable aggregates, organic carbon, available Zn and available B (Table 26). These indicators were assigned weights and scores (Table 27) and the soil quality index was calculated (Table 28).

The soil quality index of the samples varied between 175 and 295, with a mean value of 239. Mean value of SQI was found to be maximum (260) in the Nooranadu panchayath and minimum (217) in Chettikulangara panchayath (Table 28).

Samples from Nooranadu panchayath obtained the maximum scoring of the indicators belonging to the MDS and hence received the highest mean SQI. Samples from Chettikulangara panchayath received the least scoring for the soil quality indicators. In case of land uses, coconut recorded highest mean SQI (248) and rice land use recorded the least mean SQI (234) (Table 29).

Relative soil quality index was also calculated (Table 28) and the soils were categorized into poor, medium and good. Majority of the samples (78.6 per cent) fell in the medium class and 12.8 per cent into the low class of soil quality. Only 8.6 per cent of the samples were regarded as good quality soil in the post flood scenario (Fig. 35 and 36).

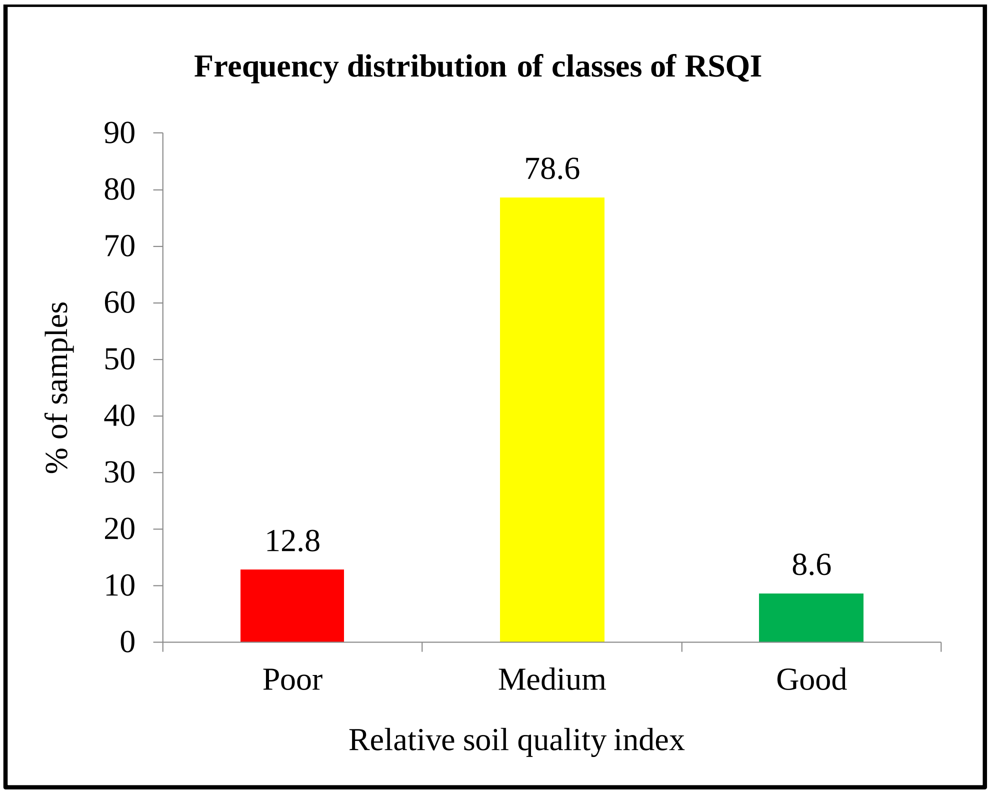


Fig. 35. Frequency distribution of classes of RSQI in the flood affected areas of the AEU 3.

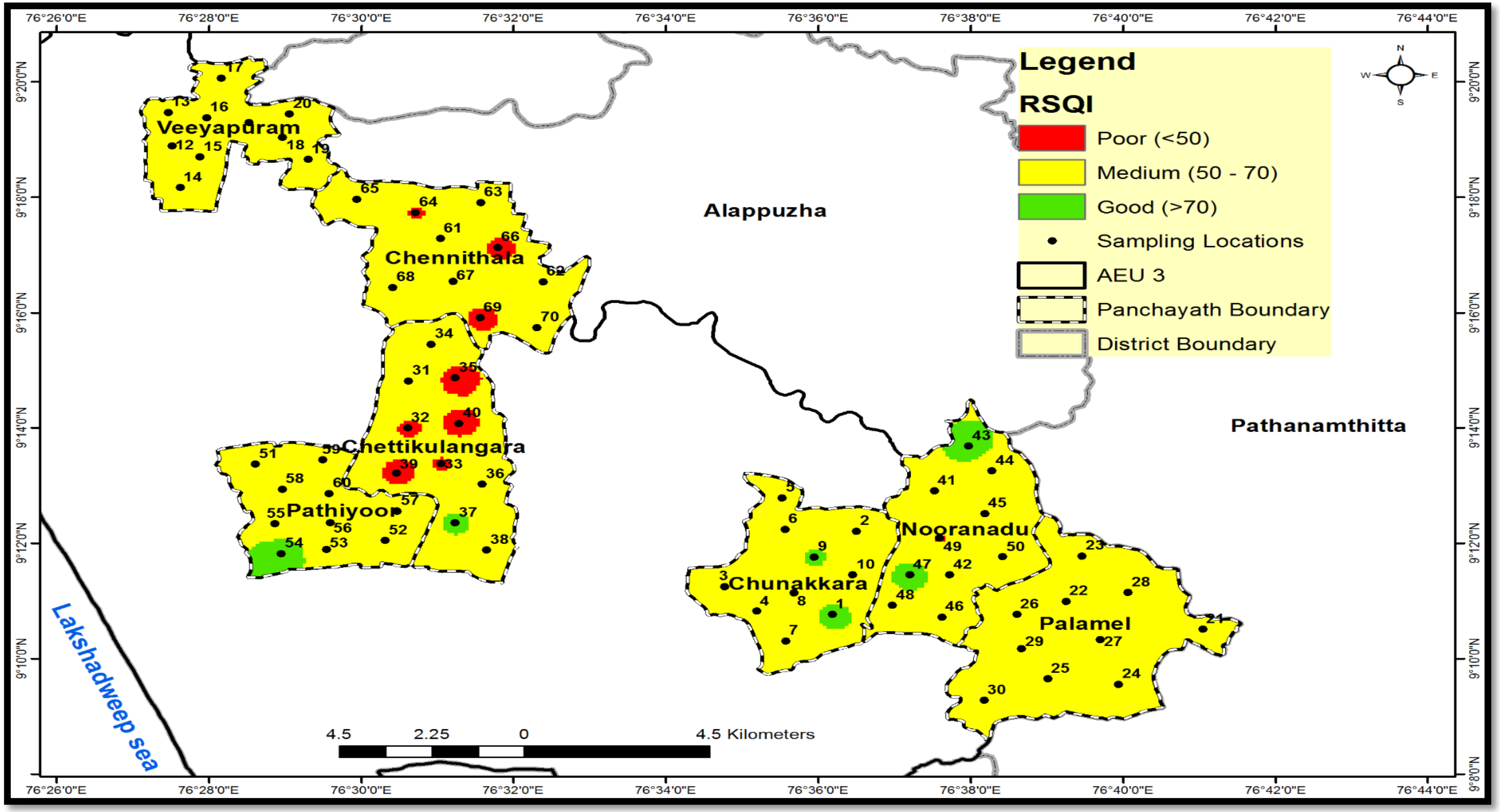


Fig. 36. Spatial distribution of relative soil quality indices in the post flood soils of AEU 3

5.3. SOIL NUTRIENT INDEX

Medium nutrient index class of organic carbon was found in most of the panchayaths. Chunakkara and Veeyapuram panchayath had high index and only Chettikulanagara had low index of organic carbon (Fig. 37).

Low nutrient index was observed for nitrogen in majority of the panchayaths. Chunakkara and Veeyapuram were the exceptions (Fig. 38). High nutrient index value for phosphorus was observed in all the panchayaths of AEU 3 (Fig. 39). In case of potassium, Nooranadu alone came under the medium nutrient index class and rest of them were in the low nutrient index class (Table 30) (Fig. 40).

The knowledge about the spatial variability and their relationship is a requisite for evaluating the land management practices. Spatial variability can occur due to pedogenic factors or due to the complex interactions between geology, topography, climate as well as soil use (Jenny, 1980). The variabilities could also be due to the influence of land use or management strategies (Brejda *et al.*, 2000).

Among the threats to sustainability, the one due to declining soil fertility is very serious (Agnew and Warren, 1996). The alterations in the quantity and availability of nutrients through the addition of fertilizers, manures, compost, mulch, sulphur, lime coupled with leaching losses, causes variations in soil fertility. It is important to have the soil testing done, to know the current fertility status, and then recommend dose of fertilizers, so that the optimum fertility can be maintained (Ravikumar and Somashekhar, 2013).

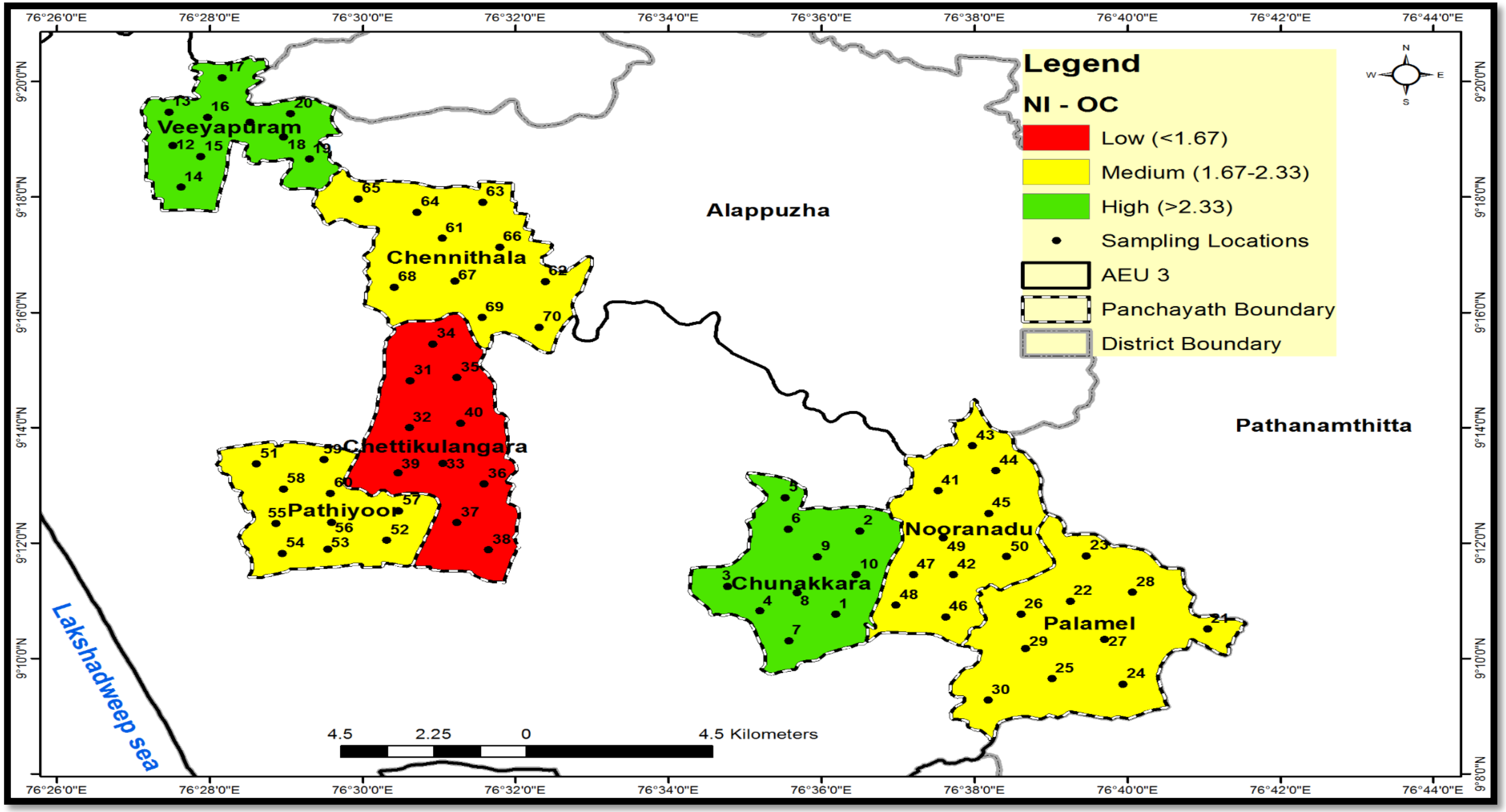


Fig. 37. Spatial distribution of nutrient indices for organic carbon in the post-flood soils of AEU 3.

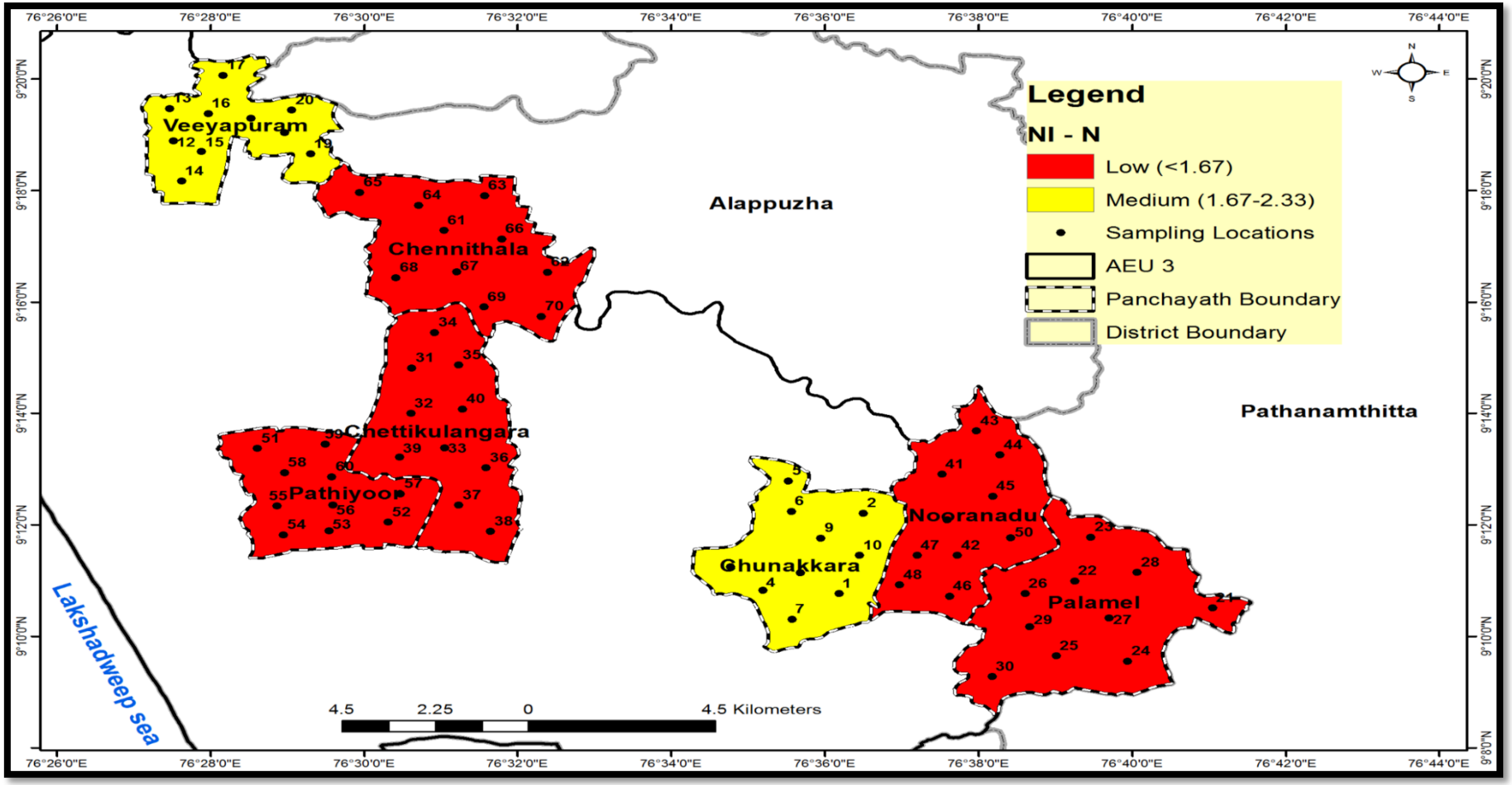


Fig. 38. Spatial distribution of nutrient indices for available N in the post-flood soils of AEU 3

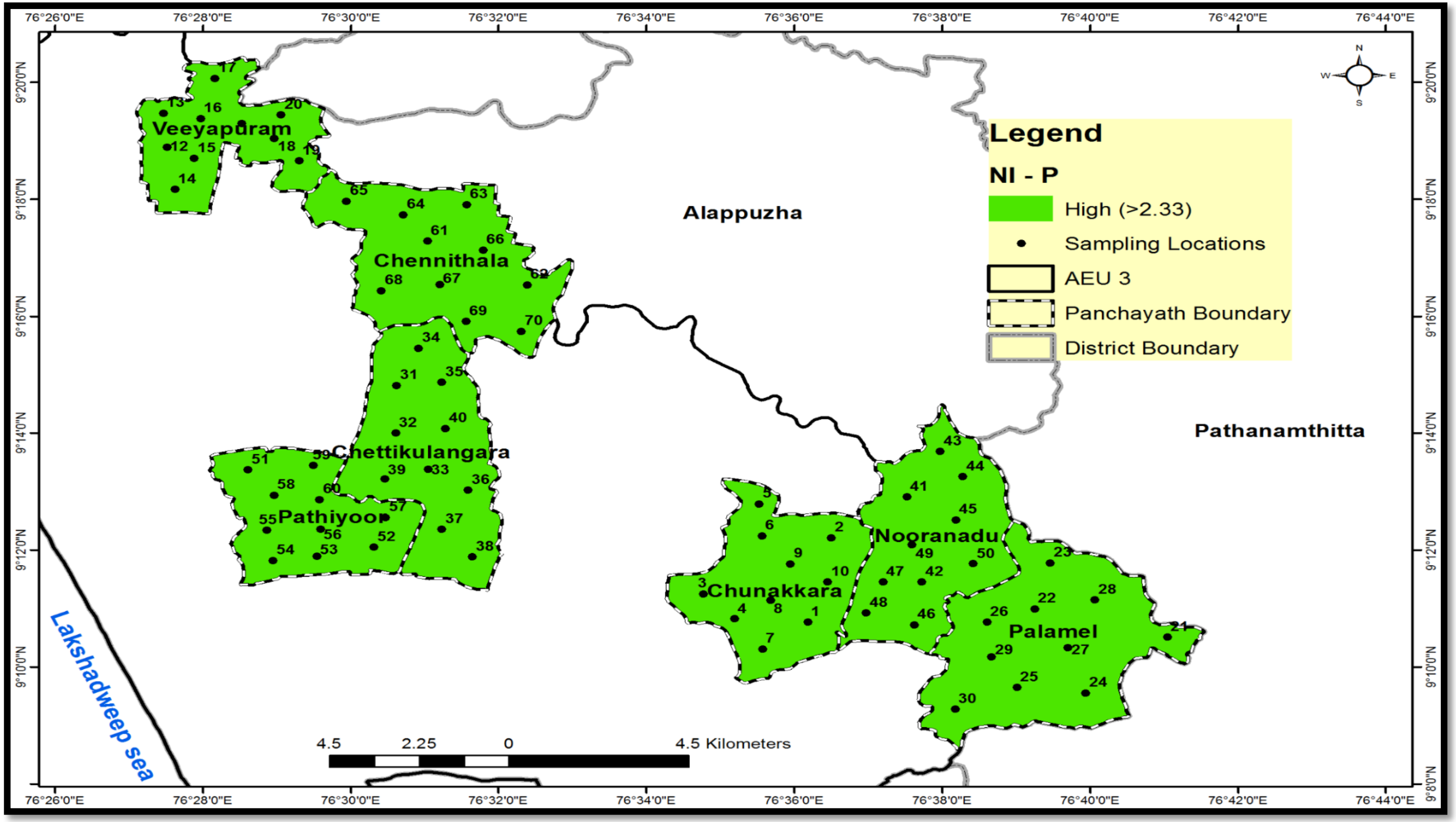


Fig. 39. Spatial distribution of nutrient indices for available P in the post-flood soils of AEU 3.

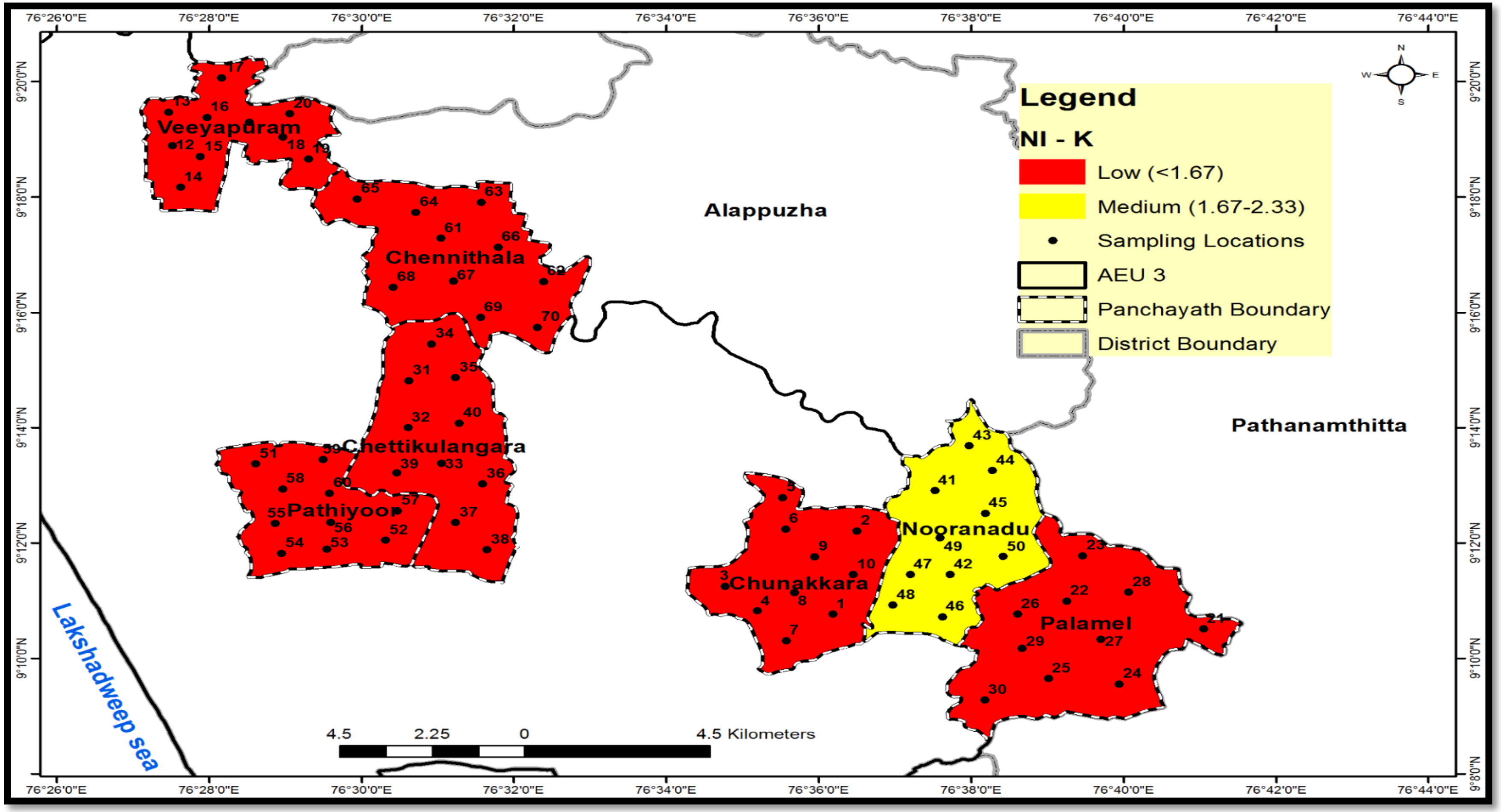


Fig. 40. Spatial distribution of nutrient indices for available K in the post-flood soils of AEU 3

5.4. LAND QUALITY INDEX

Majority (91.4 per cent) of samples from the flood affected areas of AEU 3 fell into very low class of land quality and the rest of them fell into the class low of land quality (Fig. 41 and 42). Anilkumar *et al.* (2015), confirmed the reliability of soil organic carbon as an indicator of the land quality with reference to the land use.

The SOC stock of the post flood soils of AEU 3 ranged from 0.08 kg m^{-2} to 4.14 kg m^{-2} with a mean value of 1.62 kg m^{-2}. Nooranadu panchayath had the highest mean value of SOC stock (2.12 kg m^{-2}) and Chettikulangara panchayath had the lowest mean value (1.03 kg m^{-2}). All the panchayath were classified under very low quality with respect to land quality (Table 31).

Coconut land use had the highest mean value of SOC stock (1.86 kg m^{-2}) and vegetable land use had the lowest mean value (1.51 kg m^{-2}) (Table 32). The changes in SOC stock are due to the variation in carbon concentration and bulk density in the surface soils among different land use (Lal and Kimble, 2001).

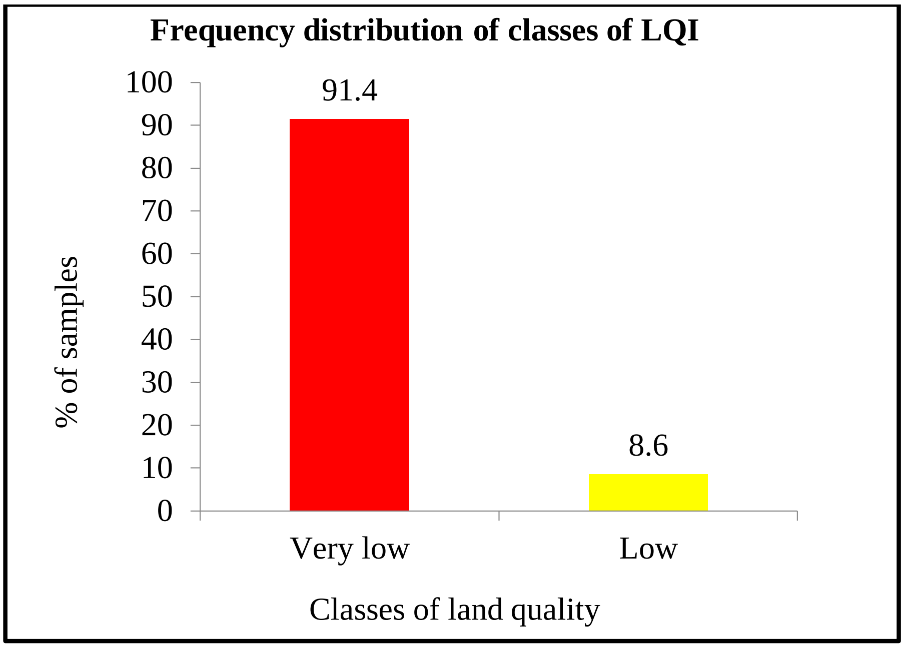


Fig. 41. Frequency distribution of classes of LQI in the flood affected areas of the AEU 3

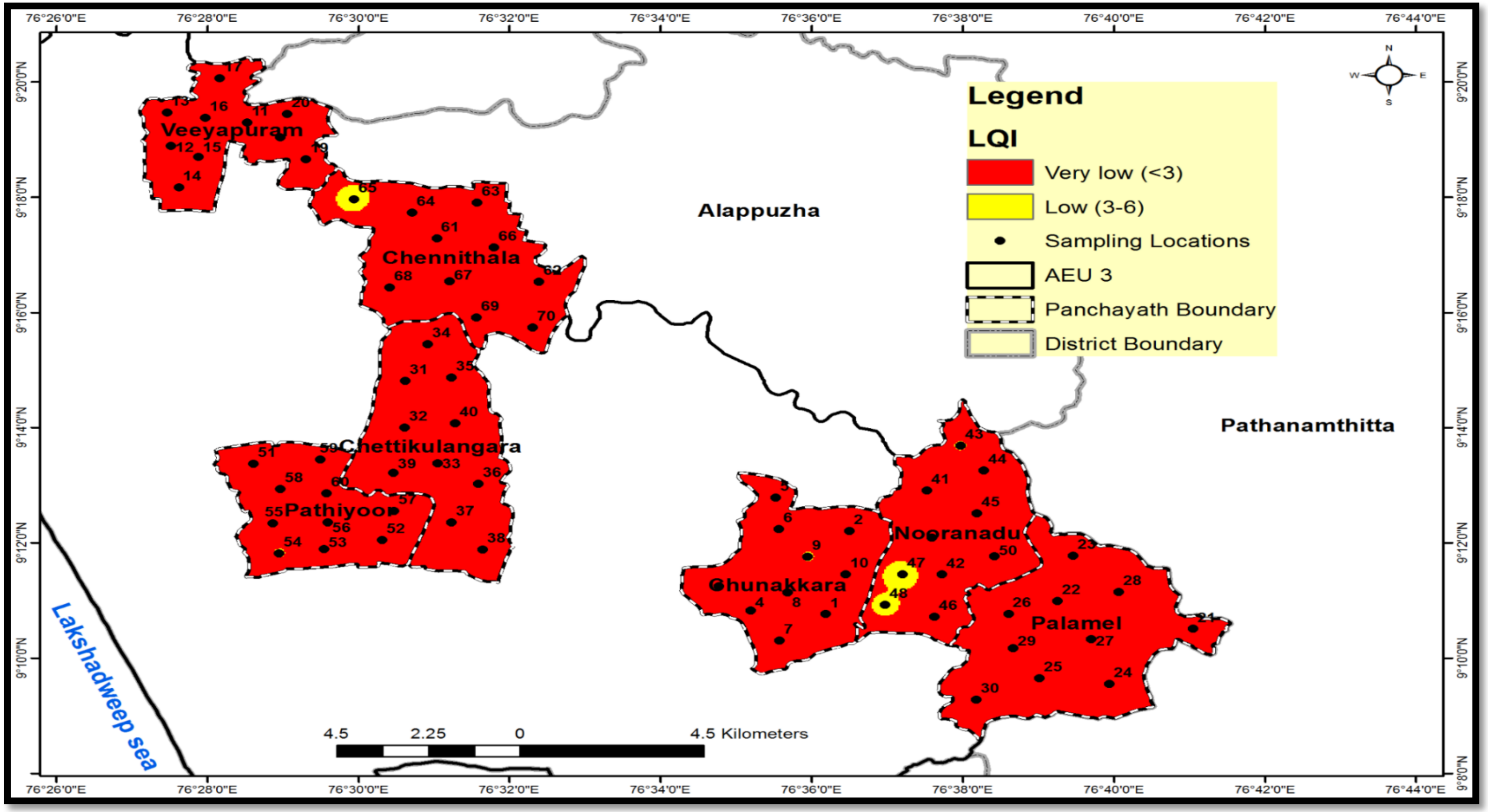


Fig. 42. Spatial distribution of land quality indices in the post-flood soils of AEU 3

5.5. CORRELATION AMONG THE ANALYSED SOIL PROPERTIES

The physical properties like MWD, per cent WSA, soil moisture, water holding capacity were found to be positively correlated with the organic carbon content (Table 33). Carter and Stewart (1995) reported that the properties like aggregation, water holding capacity, hydraulic conductivity, bulk density, the degree of compaction, fertility and resistance to water and wind erosion were enhanced by addition of organic matter. Celik *et al.* (2004) also reported that the physical properties were significantly affected by the organic fertilizers and also the available water content was seen to be increased by 86 per cent and 56 per cent through compost and manure treatments respectively.

In case of the chemical parameters, positive correlations were observed among OC and N, OC and Mg, OC and Mn, N and Fe, P and K, Mg and S, Mg and Mn, Mn and S (Table 34). Singh *et al.* (2014) reported that the available N was positively correlated with the organic carbon, available P, available K and available Fe. Addition of organic matter cause Fe and Mn to move from less soluble forms to more plant available forms (Shuman, 1988). Tisdale and Bertramson (1950) reported that the increased amount of sulphate sulphur in soil enhanced the availability of Mn to the plants. Thorne (1955) reported that the potassium sprays increased the uptake of phosphorus from the soil.

The enzyme activity in soil, both acid phosphatase and dehydrogenase activity were observed to be positively correlated with the organic content of the soil (Table 35). The increased availability of carbon in soil enhance the microbial activity and thus the cycling and turnover of nutrients (Rees and Parker, 2005). Kumar *et al.* (2014) reported highest dehydrogenase activity in the forest soil.

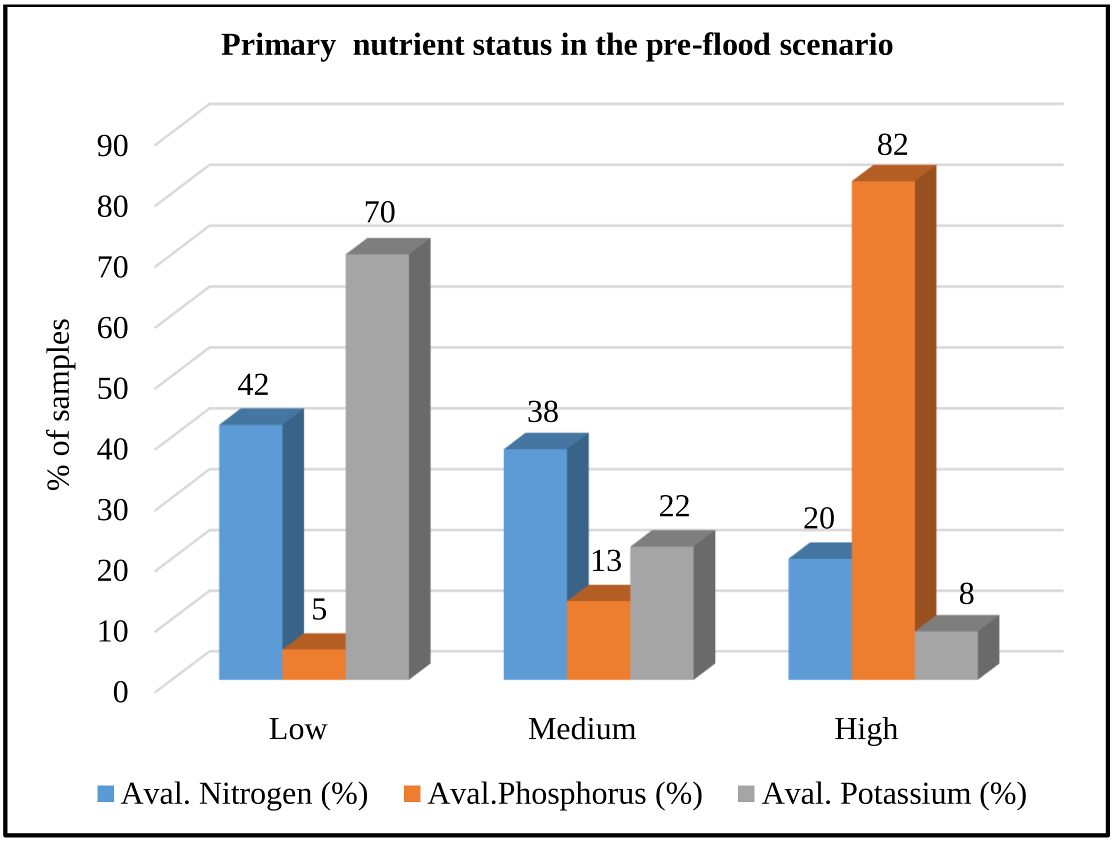
5.6. COMPARISON OF PRE AND POST-FLOOD SOIL FERTILITY STATUS OF AEU 3

The results of the analysis of the chemical parameters in the post-flood soils were compared with the pre-flood nutrient status data of the AEU 3 reported by Kerala State Planning Board, 2013 (Appendix-IV).

In the pre-flood scenario, 15 per cent of the soils belonged to extremely acidic class, 30 per cent into strongly acidic and 37 per cent into moderately acidic class. Whereas, in the post-flood analysis, the frequency distribution has changed in various classes of soil reaction as given in fig. 11 and 12. This clearly indicates the increase in the acidity of the Onattukara soil after the flood. Organic carbon status of the area had slightly increased after the flood. The organic carbon content in the soil was seen to increase after the flood. This may be as a result of the sediment rich in organic matter and humus (DSSSC, 2018).

Depletion in the status of nitrogen, potassium, sulphur, copper and boron has been observed. Majority of the samples were having low available N and K (Fig. 43 and 44), whereas S, Cu and B were deficient in 100 % of the samples. The flood water had removed the bases and other nutrients which are easily leachable from the sandy soils of AEU 3. Phosphorus content of the soil was found to be medium to high even after flood but reduced from the very high status of pre-flood scenario in certain areas (Fig. 43 and 44). This may be due to the increase in Fe content in the post-flood soils and this might have led to the fixation of Phosphorous. There was slight enrichment in the Ca and Zn status in comparison with the pre-flood conditions. 72.9 % and 14.3 % samples were deficient in Ca and Zn in the post-flood soils in comparison with the pre-flood status of 98% and 23% respectively (Fig. 45 and 46). This may be due to the effect of sediments deposited by the flood water. High input of phosphatic fertilizers might have ensured adequate level of zinc in majority (85.7 %) of the soils (Nair *et al.,* 2013).

Magnesium remained 100% deficient both before and after the flood. But the level of magnesium in post flood soil was even more deficient than pre-flood soils. On the other hand, Fe and Mn were sufficient in pre-flood and post-flood soils and the level of post-flood soils was even higher than pre-flood conditions. The possible reason for nutrient depletion in the post-flood soils may be the intensive leaching condition brought in by the flood and the very strong acid condition which does not permit any retention and lead to leaching loss of nutrients. Sharda (2011) also reported that the main degradation processes in coastal soils were acidification of soil, removal of bases, low CEC, erosion and vegetative degradation.



Source of the data: KSPB, 2013

Fig. 43. Status of available primary nutrients in the pre-flood scenario of AEU 3

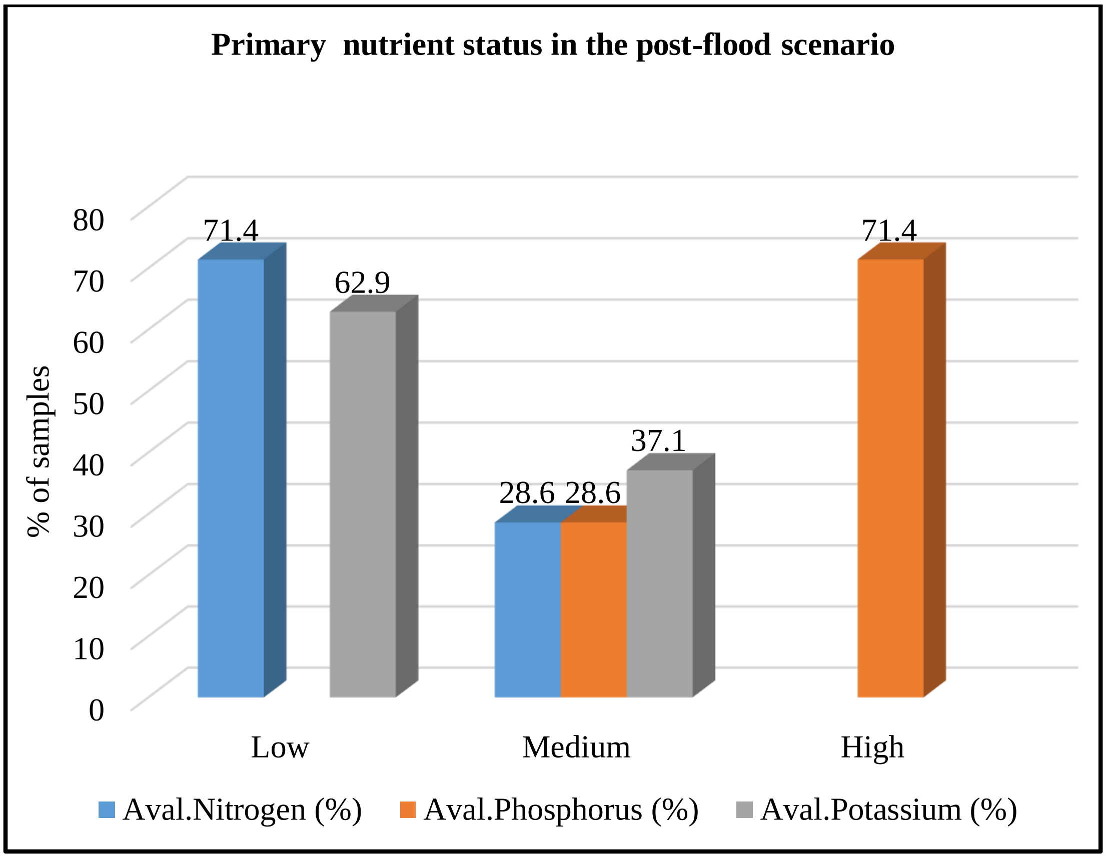
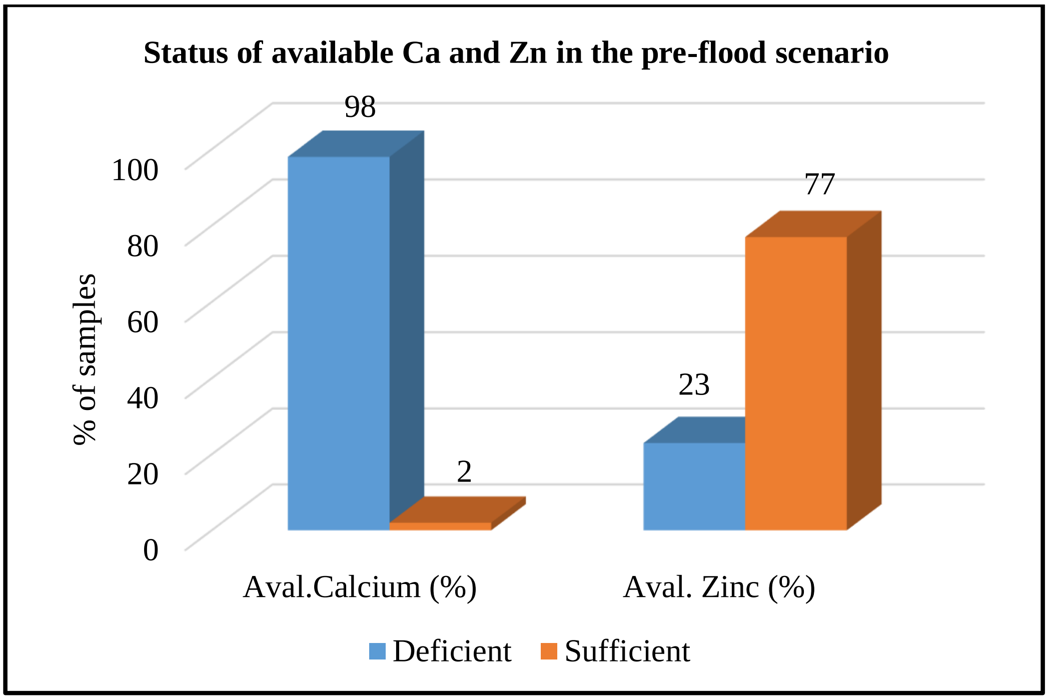


Fig. 44. Status of available primary nutrients in the post-flood scenario of AEU 3



Source of the data: KSPB, 2013

Fig. 45. Status of avail. Ca and Zn in the pre-flood scenario of AEU 3

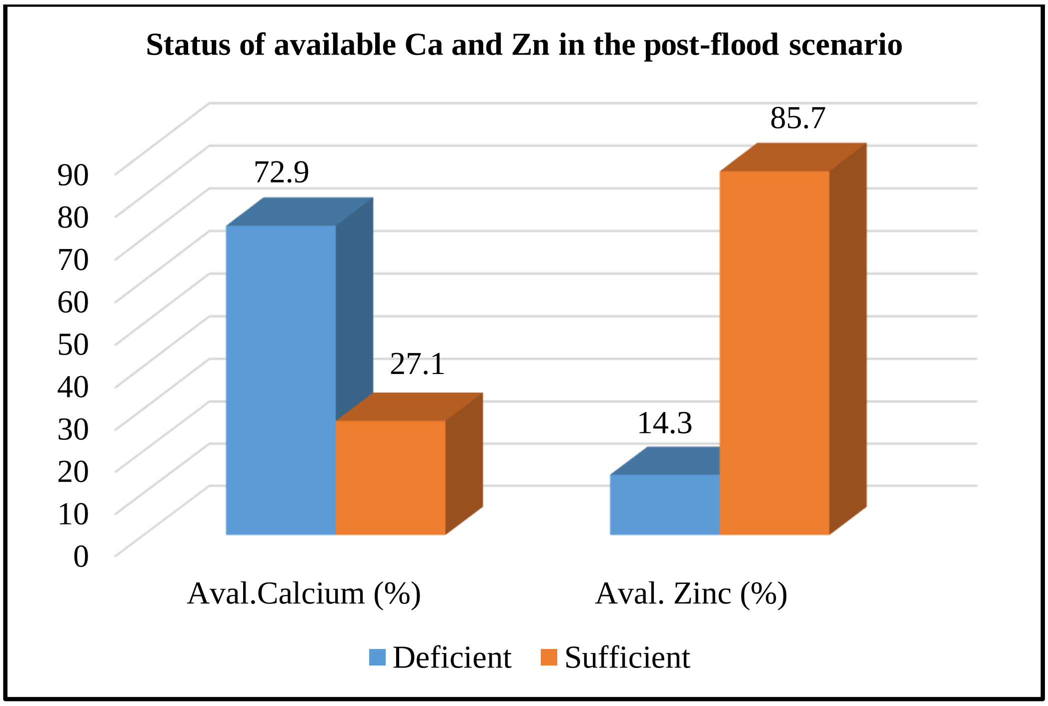


Fig. 46. Status of avail. Ca and Zn in the post-flood scenario of AEU 3

5.7. RECOMMENDED CROP MANAGEMENT PRACTICES IN THE POST-FLOOD SCENARIO

The results of soil quality analysis conducted in the flood affected areas of the AEU 3 can be considered as a base for the further modifications and recommendations in the crop management practices to be followed in the AEU 3.

The increase in the acidity of the soils, demands for the adequate and timely application of the liming materials. Use of required quantity of lime for regulation of soil reaction can take care of calcium nutrition as well. Instead of lime dolomite can also be used to supply both Ca and Mg especially in soils where Mg is deficient.

A slight increase in the organic carbon content was observed in the region. This might be due to the organic sediments carried by the flood water. This does not meet the required additions. More organic matter additions have to be encouraged in the cultivation practices, so that, the physical constraints of the Onattukara soil can be minimized. Addition of organic inputs can improve the properties like structure, porosity, soil moisture retention, cation exchange capacity etc. This can limit the soil moisture loss and nutrient loss through leaching. Organic inputs can also enhance the biological activity in the soil and thereby improving the nutrient availability, mediated by the microbial activity.

The high availability of the P status has to be taken into consideration to modify the recommended dose of further P fertilizer applications to the soil. The dose can be reduced or completely avoided in certain cases. High levels of available P can have negative influence on uptake of other nutrients especially calcium, magnesium and zinc. The serious depletion in the status of primary nutrients, nitrogen and potassium has to be considered seriously. Split application of the N and K fertilizers might reduce the leaching losses. In areas of low N and K content, the dose of fertilizer application can be increased up to 106 to 125 per cent based on soil test values, so that excessive application of fertilizers can be avoided.

Magnesium is critically deficient in the soils. Sulphur is another secondary nutrient, lost after the flood and hence both Mg and S have to be supplemented through external input. Application of $MgSO_4$ should be included in the normal fertilizer application schedule of the AEU. Micronutrients like copper and boron were also exclusively deficient in post flood soils of AEU 3. Zn was also deficient in some of the soils. Hence application of $CuSO_4$, borax and $ZnSO_4$ has to be done based on soil test. Foliar application of borax @ 0.5% or solubor @ 0.2 % can also be recommended to correct the boron deficiency. Only need based application of micro nutrients based on soil test should be done to maintain good soil health.

Though the majority of soils fell into the medium soil quality class, site specific and crop specific management strategies have to be followed for the profitable cultivation of the crops and soil test based fertilizer application has to be followed. It is mandatory to maintain the fertility of the soil for the sustainability of the environment.

6. SUMMARY

The study entitled “Assessment of soil quality in the post-flood scenario of AEU 3 in Alappuzha District of Kerala and generation of GIS maps” was carried out with objectives to evaluate the soil quality of flood affected areas of AEU 3, to work out the soil quality index and to map the various soil attributes and quality using the GIS techniques.

A survey was initially conducted in the AEU to find the flood affected areas and found that, seven panchayaths *viz.,* Chunakkara, Veeyapuram, Palamel, chettikulangara, Nooranadu, Pathiyoor and Chennithala were affected by the flood. Ten geo-referenced soil samples were collected from each panchayath which accounted to a total of seventy samples from the AEU. Samples were collected from the prominent land uses of the AEU 3 i.e. rice, coconut, vegetables and banana.

35.7 per cent of the surveyed area was under the rice based cropping system and the rest under the coconut based cropping system. 91.5 per cent of the farmers in the area were marginal farmers and others were small farmers. Only 28.6 per cent of the farmers followed organic practices. Heavy application of the phosphorus fertilizers was found. Nitrogen, potassium, magnesium and boron were under fertilized in the region. Practice of liming was observed in rice cultivation. Some farmers followed the soil test based recommendations and recommendations from Krishibhavans.

The soil samples were analysed for their physical (bulk density, particle density, porosity, texture, depth of sand/silt/clay deposition, aggregate analysis, soil moisture and water holding capacity), chemical (pH, EC, organic carbon, available N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B, heavy metal *viz* Pb, Cd, Ni and Cr) and biological attributes (acid phosphatase and dehydrogenase activity). Soil quality assessment was done for all the samples.

Principal component analysis (PCA) was used to derive the minimum data set (MDS) of indicators to compute the soil quality assessment. Seven principal components with Eigen value more than 1 were extracted through the PCA. Nine indicators *viz.* sand per cent, available P, available Ca, available Mg, bulk density, per cent of water stable aggregates, organic carbon, available Zn and available B in the MDS were found to highly influence the soil quality. Appropriate weights and scores were assigned to each indicator and these were aggregated to compute the soil quality index value. The soils were classified as 'poor', 'medium' and 'good' quality, based on the relative soil quality index value (RSQI).

Soil nutrient index for organic carbon and primary nutrients of each panchayath were calculated. Land quality index of the area were determined from the soil organic carbon stock values. Correlation among the various analysed soil attributes were studied. The results of the chemical attributes were compared with the nutrient status before flood so that the changes brought in by the flood can be understood more.

The major findings of the study are summarized below.

- Significant depositions of sand/silt/clay was **not** found all over the AEU 3, but only localized depositions were seen mainly on the river banks in Chennithala panchayath. Still, there was not much alterations in the texture. The predominant textural class, both before and after flood was loamy sand.
- Bulk density of 65.7 per cent samples were in the range of 1.2 Mg m^{-3} to 1.6 Mgm^{-3}.
- The mean value of MWD and per cent of WSA were found to be higher in the Veeyapuram panchayath.
- Porosity of 94.3 per cent samples had values between 30 and 50 per cent. The soil moisture content in most soils varied between 10 to 25 per cent and water holding capacity was less than 50 per cent.
- Physical properties like MWD, per cent WSA, soil moisture, WHC, clay content were positively correlated with the organic carbon content.
- Reduction in the soil pH resulted in increased acidity after the flood. Majority of the samples were strongly acidic. The EC values of all samples were in the non-saline range.
- There was only a slight increase, but not a noticeable change in the organic carbon status in comparison with the pre-flood status.

- Depletion was recorded in the status of available N and K. Available P content of the soil came down slightly from the very high status, but still continues to be high.
- Available Mg and S were critically deficient in 100 per cent of the samples. Available Ca was deficient in 72.9 per cent of the samples.
- Available Fe and Mn were found to be sufficient in all the samples, whereas available Cu and B were exclusively deficient in the AEU. Available Zn was found sufficient in 85.7 per cent of the samples.
- Even though far below the critical limits, traces of heavy metals like Pb, Ni and Cr were also detected in the soils, especially from the Veeyapuram panchayath.
- The chemical parameters were also observed to be correlated among them. Positive correlations were observed between OC and N, P and K, K and Ca, Ca and Zn, pH and Zn, Mg and S, Mg and Mn and certain negative correlations between N and Cu, Fe and Cu, P and B, P and S were also noted.
- Acid phosphatase activity in most soils ranged from 10 to 50 µg p-nitrophenol released g^{-1} soil hr^{-1} and the dehydrogenase activity was mostly observed to be within 75 µg TPF hydrolysed g^{-1} soil 24 hr^{-1} . The biological attributes were observed to be positively correlated with the organic carbon content.
- PCA results revealed that the major factors affecting soil quality in AEU 3 were sand per cent, available P, available Mg, bulk density, per cent of water stable aggregates, organic carbon, available B, available Ca and available Zn.
- Nutrient index of organic carbon was high in Veeyapuram and Chunakkara, low in Chettikulangara and medium in other areas.
- Nutrient index of nitrogen was low in most areas except, medium index value in Chunakkara and Veeyapuram.
- Nutrient index value of Phosphorus remained high throughout the flood affected area of AEU.
- Except Nooranadu panchayath, all other area had a low nutrient index for potassium.
- The soils of Nooranadu was found to have highest land quality index and that of Chettikulangara had lowest land quality index.

- The soil quality analysis in the flood affected areas of the AEU 3 of Alappuzha district showed that majority of the soils belonged to medium quality (78.6%), followed by poor (12.8%) and good (8.6%).
- The soil of Nooranadu panchayath was found to be with good soil quality and that of Chettikulangara with the poor soil quality among the study area.
- The results of soil quality analysis conducted in the flood affected areas of the AEU 3 can be considered as a base for the further modifications and recommendations in the crop management practices to be followed in the AEU
- The increase in the acidity of the soils, demands for the adequate and timely application of the liming materials
- More organic matter additions have to be encouraged in the cultivation practices, so that, the physical constraints of the Onattukara soil can be minimised and nutrient leaching and soil moisture loss can be reduced.
- Soil fertility with respect to nutrient availability has changed in the AEU. Hence, soil test based fertilizer application has to be followed to restore the post flood soil fertility in the AEU.
- Though the majority of soils fell into the medium soil quality class, site specific and crop specific management strategies have to be followed for the profitable cultivation of the crops. It is mandatory to maintain the fertility of the soil for the sustainability of the environment.

Future line of work

- Adoption of site specific nutrient and crop management practices and its evaluation.
- Monitoring of the soil quality under different land uses should be done periodically.
- INM and organic crop management practices should be given more emphasis in the region.

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ASSESSMENT OF SOIL QUALITY IN THE POST-FLOOD SCENARIO OF AEU 3 IN ALAPPUZHA DISTRICT OF KERALA AND GENERATION OF GIS MAPS

by

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ABSTRACT

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ABSTRACT

A study entitled "Assessment of soil quality in the post-flood scenario of AEU 3 in Alappuzha district of Kerala and generation of GIS maps" was carried out with objectives to evaluate the soil quality of the flood affected areas of AEU 3, to work out the soil quality index and to map the various soil attributes and quality using the GIS techniques. A survey was conducted to identify the flood affected areas in the AEU 3 and identified Chunakkara, Veeyapuram, Palamel, Chettikulangara, Nooranadu, Pathiyoor and Chennithala panchayths as the major flood affected areas. The major land uses in the AEU 3 were rice, coconut, banana and vegetables. Majority of the farmers were marginal (91.5 per cent) and a few were small farmers. 28.6 per cent of farmers followed organic practices and the rest followed inorganic/ INM practices.

Seventy geo-referenced surface soil samples were collected from seven flood affected panchayaths and characterized for various physical (texture, bulk density, particle density, porosity, aggregate analysis, soil moisture, WHC and the depth of silt/sand/clay deposition), chemical (pH, EC, organic carbon, available macro and micronutrients and heavy metal contents (Pb, Ni, Cd, Cr) and biological attributes (acid phosphatase and dehydrogenase activity).

Principal component analysis was used to set up the minimum data set of the indicators to compute the soil quality index. Seven principal components were extracted from which nine indicators that highly influenced the soil quality were identified, *viz.* sand per cent, available P, available Ca, available Mg, bulk density, per cent of water stable aggregates, organic carbon, available Zn and available B. Scores and weights were assigned to each indicator, and they were aggregated to compute the soil quality index. The relative soil quality index of the soils were also found. GIS techniques were used to prepare thematic maps of various soil attributes and relative soil quality indices of the flood affected areas of the AEU 3. Correlations were worked out among the various analysed parameters.

The acidity of the flood affected areas increased in comparison with the pre flood scenario. Depletion of nutrients like nitrogen, potassium, magnesium, sulphur,

copper, and boron were also noticed in the post-flood soils. Available P content of the soil came down slightly from the very high status, but still continues to be high. Mg, S, Cu and B were deficient in 100 per cent of the samples, whereas, Fe and Mn remained sufficient. Ca and Zn exhibited 27.1 and 14.3 per cent deficiency, respectively. Heavy metals like Pb, Ni and Cr were detected (below critical limit) in the analysed samples, with relatively higher content in Veeyapuram. Physical properties like MWD, per cent WSA, soil moisture and WHC and biological attributes were positively correlated with the organic carbon content. Nutrient indices of nitrogen and potassium were low in most of the areas where as nutrient index of phosphorus was high throughout the AEU.

91.4 per cent samples fell into very low land quality and 8.6 per cent into the low land quality. Majority of the soils belonged to medium soil quality (78.6 per cent), followed by poor (12.8 per cent) and good (8.6 per cent) quality. The soils of Nooranad panchayath recorded the highest soil quality index and that of Chettikulangara panchayath, recorded the lowest.

The increase in the acidity of the post flood soils, demands the application of adequate liming materials. Addition of more organic inputs can minimise the physical constraints of Onattukara soils. Split application of N and K fertilizers can reduce the leaching losses. Dose of P fertilizer has to be modified in the light of high P status in the AEU. Monitoring of secondary and micronutrients on regular basis is also required. Site specific and crop specific nutrient management is required to restore the soil health in the post-flood soils of AEU 3.

APPENDIX I

WEATHER PARAMETERS OF THE STUDY AREA DURING MAY 2018 TO MAY 2019

Month	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	Relative Humidity (%)
May 2018	33.84	24.16	298.3	81.02
June 2018	30.6	24.23	487	86.86
July 2018	30.26	22.83	549.6	84.19
August 2018	31	23.35	611.5	85.29
September 2018	31.43	23.16	70.4	85.78
October 2018	31.71	23.81	295	83.95
November 2018	32.4	23.7	119.9	82.18
December 2018	33.09	23.25	116	76.52
January 2019	33.06	19.54	0	68.05
February 2019	35.18	17.92	0	69.91
March 2019	34.81	18.77	4.8	72.58
April 2019	34.96	21.3	81.8	72.73
May 2019	34	24.35	43.4	76.65

APPENDIX II

DETAILS OF THE SURVEY CONDUCTED IN THE FLOOD AFFECTED AREAS OF AEU 3

a. Questionnaire of the survey

Name of the panchayath :

Name of the farmer :

Address :

Size of holding :

Survey No. :

Geocordinates of the sample :

Crops cultivated :

Nutrient management practices :

Depth of sand/silt/clay deposition after floods :

a. Area and crop management of sampled locations

Sl.No.	Size of holding	Crop	Organic/ INM/Inorganic	Remarks
1.	1.8 ha	Rice	Inorganic	-Factamfos and urea are applied -Application of lime
2.	1.4 ha	Rice	Inorganic	-Factamfos and urea are applied -Application of lime
3.	0.6 ha	Rice	Inorganic	-Factamfos and urea are applied -Application of lime
4.	0.2 ha	Coconut	Organic	-Green manuring, -Application of cow dung, ash
5.	0.32 ha	Rice	INM	-Application of lime -Follows soil test based recommendation
6.	0.25 ha	Rice	Inorganic	-Factamfos and urea are applied -Application of lime
7.	0.2 ha	Rice	Inorganic	-Factamfos and urea are applied -Application of lime
8.	0.3 ha	Coconut	INM	-Green manuring, application of cow dung, ash -Application of solubor -Application of salt
9.	0.18 ha	Coconut	Organic	-Green manuring, application of cow dung, ash
10.	0.35 ha	Rice	Inorganic	-Factamfos and urea are applied -Application of lime
11.	0.32 ha	Rice	Inorganic	-Application of lime -Factamfos, urea and potash are applied
12.	0.2 ha	Rice	Inorganic	-Factamfos, urea and potash are applied
13.	0.6 ha	Rice	Inorganic	Factamfos, urea and potash are applied
14.	0.4 ha	Rice	INM	-Soil test based recommendations -Practice liming -Factamfos, urea and potash are applied
15.	0.2 ha	Rice	Inorganic	-Factamfos, urea and potash are applied
16.	0.3 ha	Rice	Inorganic	-Lime application -Factamfos, urea and are applied
17.	0.25 ha	Rice	Inorganic	-Factamfos, urea and potash are applied
18.	0.2 ha	Rice	Inorganic	-Lime application -Factamfos, urea and potash are applied
19.	0.48 ha	Rice	Inorganic	-Factamfos, urea and potash are applied
20.	1 ha	Rice	Inorganic	-Lime application -Factamfos, urea and potash are applied
21.	0.2 ha	Vegetables	INM	-Bone meal, ash and small quantity of urea are used -Improved variety of seeds -Recommendations from Krishibhavan
22.	0.28 ha	Banana	INM	-18-18-18 fertilizer mixture is used -Soil test based recommendations -Application of cow dung, ash
23.	0.16 ha	Vegetables	Organic	-Application of cow dung, compost and bone meal
24.	0.3 ha	Banana	INM	-18-18-18 fertilizer mixture is applied -Application of cow dung and ash
25.	0.2ha	Vegetables	Organic	-Cow dung, bone meal, ash and poultry manure are applied

26.	0.3 ha	Vegetables	INM	-Recommendations from Krishibhavan -Improved varieties used -Application of urea, 18-18-18 -Application of cow dung, bone meal
27.	0.25 ha	Vegetables	INM	-Cow dung, ash, compost are applied -Application of urea, 18-18-18 -Recommendations by Krisibhavan
28.	0.4 ha	Vegetables	Organic	-Cow dung, poultry manure and ash applied
29.	0.1 ha	Banana	INM	-Cow dung (basal) and 18-18-18 fertilizer mixture are applied -Use of chemicals for plant protection
30.	0.2 ha	Banana	INM	-Cow dung (basal) and 18-18-18 fertilizer mixture are applied -Use of chemicals for plant protection
31.	0.6 ha	Rice	Inorganic	-Urea, factamfos and MOP are applied
32.	0.1 ha	Banana	INM	-Cow dung, bone meal, ash and poultry manure are applied -Soil test based recommended dose of fertilizers
33.	0.24 ha	Rice	Inorganic	-Urea and factamfos are applied -Lime application
34.	0.6 ha	Banana	INM	-Cow dung, ash and -18-18-18 fertilizer mixture are applied -Use of chemicals for plant protection
35.	0.2 ha	Rice	Inorganic	-Urea and factamfos are applied -Lime application
36.	0.16 ha	Banana	INM	-18-18-18 fertilizer mixture is applied -Application of cow dung,
37.	0.12 ha	Rice	Inorganic	-Urea and factamfos are applied -Lime application
38.	0.12 ha	Banana	INM	-Urea and 18-18-18 fertilizer mixture is applied -Chemicals used for plant protection
39.	0.2 ha	Rice	Inorganic	Urea and factamfos are applied
40.	0.18 ha	Banana	INM	-Cow dung (basal) and 18-18-18 fertilizer mixture are applied.
41.	0.6 ha	Vegetables	INM	-Cow dung, bone meal and ash are applied -Fetilizers like urea, factamfos, potash used
42.	0.4 ha	Vegetables	Organic	-Cow dung, bone meal and ash, poultry manure and neem cake are applied -Use of bio control agents for plant protection
43.	1.6 ha	Vegetables	Inorganic	-Followed fertilizer recommendations from Krishibhavan. . -Plant protection chemicals were used
44.	0.28 ha	Vegetables	INM	Cow dung, bone meal and ash are applied - Followed soil test based fertilizer recommendation
45.	0.1 ha	Banana	INM	Cow dung (basal), urea and MOP are applied

46.	0.2 ha	Banana	INM	-Cow dung and bone meal(basal) and 18-18-18 fertilizer mixture are applied - Followed recommendations from Krishibhavan
47.	0.25 ha	Banana	INM	-Cow dung and bone meal(basal) and 18-18-18 fertilizer mixture are applied -Application of ash
48.	0.4 ha	Banana	INM	-Cow dung and bone meal(basal) and 18-18-18 fertilizer mixture are applied -Application of ash
49.	0.25 ha	Vegetables	Organic	-Application of cow dung, bone meal and ash
50.	0.3 ha	Banana	INM	-Cow dung and bone meal(basal) and 18-18-18 fertilizer mixture are applied
51.	0.1 ha	Coconut	INM	-Green manuring, application of cow dung, ash -Application of borax
52.	0.1 ha	Vegetables	Organic	-Application of cow dung, bone meal, ash, poultry manure
53.	0.15 ha	Coconut	Organic	-Green manuring, application of cow dung, ash, salt
54.	0.1 ha	Vegetables	Organic	-Application of cow dung, bone meal, ash, poultry manure -Bio control agents used for plant protection
55.	0.14 ha	Vegetables	Organic	-Application of cow dung, bone meal, ash, neem cake
56.	0.1 ha	Vegetables	Organic	-Application of cow dung, bone meal, ash, poultry manure
57.	0.25 ha	Coconut	Organic	-Green manuring, application of cow dung, ash, salt
58.	0.3 ha	Coconut	Organic	-Green manuring, application of cow dung, ash, salt
59.	0.2 ha	Vegetables	Organic	-Application of cow dung, bone meal, ash, poultry manure -Application of urea during early growth
60.	0.18 ha	Coconut	Organic	-Application of green manures, cow dung, ash, salt
61.	0.36 ha	Rice	Inorganic	-Lime application -Application of rock phosphate, urea, potash, factamfos 20:20
62.	0.27 ha	Vegetables	Organic	-Application of compost, bone meal, neem cake. -Use of *Pseudomonas* and *Beauveria* for plant protection
63.	4.8 ha	Rice	Inorganic	-Application of factamfos, 20-20, potash -Application of dolomite
64.	0.6 ha	Rice	Inorganic	-Lime application -Application of rock phosphate, urea, potash -Soil test based recommendations
65.	0.16 ha	Vegetables	Organic	-Application of cow dung, compost, bone meal, ash
66.	1.02 ha	Banana	INM	-Deposition of silt (2cm) thickness seen

				-Application of 18-18-18, urea, cow dung,
67.	0.74 ha	Banana	INM	-Application of 18-18-18, urea, bone meal, cowdung
68.	0.35 ha	Banana	INM	-Deposition of silt (5cm) thickness seen - Application of 18-18-18, bone meal, cow dung, ash
69.	0.54 ha	Vegetables	Organic	-Application of vermicompost, bone meal, neem cake, poultry manure, ash -Improved varieties -Biocontrol agents
70.	1.4 ha	Vegetables	Organic	-Application of compost, bone meal, ash. - Use of *Pseudomonas* and *Beauveria* for plant protection

APPENDIX III

SOIL ANALYSIS DATA OF POST-FLOOD SOILS OF AEU 3

a. Physical attributes of post-flood soils of AEU3

Sample No.	Sample ID	Panchayath	Land Use	Textural Class	% sand	% silt	% clay	BD (Mg m^{-3})	PD (Mg m^{-3})	Porosity (%)
1	C1	Chunakkara	Rice	Sandy loam	77.4	5	17.6	1.33	2.06	35.4
2	C2	Chunakkara	Rice	Sandy loam	77.4	10	12.6	1.47	2.13	31.0
3	C3	Chunakkara	Rice	Sandy loam	72.4	10	17.6	1.42	2.12	33.0
4	C4	Chunakkara	Coconut	Loamy sand	82.4	12	5.6	1.48	2.38	37.8
5	C5	Chunakkara	Rice	Sandy clay loam	62.4	10	27.6	1.22	1.99	38.7
6	C6	Chunakkara	Rice	Sandy loam	68.4	13.6	18	1.19	1.88	36.7
7	C7	Chunakkara	Rice	Sandy loam	72.4	8	19.6	1.49	2.25	33.8
8	C8	Chunakkara	Coconut	Sandy loam	75.6	11	13.4	1.52	2.5	39.2
9	C9	Chunakkara	Coconut	Sandy loam	77.4	10	12.6	1.56	2.24	30.4
10	C10	Chunakkara	Rice	Loamy sand	83.4	6	10.6	1.18	2.09	43.5
11	V1	Veeyapuram	Rice	Clay loam	40.4	30.2	29.4	0.89	1.35	34.1
12	V2	Veeyapuram	Rice	Clay loam	40.4	31	28.6	0.82	1.33	38.3

13	V3	Veeyapuram	Rice	Loam	37.4	40	22.6	0.88	1.52	42.1
14	V4	Veeyapuram	Rice	Clay loam	40.4	30	29.6	0.84	1.34	37.3
15	V5	Veeyapuram	Rice	Sandy clay loam	57.4	20	22.6	0.76	1.5	49.3
16	V6	Veeyapuram	Rice	Clay loam	37	30.6	32.4	0.82	1.34	38.8
17	V7	Veeyapuram	Rice	Clay loam	36.4	30.2	33.4	0.85	1.34	36.6
18	V8	Veeyapuram	Rice	Clay loam	40.4	30	29.6	0.85	1.42	40.1
19	V9	Veeyapuram	Rice	Sandy clay loam	52.4	15	32.6	1.12	1.91	41.4
20	V10	Veeyapuram	Rice	Clay loam	36.2	32.4	31.4	0.82	1.33	38.3
21	P1	Palamel	Vegetables	Loamy sand	82.4	12	5.6	1.35	2.33	42.1
22	P2	Palamel	Banana	Loamy sand	80.4	11.4	8.2	1.29	2.33	44.6
23	P3	Palamel	Vegetables	Sandy clay loam	67.4	10	22.6	1.43	1.99	28.1
24	P4	Palamel	Banana	Loamy sand	87.4	6.4	6.2	1.76	2.4	26.7
25	P5	Palamel	Vegetables	Loamy sand	81.8	11.4	6.8	1.5	2.25	33.3
26	P6	Palamel	Vegetables	Loamy sand	82.4	12.2	5.4	1.22	2.05	40.5
27	P7	Palamel	Vegetables	Loamy sand	82.4	12.4	5.2	1.44	2.47	41.7
28	P8	Palamel	Vegetables	Loamy sand	83.4	11.2	5.4	1.37	2.38	42.4
29	P9	Palamel	Banana	Loamy sand	84.2	9	6.8	1.5	2	25.0
30	P10	Palamel	Banana	Loamy sand	85.2	5.4	9.4	1.55	2.47	37.2

31	T1	Chettikulangara	Rice	Loamy sand	83.4	6	10.6	1.18	2.06	42.7
32	T2	Chettikulangara	Banana	Loamy sand	81.8	11.4	6.8	1.52	2.01	24.4
33	T3	Chettikulangara	Rice	Loamy sand	82.4	12	5.6	1.15	1.8	36.1
34	T4	Chettikulangara	Banana	Loamy sand	80.8	12	7.2	1.59	2.4	33.8
35	T5	Chettikulangara	Rice	Loamy sand	82.2	11.2	6.6	1.16	2.08	44.2
36	T6	Chettikulangara	Banana	Loam	48	32	20	1.48	2.17	31.8
37	T7	Chettikulangara	Rice	Loamy sand	80.4	12	7.6	1.38	2.39	42.3
38	T8	Chettikulangara	Banana	Loamy sand	83.5	8.5	8	1.39	2.34	40.6
39	T9	Chettikulangara	Rice	Loamy sand	81.4	12	6.6	1.07	1.76	39.2
40	T10	Chettikulangara	Banana	Loamy sand	81.6	12.6	5.8	1.47	2.31	36.4
41	N1	Nooranadu	Vegetables	Loamy sand	84.5	9	6.5	1.48	2.23	33.6
42	N2	Nooranadu	Vegetables	Loamy sand	82.2	11.8	6	1.46	2.27	35.7
43	N3	Nooranadu	Vegetables	Loamy sand	83.4	6	10.6	1.22	2.05	40.5
44	N4	Nooranadu	Vegetables	Loamy sand	80.8	11.2	8	1.28	2.28	43.9
45	N5	Nooranadu	Banana	Loamy sand	81.4	12	6.6	1.51	2.29	34.1
46	N6	Nooranadu	Banana	Loamy sand	82.4	12	5.6	1.45	2.46	41.1
47	N7	Nooranadu	Banana	Sandy loam	75.6	11	13.4	1.44	2.25	36.0
48	N8	Nooranadu	Banana	Loamy sand	81.8	11.4	6.8	1.49	2.32	35.8

49	N9	Nooranadu	Vegetables	Loamy sand	80.8	12.8	6.4	1.46	2.48	41.1
50	N10	Nooranadu	Banana	Sandy loam	74.8	11.2	14	1.49	2.27	34.4
51	A1	Pathiyoor	Coconut	Loamy sand	82.2	11.2	6.6	1.37	2.28	39.9
52	A2	Pathiyoor	Vegetables	Loamy sand	84.4	9	6.6	1.36	2.37	42.6
53	A3	Pathiyoor	Coconut	Loamy sand	82.2	11	6.8	1.34	2.15	37.7
54	A4	Pathiyoor	Vegetables	Loamy sand	83.4	6	10.6	1.35	2.28	40.8
55	A5	Pathiyoor	Vegetables	Loamy sand	80.4	12	7.6	1.26	2.38	47.1
56	A6	Pathiyoor	Vegetables	Loamy sand	81.4	12	6.6	1.28	2.25	43.1
57	A7	Pathiyoor	Coconut	Loamy sand	87.4	6.4	6.2	1.31	2.49	47.4
58	A8	Pathiyoor	Coconut	Loamy sand	84.5	9	6.5	1.16	1.94	40.2
59	A9	Pathiyoor	Vegetables	Loamy sand	82.2	11.2	6.6	1.34	2.15	37.7
60	A10	Pathiyoor	Coconut	Loamy sand	79.6	14.6	5.8	1.24	1.83	32.2
61	H1	Chennithala	Rice	Loamy sand	80.8	12.8	6.4	1.15	1.8	36.1
62	H2	Chennithala	Vegetables	Loamy sand	84.2	9	6.8	1.41	2.19	35.6
63	H3	Chennithala	Rice	Loamy sand	82.4	12.6	5	1.07	1.76	39.2
64	H4	Chennithala	Rice	Loamy sand	83.4	6	10.6	1.18	2.06	42.7
65	H5	Chennithala	Vegetables	Loamy sand	81.4	14.2	4.4	1.46	2.27	35.7
66	H6	Chennithala	Banana	Loamy sand	81.8	11.4	6.8	1.62	2.38	31.9

67	H7	Chennithala	Banana	Loamy sand	87.4	6.4	6.2	1.36	2.1	35.2
68	H8	Chennithala	Banana	Clay	27.4	30	42.6	1.07	1.68	36.3
69	H9	Chennithala	Vegetables	Loamy sand	82.2	11.2	6.6	1.07	1.88	43.1
70	H10	Chennithala	Vegetables	Loamy sand	84.2	9	6.8	1.49	2.25	33.8

a. Physical attributes of post-flood soils of AEU 3 (Continued..)

Sample No.	Sample ID	Panchayath	Land Use	MWD (mm)	WSA (%)	Soil moisture (%)	WHC (%)
1	C1	Chunakkara	Rice	1.04	65.9	6.19	32.08
2	C2	Chunakkara	Rice	0.44	58.8	16.85	23.52
3	C3	Chunakkara	Rice	1.69	76.5	23.26	30.69
4	C4	Chunakkara	Coconut	0.67	62.7	8.52	28.36
5	C5	Chunakkara	Rice	2.88	82.2	21.35	31.77
6	C6	Chunakkara	Rice	1.91	78.9	24.81	39.31
7	C7	Chunakkara	Rice	1.20	75.7	21.05	29.39
8	C8	Chunakkara	Coconut	0.80	69.8	14.12	26.33
9	C9	Chunakkara	Coconut	1.77	77.8	12.53	17.74
10	C10	Chunakkara	Rice	0.89	67.9	24.87	36.59
11	V1	Veeyapuram	Rice	3.57	84.2	20.23	53.18

12	V2	Veeyapuram	Rice	2.95	79.6	21.12	54.35
13	V3	Veeyapuram	Rice	2.45	68.0	39.53	71.65
14	V4	Veeyapuram	Rice	3.02	81.5	22.04	55.21
15	V5	Veeyapuram	Rice	2.86	81.3	48.42	66.49
16	V6	Veeyapuram	Rice	3.74	87.4	23.02	57.52
17	V7	Veeyapuram	Rice	2.64	76.3	22.24	55.62
18	V8	Veeyapuram	Rice	2.81	77.4	35.92	69.1
19	V9	Veeyapuram	Rice	2.76	77.7	18.16	51.8
20	V10	Veeyapuram	Rice	2.36	78.6	21.12	54.35
21	P1	Palamel	Vegetables	0.32	65.0	9.28	34.35
22	P2	Palamel	Banana	0.91	75.3	11.53	34.91
23	P3	Palamel	Vegetables	1.86	71.8	20.35	31.77
24	P4	Palamel	Banana	0.82	68.4	7.43	21.23
25	P5	Palamel	Vegetables	0.76	65.4	17.36	23.66
26	P6	Palamel	Vegetables	0.90	69.2	14.04	35.1
27	P7	Palamel	Vegetables	0.48	58.4	19.9	32.05
28	P8	Palamel	Vegetables	0.64	60.3	13.78	32.23
29	P9	Palamel	Banana	0.79	66.1	5.52	12.21

30	P10	Palamel	Banana	0.81	67.5	19.74	27.94
31	T1	Chettikulangara	Rice	0.82	68.9	23.47	35.79
32	T2	Chettikulangara	Banana	0.29	51.1	5.03	11.62
33	T3	Chettikulangara	Rice	0.48	59.2	21.98	32.56
34	T4	Chettikulangara	Banana	0.32	65.2	6.56	24.04
35	T5	Chettikulangara	Rice	0.89	69.9	23.47	35.79
36	T6	Chettikulangara	Banana	1.56	60.8	21.7	57.66
37	T7	Chettikulangara	Rice	0.88	68.5	16.53	23.37
38	T8	Chettikulangara	Banana	0.48	56.9	11.13	32.91
39	T9	Chettikulangara	Rice	0.32	66.3	25.14	38.82
40	T10	Chettikulangara	Banana	0.37	67.1	9.11	31.53
41	N1	Nooranadu	Vegetables	0.90	69.4	18.26	24.66
42	N2	Nooranadu	Vegetables	0.83	65.7	20.43	30.45
43	N3	Nooranadu	Vegetables	1.56	78.6	14.04	35.1
44	N4	Nooranadu	Vegetables	0.90	66.0	15.78	36.2
45	N5	Nooranadu	Banana	0.89	70.9	12.35	23.78
46	N6	Nooranadu	Banana	0.88	68.5	21.74	28.94
47	N7	Nooranadu	Banana	2.54	78.9	10.65	31.49

48	N8	Nooranadu	Banana	1.54	76.9	24.47	30.54
49	N9	Nooranadu	Vegetables	0.38	56.2	22.8	31.05
50	N10	Nooranadu	Banana	0.39	57.6	20.05	30.77
51	A1	Pathiyoor	Coconut	0.82	67.3	12.01	26.38
52	A2	Pathiyoor	Vegetables	0.37	57.2	12.55	30.57
53	A3	Pathiyoor	Coconut	0.85	66.3	13.21	28.56
54	A4	Pathiyoor	Vegetables	1.48	72.3	13.85	28.25
55	A5	Pathiyoor	Vegetables	0.61	62.1	11.14	26.62
56	A6	Pathiyoor	Vegetables	0.38	67.9	14.52	30.24
57	A7	Pathiyoor	Coconut	0.42	58.9	15.78	37.78
58	A8	Pathiyoor	Coconut	1.45	71.3	30.28	51.28
59	A9	Pathiyoor	Vegetables	0.30	65.0	13.21	28.56
60	A10	Pathiyoor	Coconut	1.27	70.9	28.27	42.36
61	H1	Chennithala	Rice	0.85	69.2	31.98	42.56
62	H2	Chennithala	Vegetables	0.29	52.6	11.35	27.55
63	H3	Chennithala	Rice	1.19	71.7	35.14	48.82
64	H4	Chennithala	Rice	0.35	65.5	23.47	35.79
65	H5	Chennithala	Vegetables	1.61	78.7	20.43	30.45

66	H6	Chennithala	Banana	0.28	49.6	11.14	26.62
67	H7	Chennithala	Banana	0.29	50.4	14.76	32.07
68	H8	Chennithala	Banana	2.85	84.2	10.59	50.8
69	H9	Chennithala	Vegetables	0.91	70.5	14.9	41.86
70	H10	Chennithala	Vegetables	0.90	66.7	21.05	29.39

b. Status of soil reaction and organic carbon in the post-flood soils of AEU 3

Sample No.	Sample ID	Panchayath	Land Use	pH	EC (dSm^{-1})	OC (%)
1	C1	Chunakkara	Rice	4.86	0.08	0.78
2	C2	Chunakkara	Rice	4.61	0.04	0.33
3	C3	Chunakkara	Rice	4.51	0.16	1.26
4	C4	Chunakkara	Coconut	4.92	0.13	0.66
5	C5	Chunakkara	Rice	4.43	0.08	1.44
6	C6	Chunakkara	Rice	4.83	0.2	1.43
7	C7	Chunakkara	Rice	4.04	0.07	0.9
8	C8	Chunakkara	Coconut	4.91	0.05	0.6
9	C9	Chunakkara	Coconut	4.67	0.12	1.32
10	C10	Chunakkara	Rice	4.28	0.2	0.88
11	V1	Veeyapuram	Rice	4.9	0.12	1.89
12	V2	Veeyapuram	Rice	4.12	0.13	1.56
13	V3	Veeyapuram	Rice	4.25	0.81	1.38
14	V4	Veeyapuram	Rice	3.52	0.59	1.56
15	V5	Veeyapuram	Rice	4.24	0.16	1.43
16	V6	Veeyapuram	Rice	4.96	0.42	1.91
17	V7	Veeyapuram	Rice	4.3	0.12	0.87
18	V8	Veeyapuram	Rice	4.75	0.15	1.49
19	V9	Veeyapuram	Rice	4.4	0.16	1.38
20	V10	Veeyapuram	Rice	4.93	0.14	0.72
21	P1	Palamel	Vegetables	4.97	0.12	0.21
22	P2	Palamel	Banana	4.51	0.06	0.9
23	P3	Palamel	Vegetables	4.64	0.1	0.9
24	P4	Palamel	Banana	4.58	0.06	0.81
25	P5	Palamel	Vegetables	4.78	0.06	0.75
26	P6	Palamel	Vegetables	4.02	0.13	0.89
27	P7	Palamel	Vegetables	4.2	0.53	0.48
28	P8	Palamel	Vegetables	4.17	0.71	0.63
29	P9	Palamel	Banana	4.86	0.11	0.78
30	P10	Palamel	Banana	4.98	0.29	0.8
31	T1	Chettikulangara	Rice	4.6	0.14	0.81
32	T2	Chettikulangara	Banana	4.62	0.17	0.12
33	T3	Chettikulangara	Rice	4.68	0.09	0.48
34	T4	Chettikulangara	Banana	4.67	0.24	0.21
35	T5	Chettikulangara	Rice	4.98	0.37	0.88
36	T6	Chettikulangara	Banana	4.81	0.28	0.88
37	T7	Chettikulangara	Rice	4.8	0.13	0.87
38	T8	Chettikulangara	Banana	4.13	0.48	0.48
39	T9	Chettikulangara	Rice	3.98	0.39	0.21
40	T10	Chettikulangara	Banana	4.59	0.33	0.28
41	N1	Nooranadu	Vegetables	4.71	0.94	0.89
42	N2	Nooranadu	Vegetables	4.57	0.9	0.82
43	N3	Nooranadu	Vegetables	4.97	0.39	1.56
44	N4	Nooranadu	Vegetables	4.05	0.88	0.89
45	N5	Nooranadu	Banana	4.72	0.38	0.88
46	N6	Nooranadu	Banana	4.76	0.49	0.87
47	N7	Nooranadu	Banana	4.36	0.54	1.9
48	N8	Nooranadu	Banana	4.07	0.19	1.53
49	N9	Nooranadu	Vegetables	4.55	0.61	0.3
50	N10	Nooranadu	Banana	4.45	0.37	0.24
51	A1	Pathiyoor	Coconut	4.33	0.13	0.81

52	A2	Pathiyoor	Vegetables	5.11	0.06	0.26
53	A3	Pathiyoor	Coconut	4.23	0.02	0.84
54	A4	Pathiyoor	Vegetables	5.37	0.06	1.47
55	A5	Pathiyoor	Vegetables	5.15	0.55	0.6
56	A6	Pathiyoor	Vegetables	4.38	0.55	0.3
57	A7	Pathiyoor	Coconut	4.35	0.97	0.42
58	A8	Pathiyoor	Coconut	4.82	0.18	1.44
59	A9	Pathiyoor	Vegetables	4.75	0.09	0.15
60	A10	Pathiyoor	Coconut	4.68	0.09	1.26
61	H1	Chennithala	Rice	4.49	0.52	0.84
62	H2	Chennithala	Vegetables	4.57	0.04	0.12
63	H3	Chennithala	Rice	4.82	0.33	1.98
64	H4	Chennithala	Rice	4.5	0.33	0.24
65	H5	Chennithala	Vegetables	4.83	0.18	1.6
66	H6	Chennithala	Banana	4.88	0.18	0.03
67	H7	Chennithala	Banana	4.7	0.16	0.06
68	H8	Chennithala	Banana	4.02	0.21	1.42
69	H9	Chennithala	Vegetables	5.11	0.23	0.9
70	H10	Chennithala	Vegetables	4.25	0.17	0.89

c. Status of available primary nutrients in the post-flood soils of AEU 3

Sample No.	Sample ID	Panchayath	Land Use	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
1	C1	Chunakkara	Rice	275.97	98.18	38.97
2	C2	Chunakkara	Rice	288.5	29.99	12.76
3	C3	Chunakkara	Rice	413.95	26.72	43
4	C4	Chunakkara	Coconut	263.42	119.9	92.17
5	C5	Chunakkara	Rice	338.68	12.54	34.49
6	C6	Chunakkara	Rice	351.23	16.9	48.94
7	C7	Chunakkara	Rice	338.68	20.99	24.86
8	C8	Chunakkara	Coconut	288.51	48.82	49.72
9	C9	Chunakkara	Coconut	301.06	95.99	21.17
10	C10	Chunakkara	Rice	301.06	32.18	43.12
11	V1	Veeyapuram	Rice	338.7	13.27	164
12	V2	Veeyapuram	Rice	338.69	12.45	154
13	V3	Veeyapuram	Rice	326.14	13.82	177.5
14	V4	Veeyapuram	Rice	351.23	49.9	250.2
15	V5	Veeyapuram	Rice	351.23	14.63	79.5
16	V6	Veeyapuram	Rice	288.51	16.54	101.47
17	V7	Veeyapuram	Rice	363.78	64.36	52.6
18	V8	Veeyapuram	Rice	401.4	14.09	98.67
19	V9	Veeyapuram	Rice	338.7	58.08	84.43
20	V10	Veeyapuram	Rice	250.88	33.4	166
21	P1	Palamel	Vegetables	225.97	26.99	133.6
22	P2	Palamel	Banana	238.33	26.99	74.81
23	P3	Palamel	Vegetables	263.42	41.18	71.34
24	P4	Palamel	Banana	225.79	55.9	59.47
25	P5	Palamel	Vegetables	238.34	96.81	38.08
26	P6	Palamel	Vegetables	288.51	25.63	207.2
27	P7	Palamel	Vegetables	188.16	66.9	176.62
28	P8	Palamel	Vegetables	137.98	29.99	40.99
29	P9	Palamel	Banana	87.81	107.45	97.1
30	P10	Palamel	Banana	112.89	65.99	257.48

31	T1	Chettikulangara	Rice	250.88	67.36	241.58
32	T2	Chettikulangara	Banana	250.88	134.17	50.17
33	T3	Chettikulangara	Rice	250.88	27.81	46.7
34	T4	Chettikulangara	Banana	200.7	127.63	181.4
35	T5	Chettikulangara	Rice	112.89	14.18	41.55
36	T6	Chettikulangara	Banana	213.24	46.08	38.86
37	T7	Chettikulangara	Rice	250.88	78.35	247.3
38	T8	Chettikulangara	Banana	100.35	44.73	47.04
39	T9	Chettikulangara	Rice	100.35	31.09	25.31
40	T10	Chettikulangara	Banana	100.35	128.45	46.48
41	N1	Nooranadu	Vegetables	213.24	126	198.24
42	N2	Nooranadu	Vegetables	225.79	111.53	231.84
43	N3	Nooranadu	Vegetables	301.06	139.17	207.2
44	N4	Nooranadu	Vegetables	100.35	65.99	253.9
45	N5	Nooranadu	Banana	225.79	173.8	247.63
46	N6	Nooranadu	Banana	250.88	182.16	232.06
47	N7	Nooranadu	Banana	275.97	185.18	231.28
48	N8	Nooranadu	Banana	250.88	164.89	153.66
49	N9	Nooranadu	Vegetables	175.62	83.72	200.14
50	N10	Nooranadu	Banana	187.81	83.73	44.02
51	A1	Pathiyoor	Coconut	213.24	15.81	21.81
52	A2	Pathiyoor	Vegetables	250.88	67.91	154.67
53	A3	Pathiyoor	Coconut	250.88	11.9	54.65
54	A4	Pathiyoor	Vegetables	301.06	134.99	51.18
55	A5	Pathiyoor	Vegetables	250.88	132.44	51.41
56	A6	Pathiyoor	Vegetables	250.88	114.26	42.67
57	A7	Pathiyoor	Coconut	75.26	85.63	36.85
58	A8	Pathiyoor	Coconut	100.35	10.9	71.12
59	A9	Pathiyoor	Vegetables	187.8	32.45	173.8
60	A10	Pathiyoor	Coconut	150.18	18.27	74.4
61	H1	Chennithala	Rice	112.89	34.9	224.56
62	H2	Chennithala	Vegetables	75.26	35.18	76.72
63	H3	Chennithala	Rice	125.44	10.09	82.2
64	H4	Chennithala	Rice	75.26	17.45	47.49
65	H5	Chennithala	Vegetables	125.44	16.63	50.2
66	H6	Chennithala	Banana	75.26	14.18	149.4
67	H7	Chennithala	Banana	37.63	34.36	122.3
68	H8	Chennithala	Banana	47.63	29.45	91.7
69	H9	Chennithala	Vegetables	62.72	17.45	67.2
70	H10	Chennithala	Vegetables	125.44	17.32	58.6

d. Status of available secondary nutrients in the post-flood soils of AEU 3

Sample No.	Sample ID	Panchayath	Land Use	Ca (mg kg^{-1})	Mg (mg kg^{-1})	S (mg kg^{-1})
1	C1	Chunakkara	Rice	316.1	13.98	0.61
2	C2	Chunakkara	Rice	101.8	13.53	0.53
3	C3	Chunakkara	Rice	129.1	14.87	0.6
4	C4	Chunakkara	Coconut	321.55	14.18	0.56
5	C5	Chunakkara	Rice	149.35	14.43	0.22
6	C6	Chunakkara	Rice	131.05	14.15	0.46
7	C7	Chunakkara	Rice	90.2	13.53	0.43
8	C8	Chunakkara	Coconut	83.7	13.79	0.18
9	C9	Chunakkara	Coconut	301.85	14.3	0.64

10	C10	Chunakkara	Rice	106.35	13.92	0.82
11	V1	Veeyapuram	Rice	312	15.35	4.23
12	V2	Veeyapuram	Rice	298.65	15.27	4.51
13	V3	Veeyapuram	Rice	196.35	15.27	4.4
14	V4	Veeyapuram	Rice	189.9	15.11	2.37
15	V5	Veeyapuram	Rice	218.4	15.28	3.77
16	V6	Veeyapuram	Rice	321.05	15.22	2.16
17	V7	Veeyapuram	Rice	217.55	15.15	3.12
18	V8	Veeyapuram	Rice	229.8	15.21	2.12
19	V9	Veeyapuram	Rice	355.1	14.95	0.39
20	V10	Veeyapuram	Rice	180.8	14.59	0.44
21	P1	Palamel	Vegetables	39.75	12.53	0.21
22	P2	Palamel	Banana	230.95	13.73	0.09
23	P3	Palamel	Vegetables	42.84	13.05	0.08
24	P4	Palamel	Banana	305.7	14.12	0.12
25	P5	Palamel	Vegetables	68	13.46	0.06
26	P6	Palamel	Vegetables	74.65	14.09	0.07
27	P7	Palamel	Vegetables	81.4	14.1	0.29
28	P8	Palamel	Vegetables	27.24	13.47	0.19
29	P9	Palamel	Banana	303.2	14.31	0.31
30	P10	Palamel	Banana	440.95	14.69	0.54
31	T1	Chettikulangara	Rice	144.05	14.99	0.63
32	T2	Chettikulangara	Banana	67.5	13.85	0.16
33	T3	Chettikulangara	Rice	103.5	14.63	0.54
34	T4	Chettikulangara	Banana	313	14.73	1.33
35	T5	Chettikulangara	Rice	93.5	13.89	0.37
36	T6	Chettikulangara	Banana	212	14.47	0.2
37	T7	Chettikulangara	Rice	309.95	14.37	0.57
38	T8	Chettikulangara	Banana	126.45	13.37	0.09
39	T9	Chettikulangara	Rice	141.9	12.52	0.11
40	T10	Chettikulangara	Banana	110.9	13.68	0.13
41	N1	Nooranadu	Vegetables	308.34	14.81	0.23
42	N2	Nooranadu	Vegetables	249.45	14.33	0.55
43	N3	Nooranadu	Vegetables	265.1	14.85	0.23
44	N4	Nooranadu	Vegetables	123.95	14.32	0.18
45	N5	Nooranadu	Banana	357.45	14.64	0.51
46	N6	Nooranadu	Banana	297.55	14.64	0.39
47	N7	Nooranadu	Banana	429.55	14.91	0.24
48	N8	Nooranadu	Banana	183.25	14.5	0.31
49	N9	Nooranadu	Vegetables	161.91	13.11	0.14
50	N10	Nooranadu	Banana	182.1	13.87	0.13
51	A1	Pathiyoor	Coconut	201.9	14.16	0.28
52	A2	Pathiyoor	Vegetables	206.85	14.27	1.78
53	A3	Pathiyoor	Coconut	150.1	14.18	3
54	A4	Pathiyoor	Vegetables	351.2	14.41	0.7
55	A5	Pathiyoor	Vegetables	273.9	13.76	0.9
56	A6	Pathiyoor	Vegetables	311.75	14.26	0.53
57	A7	Pathiyoor	Coconut	192.6	13.55	0.48
58	A8	Pathiyoor	Coconut	89.25	15.61	1.08
59	A9	Pathiyoor	Vegetables	362.7	15.71	0.88
60	A10	Pathiyoor	Coconut	69.45	15.56	1.67
61	H1	Chennithala	Rice	77.85	15.46	3.26
62	H2	Chennithala	Vegetables	84.35	14.7	4.21
63	H3	Chennithala	Rice	59.5	15.69	0.73
64	H4	Chennithala	Rice	14.73	14.65	1.94

65	H5	Chennithala	Vegetables	34.06	15.97	0.74
66	H6	Chennithala	Banana	304.05	15.49	1.95
67	H7	Chennithala	Banana	71.65	15.17	0.86
68	H8	Chennithala	Banana	303.6	16.09	1.28
69	H9	Chennithala	Vegetables	74.9	15.98	0.74
70	H10	Chennithala	Vegetables	53.1	15.64	0.52

e. Status of available micronutrients in the post-flood soils of AEU 3

Sample No.	Sample ID	Panchayath	Land Use	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	B (mg kg^{-1})
1	C1	Chunakkara	Rice	819.9	2.08	0.46	2.83	0.18
2	C2	Chunakkara	Rice	741.3	2.06	0.52	1.80	0.13
3	C3	Chunakkara	Rice	825.4	2.09	0.42	2.37	0.05
4	C4	Chunakkara	Coconut	815.9	2.17	0.55	1.17	0.16
5	C5	Chunakkara	Rice	860.2	2.1	0.26	3.33	0.07
6	C6	Chunakkara	Rice	895.8	2.15	0.29	3.17	0.15
7	C7	Chunakkara	Rice	802.8	2.1	0.49	1.55	0.17
8	C8	Chunakkara	Coconut	931.9	1.91	0.52	2.87	0.16
9	C9	Chunakkara	Coconut	923.3	2.02	0.34	3.25	0.14
10	C10	Chunakkara	Rice	822.9	2.48	0.43	1.30	0.16
11	V1	Veeyapuram	Rice	973.1	38.46	0.25	1.45	0.12
12	V2	Veeyapuram	Rice	975.4	35.63	0.38	1.07	0.15
13	V3	Veeyapuram	Rice	950.1	29.75	0.29	1.66	0.15
14	V4	Veeyapuram	Rice	968.8	25.55	0.41	2.71	0.18
15	V5	Veeyapuram	Rice	929.7	23.99	0.18	2.16	0.14
16	V6	Veeyapuram	Rice	846.6	27.24	0.03	0.93	0.13
17	V7	Veeyapuram	Rice	944.9	22.46	0.13	0.96	0.15
18	V8	Veeyapuram	Rice	912.7	19.39	0.12	0.82	0.16
19	V9	Veeyapuram	Rice	866.9	14.56	0.05	1.80	0.18
20	V10	Veeyapuram	Rice	744.5	18.37	0.47	1.95	0.02
21	P1	Palamel	Vegetables	620.5	1.31	0.61	1.18	0.13
22	P2	Palamel	Banana	828.6	5.51	0.52	3.15	0.16
23	P3	Palamel	Vegetables	692.8	1.55	0.49	1.10	0.19
24	P4	Palamel	Banana	355.1	6.12	0.48	1.04	0.18
25	P5	Palamel	Vegetables	387.5	1.56	0.63	1.62	0.11
26	P6	Palamel	Vegetables	786.3	1.18	0.53	2.48	0.14
27	P7	Palamel	Vegetables	907	2.74	0.53	1.72	0.05
28	P8	Palamel	Vegetables	779.7	2.53	0.6	0.96	0.15
29	P9	Palamel	Banana	846.9	8.89	0.49	2.30	0.13
30	P10	Palamel	Banana	840.3	12.78	0.44	3.50	0.17
31	T1	Chettikulangara	Rice	563	2.08	0.58	1.80	0.16
32	T2	Chettikulangara	Banana	302	2.1	0.64	1.89	0.18
33	T3	Chettikulangara	Rice	585.4	2.11	0.63	1.72	0.15
34	T4	Chettikulangara	Banana	484.7	2.05	0.54	2.03	0.13
35	T5	Chettikulangara	Rice	909.8	5.16	0.39	0.66	0.14
36	T6	Chettikulangara	Banana	853	5.89	0.39	3.96	0.05
37	T7	Chettikulangara	Rice	747.5	8.6	0.55	1.60	0.14
38	T8	Chettikulangara	Banana	830.6	5.39	0.55	0.75	0.15
39	T9	Chettikulangara	Rice	367.8	5.16	0.64	1.83	0.17
40	T10	Chettikulangara	Banana	906.7	6.49	0.56	0.38	0.09
41	N1	Nooranadu	Vegetables	673.9	8.34	0.51	3.15	0.11
42	N2	Nooranadu	Vegetables	885	16.56	0.37	2.20	0.05

43	N3	Nooranadu	Vegetables	735.2	12.14	0.45	2.93	0.14
44	N4	Nooranadu	Vegetables	978.4	7.69	0.43	2.02	0.18
45	N5	Nooranadu	Banana	772.8	11.37	0.49	2.20	0.26
46	N6	Nooranadu	Banana	886.9	10.48	0.3	1.57	0.03
47	N7	Nooranadu	Banana	926.5	31.1	0.1	2.59	0.01
48	N8	Nooranadu	Banana	863.4	10.05	0.41	1.19	0.09
49	N9	Nooranadu	Vegetables	788.3	5.34	0.61	0.89	0.01
50	N10	Nooranadu	Banana	623	7.28	0.57	1.58	0.13
51	A1	Pathiyoor	Coconut	748.8	2.13	0.49	3.16	0.15
52	A2	Pathiyoor	Vegetables	848.4	2.23	0.59	2.83	0.16
53	A3	Pathiyoor	Coconut	783.9	4.8	0.53	2.19	0.17
54	A4	Pathiyoor	Vegetables	920.8	3.36	0.47	3.18	0.13
55	A5	Pathiyoor	Vegetables	615.5	5.34	0.53	2.45	0.17
56	A6	Pathiyoor	Vegetables	973.1	6.8	0.28	2.09	0.09
57	A7	Pathiyoor	Coconut	920.8	9.45	0.49	1.14	0.15
58	A8	Pathiyoor	Coconut	350.2	5.71	0.97	1.39	0.05
59	A9	Pathiyoor	Vegetables	767.9	6.65	0.28	3.50	0.13
60	A10	Pathiyoor	Coconut	405.8	8.82	0.97	1.82	0.13
61	H1	Chennithala	Rice	183.8	11	0.44	2.49	0.04
62	H2	Chennithala	Vegetables	747	9.79	0.07	3.21	0.01
63	H3	Chennithala	Rice	170.7	38.54	0.98	4.26	0.09
64	H4	Chennithala	Rice	280	10.74	0.02	2.42	0.05
65	H5	Chennithala	Vegetables	183.5	37.5	0.82	1.61	0.09
66	H6	Chennithala	Banana	225.5	27.1	0.34	4.23	0.01
67	H7	Chennithala	Banana	170.5	16.31	0.21	1.35	0.09
68	H8	Chennithala	Banana	339.8	27.1	0.91	1.80	0.14
69	H9	Chennithala	Vegetables	183.5	37.48	0.83	0.94	0.09
70	H10	Chennithala	Vegetables	186.2	35.24	0.75	0.95	0.05

f. Heavy metal status of post-flood soils of AEU 3

Sample No.	Sample ID	Panchayath	Land Use	Pb (mg kg^{-1})	Cd (mg kg-1)	Ni (mgkg-1)	Cr (mg kg-1)
1	C1	Chunakkara	Rice	0.4956	ND	0.0182	0.2285
2	C2	Chunakkara	Rice	0.3452	ND	0.0201	0.1623
3	C3	Chunakkara	Rice	0.6441	ND	0.0472	0.1877
4	C4	Chunakkara	Coconut	0.2965	ND	ND	0.1946
5	C5	Chunakkara	Rice	0.4256	ND	0.0192	0.1745
6	C6	Chunakkara	Rice	0.3954	ND	0.0211	0.1649
7	C7	Chunakkara	Rice	0.1719	ND	0.0122	0.1535
8	C8	Chunakkara	Coconut	0.3881	ND	ND	0.2066
9	C9	Chunakkara	Coconut	0.1350	ND	0.0172	0.1935
10	C10	Chunakkara	Rice	0.2946	ND	0.0265	0.1753
11	V1	Veeyapuram	Rice	0.2595	ND	0.6145	0.2462
12	V2	Veeyapuram	Rice	0.3156	ND	0.3149	0.2325
13	V3	Veeyapuram	Rice	0.4125	ND	0.4865	0.2152
14	V4	Veeyapuram	Rice	0.3647	ND	0.4731	0.2541
15	V5	Veeyapuram	Rice	0.7953	ND	0.3202	0.2637
16	V6	Veeyapuram	Rice	0.4218	ND	0.3496	0.2235
17	V7	Veeyapuram	Rice	0.2984	ND	0.2469	0.2453
18	V8	Veeyapuram	Rice	0.6395	ND	0.2977	0.2086
19	V9	Veeyapuram	Rice	0.2853	ND	0.2148	0.2014
20	V10	Veeyapuram	Rice	0.3476	ND	0.4679	0.2304
21	P1	Palamel	Vegetables	0.1688	ND	ND	0.1424

22	P2	Palamel	Banana	0.3279	ND	0.0223	0.1784
23	P3	Palamel	Vegetables	0.1578	ND	ND	0.1342
24	P4	Palamel	Banana	0.3787	ND	0.0404	0.1622
25	P5	Palamel	Vegetables	0.1667	ND	ND	0.1419
26	P6	Palamel	Vegetables	0.1532	ND	ND	0.1349
27	P7	Palamel	Vegetables	0.1546	ND	ND	0.1328
28	P8	Palamel	Vegetables	0.1649	ND	ND	0.1294
29	P9	Palamel	Banana	0.2641	ND	0.0314	0.2179
30	P10	Palamel	Banana	0.2047	ND	0.7630	0.5134
31	T1	Chettikulangara	Rice	0.3770	ND	ND	0.1717
32	T2	Chettikulangara	Banana	0.2832	ND	ND	0.1257
33	T3	Chettikulangara	Rice	0.0343	ND	ND	0.1209
34	T4	Chettikulangara	Banana	0.0469	ND	ND	0.1184
35	T5	Chettikulangara	Rice	0.0321	ND	ND	0.1248
36	T6	Chettikulangara	Banana	0.0354	ND	ND	0.1147
37	T7	Chettikulangara	Rice	0.0278	ND	ND	0.1648
38	T8	Chettikulangara	Banana	0.0264	ND	ND	0.1231
39	T9	Chettikulangara	Rice	0.0315	ND	ND	0.1701
40	T10	Chettikulangara	Banana	0.0348	ND	ND	0.1224
41	N1	Nooranadu	Vegetables	0.2495	ND	0.0512	0.2132
42	N2	Nooranadu	Vegetables	0.2125	ND	0.0374	0.2215
43	N3	Nooranadu	Vegetables	0.2976	ND	0.0735	0.2455
44	N4	Nooranadu	Vegetables	0.0704	ND	0.0429	0.3255
45	N5	Nooranadu	Banana	0.2506	ND	0.0849	0.2638
46	N6	Nooranadu	Banana	0.2674	ND	0.1234	0.2416
47	N7	Nooranadu	Banana	0.2016	ND	0.1798	0.1462
48	N8	Nooranadu	Banana	0.2237	ND	0.1356	0.2178
49	N9	Nooranadu	Vegetables	0.4001	ND	0.0076	0.1679
50	N10	Nooranadu	Banana	0.2467	ND	0.1295	0.1523
51	A1	Pathiyoor	Coconut	0.1702	ND	0.0434	0.1334
52	A2	Pathiyoor	Vegetables	0.2156	ND	ND	0.1234
53	A3	Pathiyoor	Coconut	0.1854	ND	0.0243	0.1265
54	A4	Pathiyoor	Vegetables	0.2238	ND	ND	0.1246
55	A5	Pathiyoor	Vegetables	0.2194	ND	ND	0.1294
56	A6	Pathiyoor	Vegetables	0.2316	ND	ND	0.1191
57	A7	Pathiyoor	Coconut	0.2143	ND	0.0196	0.1378
58	A8	Pathiyoor	Coconut	0.6965	ND	0.0153	0.1695
59	A9	Pathiyoor	Vegetables	0.2153	ND	ND	0.1245
60	A10	Pathiyoor	Coconut	0.2031	ND	0.0426	0.1324
61	H1	Chennithala	Rice	0.3116	ND	0.2090	0.1348
62	H2	Chennithala	Vegetables	0.0829	ND	ND	0.1828
63	H3	Chennithala	Rice	0.2187	ND	0.1953	0.1386
64	H4	Chennithala	Rice	0.1762	ND	0.0422	0.1448
65	H5	Chennithala	Vegetables	0.0725	ND	ND	0.1792
66	H6	Chennithala	Banana	0.1254	ND	0.1726	0.1523
67	H7	Chennithala	Banana	0.2151	ND	0.1748	0.1465
68	H8	Chennithala	Banana	0.1584	ND	0.1739	0.1542
69	H9	Chennithala	Vegetables	0.0876	ND	ND	0.1834
70	H10	Chennithala	Vegetables	0.0792	ND	ND	0.1841

g. Biological attributes of post-flood soils of AEU 3

Sample No.	Sample ID	Panchayath	Land Use	Acid Phosphatase activity (µg p-nitrophenol released g^{-1} soil hr^{-1})	Dehydrogenase activity (µg TPF hydrolysed g^{-1} soil 24 hr^{-1})
1	C1	Chunakkara	Rice	26.91	27.06
2	C2	Chunakkara	Rice	10.36	6.91
3	C3	Chunakkara	Rice	36.36	70.44
4	C4	Chunakkara	Coconut	11.54	29.17
5	C5	Chunakkara	Rice	39.81	43.57
6	C6	Chunakkara	Rice	38.63	34.55
7	C7	Chunakkara	Rice	27.17	23.42
8	C8	Chunakkara	Coconut	22.81	33.01
9	C9	Chunakkara	Coconut	31.27	57.39
10	C10	Chunakkara	Rice	19.82	46.64
11	V1	Veeyapuram	Rice	37.36	14.01
12	V2	Veeyapuram	Rice	71.72	48.56
13	V3	Veeyapuram	Rice	78.63	53.17
14	V4	Veeyapuram	Rice	20.08	50.48
15	V5	Veeyapuram	Rice	89.26	54.89
16	V6	Veeyapuram	Rice	32.99	69.67
17	V7	Veeyapuram	Rice	58.26	31.28
18	V8	Veeyapuram	Rice	69.89	20.73
19	V9	Veeyapuram	Rice	56.26	40.69
20	V10	Veeyapuram	Rice	17.54	9.4
21	P1	Palamel	Vegetables	26.08	22.65
22	P2	Palamel	Banana	34.63	24.95
23	P3	Palamel	Vegetables	46.9	55.09
24	P4	Palamel	Banana	27.99	22.59
25	P5	Palamel	Vegetables	29.82	29.36
26	P6	Palamel	Vegetables	49.17	23.03
27	P7	Palamel	Vegetables	15.63	26.9
28	P8	Palamel	Vegetables	18.27	26.68
29	P9	Palamel	Banana	23.54	21.3
30	P10	Palamel	Banana	57.44	61.99
31	T1	Chettikulangara	Rice	53.99	27.26
32	T2	Chettikulangara	Banana	20.9	34.35
33	T3	Chettikulangara	Rice	18.99	25.72
34	T4	Chettikulangara	Banana	32.9	26.87
35	T5	Chettikulangara	Rice	51.63	72.17
36	T6	Chettikulangara	Banana	34.54	26.87
37	T7	Chettikulangara	Rice	19.9	17.85
38	T8	Chettikulangara	Banana	16.27	16.5
39	T9	Chettikulangara	Rice	14.63	44.91
40	T10	Chettikulangara	Banana	29.26	16.31
41	N1	Nooranadu	Vegetables	20.36	28.02
42	N2	Nooranadu	Vegetables	45.26	12.47
43	N3	Nooranadu	Vegetables	40.81	77.92
44	N4	Nooranadu	Vegetables	32.26	25.33
45	N5	Nooranadu	Banana	34.36	38.19
46	N6	Nooranadu	Banana	25.36	24.56
47	N7	Nooranadu	Banana	59.99	93.47
48	N8	Nooranadu	Banana	33.63	21.49

49	N9	Nooranadu	Vegetables	20.63	29.36
50	N10	Nooranadu	Banana	14.08	20.53
51	A1	Pathiyoor	Coconut	14.18	8.83
52	A2	Pathiyoor	Vegetables	26.18	23.61
53	A3	Pathiyoor	Coconut	22.73	6.14
54	A4	Pathiyoor	Vegetables	29.63	11.9
55	A5	Pathiyoor	Vegetables	19.99	55.85
56	A6	Pathiyoor	Vegetables	14.27	12.09
57	A7	Pathiyoor	Coconut	17.45	39.34
58	A8	Pathiyoor	Coconut	32.72	58.15
59	A9	Pathiyoor	Vegetables	11.18	17.46
60	A10	Pathiyoor	Coconut	33.81	33.58
61	H1	Chennithala	Rice	35.08	29.36
62	H2	Chennithala	Vegetables	10.18	15.54
63	H3	Chennithala	Rice	27.99	11.51
64	H4	Chennithala	Rice	2.72	5.75
65	H5	Chennithala	Vegetables	62.9	35.5
66	H6	Chennithala	Banana	7.18	12.4
67	H7	Chennithala	Banana	24.27	29.17
68	H8	Chennithala	Banana	59.9	18.42
69	H9	Chennithala	Vegetables	34.26	40.11
70	H10	Chennithala	Vegetables	45.66	45.3

h. SOC stock and land quality index of post-flood soils of AEU 3

Sample No.	Sample ID	Panchayath	Land Use	SOC stock (kg m^{-2})	LQI
1	C1	Chunakkara	Rice	1.56	Very low
2	C2	Chunakkara	Rice	0.73	Very low
3	C3	Chunakkara	Rice	2.68	Very low
4	C4	Chunakkara	Coconut	1.47	Very low
5	C5	Chunakkara	Rice	2.64	Very low
6	C6	Chunakkara	Rice	2.55	Very low
7	C7	Chunakkara	Rice	2.01	Very low
8	C8	Chunakkara	Coconut	1.37	Very low
9	C9	Chunakkara	Coconut	3.11	Low
10	C10	Chunakkara	Rice	1.56	Very low
11	V1	Veeyapuram	Rice	2.52	Very low
12	V2	Veeyapuram	Rice	1.92	Very low
13	V3	Veeyapuram	Rice	1.82	Very low
14	V4	Veeyapuram	Rice	1.97	Very low
15	V5	Veeyapuram	Rice	1.63	Very low
16	V6	Veeyapuram	Rice	2.44	Very low
17	V7	Veeyapuram	Rice	1.11	Very low
18	V8	Veeyapuram	Rice	1.89	Very low
19	V9	Veeyapuram	Rice	2.32	Very low
20	V10	Veeyapuram	Rice	0.89	Very low
21	P1	Palamel	Vegetables	0.43	Very low
22	P2	Palamel	Banana	1.74	Very low
23	P3	Palamel	Vegetables	1.93	Very low
24	P4	Palamel	Banana	2.14	Very low
25	P5	Palamel	Vegetables	1.69	Very low
26	P6	Palamel	Vegetables	1.63	Very low
27	P7	Palamel	Vegetables	1.04	Very low

28	P8	Palamel	Vegetables	1.29	Very low
29	P9	Palamel	Banana	1.76	Very low
30	P10	Palamel	Banana	1.86	Very low
31	T1	Chettikulangara	Rice	1.43	Very low
32	T2	Chettikulangara	Banana	0.27	Very low
33	T3	Chettikulangara	Rice	0.83	Very low
34	T4	Chettikulangara	Banana	0.51	Very low
35	T5	Chettikulangara	Rice	1.53	Very low
36	T6	Chettikulangara	Banana	1.95	Very low
37	T7	Chettikulangara	Rice	1.81	Very low
38	T8	Chettikulangara	Banana	1.01	Very low
39	T9	Chettikulangara	Rice	0.34	Very low
40	T10	Chettikulangara	Banana	0.62	Very low
41	N1	Nooranadu	Vegetables	1.98	Very low
42	N2	Nooranadu	Vegetables	1.79	Very low
43	N3	Nooranadu	Vegetables	3.05	Low
44	N4	Nooranadu	Vegetables	1.71	Very low
45	N5	Nooranadu	Banana	1.99	Very low
46	N6	Nooranadu	Banana	1.89	Very low
47	N7	Nooranadu	Banana	4.14	Very low
48	N8	Nooranadu	Banana	3.42	Low
49	N9	Nooranadu	Vegetables	0.66	Very low
50	N10	Nooranadu	Banana	0.54	Very low
51	A1	Pathiyoor	Coconut	1.66	Very low
52	A2	Pathiyoor	Vegetables	0.53	Very low
53	A3	Pathiyoor	Coconut	1.69	Very low
54	A4	Pathiyoor	Vegetables	3.09	Low
55	A5	Pathiyoor	Vegetables	1.13	Very low
56	A6	Pathiyoor	Vegetables	0.58	Very low
57	A7	Pathiyoor	Coconut	0.83	Very low
58	A8	Pathiyoor	Coconut	2.51	Very low
59	A9	Pathiyoor	Vegetables	0.31	Very low
60	A10	Pathiyoor	Coconut	2.34	Very low
61	H1	Chennithala	Rice	1.45	Very low
62	H2	Chennithala	Vegetables	0.25	Very low
63	H3	Chennithala	Rice	1.89	Very low
64	H4	Chennithala	Rice	0.42	Very low
65	H5	Chennithala	Vegetables	3.51	Low
66	H6	Chennithala	Banana	0.08	Very low
67	H7	Chennithala	Banana	0.12	Very low
68	H8	Chennithala	Banana	2.28	Very low
69	H9	Chennithala	Vegetables	1.44	Very low
70	H10	Chennithala	Vegetables	1.99	Very low

i. Soil quality index and relative soil quality index of post-flood soils of AEU 3

Sample No.	Sample ID	Panchayath	Land Use	SQI	RSQI	RSQI Class
1	C1	Chunakkara	Rice	295	73.75	Good
2	C2	Chunakkara	Rice	210	52.5	Medium
3	C3	Chunakkara	Rice	275	68.75	Medium
4	C4	Chunakkara	Coconut	255	63.75	Medium
5	C5	Chunakkara	Rice	240	60	Medium
6	C6	Chunakkara	Rice	250	62.5	Medium

7	C7	Chunakkara	Rice	240	60	Medium
8	C8	Chunakkara	Coconut	220	55	Medium
9	C9	Chunakkara	Coconut	290	72.5	Good
10	C10	Chunakkara	Rice	225	56.25	Medium
11	V1	Veeyapuram	Rice	255	63.75	Medium
12	V2	Veeyapuram	Rice	245	61.25	Medium
13	V3	Veeyapuram	Rice	230	57.5	Medium
14	V4	Veeyapuram	Rice	255	63.75	Medium
15	V5	Veeyapuram	Rice	235	58.75	Medium
16	V6	Veeyapuram	Rice	245	61.25	Medium
17	V7	Veeyapuram	Rice	220	55	Medium
18	V8	Veeyapuram	Rice	215	53.75	Medium
19	V9	Veeyapuram	Rice	275	68.75	Medium
20	V10	Veeyapuram	Rice	225	56.25	Medium
21	P1	Palamel	Vegetables	225	56.25	Medium
22	P2	Palamel	Banana	270	67.5	Medium
23	P3	Palamel	Vegetables	250	62.5	Medium
24	P4	Palamel	Banana	240	60	Medium
25	P5	Palamel	Vegetables	225	56.25	Medium
26	P6	Palamel	Vegetables	250	62.5	Medium
27	P7	Palamel	Vegetables	200	50	Medium
28	P8	Palamel	Vegetables	220	55	Medium
29	P9	Palamel	Banana	265	66.25	Medium
30	P10	Palamel	Banana	265	66.25	Medium
31	T1	Chettikulangara	Rice	225	56.25	Medium
32	T2	Chettikulangara	Banana	195	48.75	Poor
33	T3	Chettikulangara	Rice	195	48.75	Poor
34	T4	Chettikulangara	Banana	235	58.75	Medium
35	T5	Chettikulangara	Rice	185	46.25	Poor
36	T6	Chettikulangara	Banana	270	67.5	Medium
37	T7	Chettikulangara	Rice	295	73.75	Good
38	T8	Chettikulangara	Banana	205	51.25	Medium
39	T9	Chettikulangara	Rice	170	42.5	Poor
40	T10	Chettikulangara	Banana	190	47.5	Poor
41	N1	Nooranadu	Vegetables	275	68.75	Medium
42	N2	Nooranadu	Vegetables	255	63.75	Medium
43	N3	Nooranadu	Vegetables	295	73.75	Good
44	N4	Nooranadu	Vegetables	255	63.75	Medium
45	N5	Nooranadu	Banana	280	70	Medium
46	N6	Nooranadu	Banana	245	61.25	Medium
47	N7	Nooranadu	Banana	305	76.25	Good
48	N8	Nooranadu	Banana	275	68.75	Medium
49	N9	Nooranadu	Vegetables	195	48.75	Poor
50	N10	Nooranadu	Banana	215	53.75	Medium
51	A1	Pathiyoor	Coconut	265	66.25	Medium
52	A2	Pathiyoor	Vegetables	245	61.25	Medium
53	A3	Pathiyoor	Coconut	245	61.25	Medium
54	A4	Pathiyoor	Vegetables	320	80	Good
55	A5	Pathiyoor	Vegetables	255	63.75	Medium
56	A6	Pathiyoor	Vegetables	240	60	Medium
57	A7	Pathiyoor	Coconut	235	58.75	Medium
58	A8	Pathiyoor	Coconut	230	57.5	Medium
59	A9	Pathiyoor	Vegetables	265	66.25	Medium
60	A10	Pathiyoor	Coconut	255	63.75	Medium
61	H1	Chennithala	Rice	235	58.75	Medium

62	H2	Chennithala	Vegetables	220	55	Medium
63	H3	Chennithala	Rice	225	56.25	Medium
64	H4	Chennithala	Rice	195	48.75	Poor
65	H5	Chennithala	Vegetables	255	63.75	Medium
66	H6	Chennithala	Banana	190	47.5	Poor
67	H7	Chennithala	Banana	225	56.25	Medium
68	H8	Chennithala	Banana	255	63.75	Medium
69	H9	Chennithala	Vegetables	190	47.5	Poor
70	H10	Chennithala	Vegetables	210	52.5	Medium

APPENDIX IV

PRE AND POST-FLOOD STATUS OF SOIL REACTION AND NUTRIENTS IN AEU 3

Parameter	Fertility class	Per cent samples	
		Pre-flood status (KSPB, 2013)	Post-flood status
pH	Extremely acidic	15	37.2
	Very strongly acidic		57.1
	Strongly acidic	30	5.7
	Moderately acidic	37	
	Neutral or alkaline	18	
Organic carbon (%)	Low	42	20
	Medium	38	50
	High	20	30
Available N (kg ha^{-1})	Low	42	71.4
	Medium	38	28.6
	High	20	
Available P (kg ha^{-1})	Low	5	
	Medium	13	28.6
	High	82	71.4
Available K (kg ha^{-1})	Low	70	62.9
	Medium	22	37.1
	High	8	
Available Ca (mg kg^{-1})	Deficient	98	72.9
	Sufficient	2	27.1
Available Mg (mg kg^{-1})	Deficient	100	100
	Sufficient		
Available S (mg kg^{-1})	Low	90	100
	Medium	3	
	Adequate	7	
Available Zn (mg kg^{-1})	Deficient	23	14.3
	Sufficient	77	85.7
Available Cu (mg kg^{-1})	Deficient	43	100
	Sufficient	57	
Available B (mg kg^{-1})	Deficient	28	100
	Sufficient	72	