ASSESSMENT OF SOIL QUALITY IN THE POST FLOOD SCENARIO OF AEU 6 IN THRISSUR AND MALAPPURAM DISTRICTS OF KERALA AND MAPPING USING GIS TECHNIQUES

By

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(2018-11-047)

THESIS

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DECLARATION

I, **Safnathmol P. (2018-11-047)**, hereby declare that this thesis entitled **"Assessment of soil quality in the post flood scenario of AEU 6 in Thrissur and Malappuram districts of Kerala and mapping using GIS techniques"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, 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 6 in Thrissur and Malappuram districts of Kerala and mapping using GIS techniques"** is a record of research work done independently by **Ms. Safnathmol P. (2018-11-047)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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LIST OF ABBREVIATION AND SYMBOLS USED

Symbols	Abbreviation
%	Per cent
µ	Micro
°E	Degree east
°N	Degree north
BD	Bulk density
B	Boron
^{0}C	Degree Celsius
CD	Critical difference
Ca	Calcium
cm	Centimetre
Cu	Copper
dS	Deci Siemen
DHA	Dehydrogenase activity
et al.	And co-workers
EA	Exchangeable acidity
EC	Electrical conductivity
ECEC	Effective cation exchange capacity
Fe	Iron
Fig.	Figure
IUCN	International Union for Conservation of Nature
g	Gram

GIS	Geographical information system
GoK	Government of Kerala
GPS	Global positioning system
ha	Hectare
HCl	Hydrochloric acid
hr	Hour
K	Potassium
KAU	Kerala Agricultural University
KCl	Potassium chloride
kg	Kilogram
kg^{-1}	Per kilogram
KR	Keen Raczkowski
m	Meter
M	Molar
mm	Milli meter
mg	Milli gram
m^{-3}	Per cubic meter
MBC	Microbial biomass carbon
MDS	Minimum data set
Mg	Magnesium
Mg	Mega gram
Mn	Manganese
MWD	Mean weight diameter
N	Nitrogen

No.	Number
NBSS&LUP	National Bureau of Soil Survey and Land use Planning
OC	Organic carbon
P	Phosphorus
PCA	Principal component analysis
PD	Particle density
pH	Hydrogen ion concentration
POP	Package of practices
S	Sulphur
SD	Standard deviation
TPF	Triphenyl formazan
WHC	Water holding capacity
Zn	Zinc

Introduction

1. INTRODUCTION

Soil is a non-renewable resource which acts as a medium for plant growth. It acts as a habitat for various microorganisms, helps in nutrient cycling and supports plant growth; hence considered as an ecosystem service provider in the earth. Soil differs widely in their properties due to variation in climate and geology over time and space. It is the principal substrate on earth which acts as reservoir of nutrients and water and supports life on earth. Most of the soils in the world are being exposed to various unprecedented weather events which adversely affect its various properties. Since soil is a complex entity, any change in one of its properties wholly affects its fertility. Soils all around the world have been subjected to severe degradation by intensive land use and improper management along with adverse weather events which may lead to deterioration in its quality.

The Kerala State receives very high rainfall during the monsoon season. In August 2018, the State received a terrific rainfall of nearly 2346.6 mm against the normal value of 1649.5 mm causing much havoc to entire Kerala except Kasargod district. Vishnu *et al.* (2019) found that 36 per cent excess rainfall occurred during this period led to widespread floods and landslides events. The soils of Kerala, exposed to this devastating flood in this incessant rainfall experienced great damage to the soil environment in different ways. Besides heavy agricultural losses, soil fertility and productivity have been disturbed, the exposed soils were eroded and various kinds of debris accumulated on farm fields. Compaction of soil occurred due to sedimentation and soluble nutrients were leached from surface soil. The top soil in the hills and upland areas have been removed in the flash flood and plantations were completely destroyed. Physical, chemical and biological properties of soil were highly altered and this demanded a site specific investigation in the flood affected areas of *kole* lands in order to put forward post flood management strategies.

Kole lands, a part of Vembanad *kole*, is one of the major wetland systems in South-west coast of India. Since 2002, these wetlands are assigned as Ramsar site. Under the classification of National Bureau of Soil Survey and Land Use Planning (NBSS & LUP, 2012), *kole* lands come under agro-ecological unit 6 (AEU 6) with an area of 13,632 ha. The word, *kole* in Malayalam indicates bumper yield or high returns from crops and these *kole* lands form one of the rice granaries of Kerala. They extend from the northern bank of Chalakkudy river in the south to the southern bank of Bharatapuzha river in the north and mainly divided as Thrissur *kole* and Ponnani *kole*. They are the low lying tracts located 0.5 to 1 m below mean sea level situated between 10° 20' to 10° 40' N latitude and 75˚ 58' to 76˚ 11' E longitude. The Thrissur *kole* are geographically distributed mainly in Anthikkad, Puzhakkal, Irinjalakkuda, Mullassery and Cherpu block panchayats of Thrissur district and Ponnani *kole* mainly in Perumpadappu and Ponnani block panchayats of Malappuram district. Rice is the major crop which is grown under this unique wetland system. The soils are hydromorphic acid clays with brown surface soils and grey coloured subsoil. They are deep with silty clay to clay textured surface soils and highly decomposed organic sub soils causing ultra acid condition.

The flood inundation adversely affected the *kole* lands of Thrissur and Malappuram districts. An effective implementation of post flood management activities is required in these areas. To achieve this, a proper and accurate soil study should be carried out to get information on the physico-chemical changes occurred in the soil due to flood. A detailed study on soil quality of post flood soils of AEU 6 will help to develop management strategies for enhanced productivity of crop under post flood situation. Hence this study has been undertaken with the following objectives:

1. Assess the soil quality of post flood soils of AEU 6 in Thrissur and Malappuram districts
2. Develop GIS based map for the study area

Review of literature

2. REVIEW OF LITERATURE

Extreme drought, landslides, and floods are the most common natural disasters that affect human society and economy (Coumou and Rahmstorf, 2012). Major soil degradation processes includes soil erosion, decline in organic matter and soil biodiversity, pollution, sealing, compaction, salinity, floods and landslides (Bone *et al*., 2010). Floods affect soil structure, fertility, nutrient availability and in the case of strong disturbances it initiates primary succession processes in the soil (Coumou and Rahmstorf, 2012). The major critical environmental processes influencing the soil quality of wetlands includes deposition of sediments, interaction of freshwater and saltwater, delta accretion and material-energy exchanges (Bai *et al*., 2018). Therefore, a better understanding of wetland soil quality and its spatial-temporal dynamic characteristics is needed for sustainable management and conservation of coastal wetlands. Flood flow facilitates the exchange of nutrients and organic materials and sometimes improves soil fertility (Toda *et al*., 2005). Organic materials, minerals, and essential nutrients from rivers and ocean are deposited in adjacent areas during flood which makes the soil richer, fertile and productive. However, these environmental benefits are not necessarily happen always and when excessive flooding occur natural systems can no longer be resilient to the effects (Visser *et al*., 2003). In the study conducted by Vishnu *et al*. (2019) using satellite imagery, they noticed that during the flood period water raised up to a level of 10 m in the *kole* lands and the area covered by water also increased. The flood water recession was extremely slow in *kole* lands, which adversely affected the soil ecosystem and its natural properties.

2.1. *KOLE* LANDS

Kole is a low lying area with 0.5m to 1m below mean sea level. They are considered as one of the unique wetland ecosystem in Kerala and is a part of the Vembanad *kole*, one of the rice granaries of Kerala. These *kole* lands fall in AEU 6 which spreads over coastal parts of Thrissur and Malappuram districts covering an area of 13,632 ha. The block panchayats Anthikkad, Cherpu, Irinjalakkuda, Mullassery and Puzhakkal comes in Thrissur district and Perumpadappu and Ponnani block panchayats fall in Malappuram district. Thrissur *kole* lands divided into North and South *kole* by Karuvannur river, drained by Kecheri river finally discharges into the Arabian Sea. About 50 migratory bird species and 91 resident birds are found in the *kole* area. The birds from different regions come here for nesting and feeding. *Kole* lands support eight Red data book species birds in the IUCN category (Nameer, 2002). Sreenivasan (2012) in his study found that the *kole* lands remain submerged under flood water for about six months in an year and this seasonal alteration provide it both terrestrial and water related properties.

2.1.1. Characteristics of soil in *kole* lands

Soils in the *kole* land are formed by weathering of alluvial and collivial deposits brought by the rivers, Kechery and Karuvannur. Soils in this area show wide variation both in physico-chemical and morphological characteristics. Due to the difference in physiographic positions, Johnkutty and Venugopal (1993) classified the soil in *kole* in to two groups. The soils of the flood plain, comprising of *Perumpuzha, Anthikkad* and *Konchira* series fall in the first group while the soils of slightly higher elevation occupying the outer fringes consisting of *Manalur, Edathuruthy, Ayyanthole and Kizhipallikkara* series fall in the second group. *Kizhippallikkara* series are isohyperthermic, Typic Fluaquents with very strong acidity. Soils in flood plains are clayey in texture and acidic in pH ranging from 2.6 to 6.3. Kavitha (2018) observed extreme acidic conditions in *kole* lands These soils are extremely acidic since organic peat layer is present in subsurface. According to Thomas *et al*. (2003), organic matter content in soils was very high and in the surface it varied from 2.07 to 4.16 per cent. Coastal *kole* soils are shallow and acid saline soils due to intrusion of sea water. The soils are hard, brittle, and poor in fertility. EC of these soils during the growing season ranged from 0.1 to 2 dS m^{-1} (Swarajyalakshmi *et al*., 2003). Salinization causes soil degradation and seriously affects the productivity and quality. The *kole* lands near to coastal area show high salinity due to sea water inundation which often cause toxicity to plants. The climate is tropical humid monsoon type (mean annual temperature of 27.6 °C; rainfall 2,902 mm).

Soils are deep with surface soils having silty clay to clay texture and sub soils are clayey with highly decomposed organic debris causing ultra acid condition. They are poorly drained with slow permeability and have severe limitations for use under irrigation. Toxic accumulation of iron and aluminium were observed in the soil which acts as limitation for agricultural production, whereas the organic carbon content in *kole* lands varied from 0.85 to 2.47 per cent (Amritha and Durga Devi, 2017). Due to high content of organic matter, *kole* lands showed superiority in available nitrogen, phosphorus and potassium status (Amritha and Durga Devi, 2017). Fertility status of soils in the *kole* areas of Thrissur district was studied by Ambili (1995) and it revealed that the total nitrogen, phosphorus, potassium, calcium and magnesium content were low, while the cation exchange capacity values varied over a narrow range and soils were predominantly clayey in nature.

2.1.2. Cropping pattern in *kole* lands

Rice is the most important crop cultivated in the *kole* lands. *Kole* lands have a productivity of 4 to 5 tonnes per ha against the average rice productivity of State, less than two tonnes per ha. Coconut is grown on the uplands and rice in lowlands of the AEU 6. Since drainage is a major limitation, dewatering is carried out using *petti and para* which is an indigenous pumping device developed for dewatering fields (Srinivasan, 2012). Leenakumari, (2010) conducted a study on rice in Kerala and she identified a unique system of rice production practised in the *kole* lands, midway between mundakan and summer, the growing period of rice crop. Here, sowing was carried out in November to December and the crop was harvested in March to April. Water from the bordering canal system was drawn in to the field by gravity flow and used for irrigation since the fields were below mean sea level. The vast fields were divided into small blocks by channels and canals locally known as padavu. Additional crop was taken during autumn or virippu in some areas where dry sowing or wet sowing practiced just prior to the onset of monsoon.

Alternate cultivation of fish and rice carried out in some *kole* farms. Fish is cultivated after paddy harvest when the fields are flooded. The fish lings are grown in ponds until the paddy harvest is completed and fish is harvested at least 10 days before the agricultural operations for paddy starts.

2.2. CONCEPT OF SOIL QUALITY

The concept of soil quality received much attention from early 1990 onwards. The soil quality index (SQI) comes directly from the need of a science based tool to measure soil quality. Unlike air or water, soil is not directly consumed by humans and animals, and therefore soil quality standards are more complicated to identify (Doran and Parkin, 1996). The soil quality index is a unit less value, combining a variety of information on chemical, physical and biological characteristics of soil , which scores its 'fitness' to accomplish one or more functions. A low soil quality index indicates low fitness of soil. Hence interpretation of the overall 'soil health' or 'fitness for purpose' is thus simplified by introduction of soil quality. Important soil functions include: water or solute flow and retention, physical stability and support, cycling of nutrients, filtration of potentially toxic materials, and maintenance of biodiversity and habitat (Zak *et al*., 2003).

Soil quality has been defined as the capacity of a specific kind of soil to function within ecosystem and land-use boundaries, to sustain biological productivity, maintain environmental quality, and sustain plant, animal, and human health (Doran and Parkin, 1994). Soil quality is widely used to identify the status and use potential of soil and it is used as a tool to assess various production systems of agriculture and horticulture all around the world (Armenise *et al*., 2013; Mukherjee and Lal, 2014). Increased global emphasize on sustainable land use also helped in needful evolution of soil quality concept.

According to Bünemann *et al*. (2018) soil quality is the ability of soil to supply nutrients to plants, improve water and air within the soil and support human needs. Assessment of both soil properties and processes were included in concept of soil quality since they relate to the ability of soil to function effectively as a component of a healthy ecosystem. Soil quality monitoring is a science-based soil management tool that assesses soil well being and provides early warning of changes, either adverse or favourable, in soil properties and functions (Taylor *et al*., 2010).

Soil quality cannot be directly measured, but it can be possible through measuring soil physical, chemical and biological properties. Oversimplification of soil quality information can result to incoherent conclusions which can result to ill management of agricultural lands (de Paul Obade and Lal, 2016). A robust SQI should be sensitive to soil management and changes in soil functions and be easily measurable (Armenise *et al*., 2013). According to NRCS (2012), soil quality encompasses the capacity of a specific kind of soil to effectively function through supporting plant and animal survival without jeopardizing environmental quality. The measured soil attributes are converted into a simplified format by soil quality indexing that can support informed decision making on sustainable agro-ecosystem practices (Arshad and Martin, 2002).

2.3. TYPES OF SOIL QUALITY

According to Seybold *et al*. (1999) soil quality is a combination of inherent and dynamic soil quality. The dynamic soil quality might change with change in soil management whereas inherent soil quality does not show much change over time (Larson and Pierce, 1994). Changes in land use and management would reflect on dynamic soil quality whereas inherent soil quality relate to the genetic characteristics of soil and they interacted each other (Moebius-Clune *et al*., 2016). According to Karlen *et al*. (2001), the word ‘inherent’ would indicate the time before human manipulation whereas ‘dynamic’ indicate the soil quality index after various human activities in soil.

The inherent soil quality depend on the stable soil properties that were the outcome of soil-forming factors and soil management would not have any effect on this type of quality (Bonfante *et al*., 2019). The basic soil forming factors such as climate, parent material, time, topography and vegetation reflect in inherent soil quality (Karlen *et al*., 2008). Mineralogy and particle size distribution were also considered as the attributes that support inherent soil quality since they are static and show very little change over time (Carter, 2002). An inherent soil quality index for Canadian soil was developed by MacDonald *et al*. (1995) using soil drainage status, water-holding capacity, cation exchange capacity, soil depth, crusting, pH and salinity.

Dynamic soil quality was strongly affected by the agronomic practices and that could change over comparatively short time periods (Carter, 2002). Hence, in most of the studies more emphasize was given to dynamic soil quality. Soil organic carbon, labile SOM fractions, soil structural components, and macroporosity were the indicators coming under this soil quality. Soil organic carbon was considered as both inherent and dynamic soil quality (Carter, 2002). Dynamic soil quality reflects the changes formed by the past or current land use and the anthropogenic management activities (Karlen *et al*., 2001).

2.4. EFFECT OF SOIL DEGRADATION ON SOIL QUALITY

In agriculture, environmental services are mainly related to regulating processes or supporting life on earth. According to Bünemann *et al*. (2018), the most common environmental services include the production of fiber, food, and wood, as well as soil formation, nutrient cycling, water control and climate regulation. However, the removal of natural vegetation for the expansion of agricultural areas and the adoption of conventional soil management practices have declined the soil quality (Rocha *et al*., 2017) and consequently the capacity of soil to provides environmental services in the last few decades. Soil degradation implies a change or disturbance of soil quality and decline in capacity of soil to fulfil various functions through natural or anthropogenic activities (Lal, 2009). Ayoubi *et al*. (2011) reported that intensive land use is one of the major causes in soil quality deterioration. Jamala and Oke (2013) also found same trend and they stated that inappropriate land use and soil management also contribute to depletion of soil quality. Tesfahunegn (2014) also observed in addition to this, erratic and erosive rainfall, steep terrain, deforestation, and overgrazing also contribute to soil quality degradation.

According to Sharma and Mandal (2009) water logging, salinity, alkalinity and formation of acid sulphate soil are the predominant reasons of land degradation and poor soil quality. When flooding occurs there is a large flow of water, usually resulting from heavy rain within the upstream catchment, and the effects can be severe (Alves Pagotto *et al*., 2011). However, in less severe cases, there is often sediment transported through the water flow and deposited in downstream (Hayashi *et* *al*., 2012). In these cases, the flood-deposited sediment provides an incoming source of both mineral and organic material, each containing nutrients (Cockel and Gurnell, 2012). Flooding can have direct negative effects on soil properties (Capon and Brock, 2006). Hence soil quality assessment is needed for reclamation of flood affected soil. The monitoring of soil quality through chemical and physical attributes is a crucial tool to evaluate the quality of agricultural systems, as well as to measure their capacity to provide environmental services (Adhikari and Hartemink, 2016; Rinot *et al*., 2019). The evaluation of soil quality can provide a guideline for appropriate soil management in these areas. Thus according to Herrick (2000), soil quality appears to be an ideal indicator of sustainable land management. The importance of soil quality lies in achieving sustainable land use and management system, to balance productivity and environmental protection (De la Rosa and Sobral, 2008). Incorporation of soil quality aspects in land use studies is crucial in order to make it more inclusive (Murage *et al*., 2000). Various studies are conducted by scientists in different parts of world to evaluate the effect of soil quality indicators under different land uses (Ishaq *et al*., 2015; Kalu *et al*., 2015). But the major challenge in this assessment is complexity of soil processes and the temporal and spatial variability shown by soil properties (Li *et al*., 2007). This leads to difficulties in defining a single soil quality indicator which represent the overall soil quality.

2.5. INDICATORS OF SOIL QUALITY

Indicators are a composite set of measurable attributes which are derived from functional relationships. These indicators may directly monitor the soil, or monitor the outcomes that are affected by the soil. Since soil quality assessment is purpose and site specific, the indicators used or selected by different researchers in different regions may not be the same (Shukla *et al*., 2006). However, while selecting the indicators, it is important to ensure that the characteristics of an ideal indicator should be fulfilled. The major requirement for a soil characteristic to be selected as a soil quality indicator is that it shows sensitivity to the changes that occurring within the soil function. They should be easily measurable, shows a positive correlation with ecosystem services, sensitive to variation in management and climate, applicable to field conditions and whenever possible, to be a component of a pre-existing database

(Andrews *et al*., 2004). Some important soil functions (or ecosystem services) include: water flow and retention, physical stability and support; cycling of nutrients; buffering and filtering of potentially toxic materials and maintenance of biodiversity and habitat (Padekar *et al.*, 2018). According to Bouma (2015) soil functions include biomass production, climate regulation, hydrologic storage and pollution control. Soil functions are highly sensitive to soil quality indicators (Aparicio and Costa, 2007). Soil functions provided by ecosystem are varied based on spatial and temporal changes in soil physical, chemical, and biological properties and processes (Van Diepeningen *et al*., 2006).

In general, soil quality assessment is carried out by selecting a set of soil properties which are considered as indicators of soil quality. Indicators include physical, chemical and biological properties, processes, or characteristics of soils. They can also be morphological or visual features of plants (Karltun *et al*., 2013). A unique balance of chemical, physical and biological components contribute to maintaining soil quality (Van der Heijden *et al*., 2008). Evaluation of soil quality therefore, requires indicators of all these components. The indicators used or selected by different researchers in different regions may not be the same because soil quality assessment is purpose and site specific (Shukla *et al*., 2006). Soil quality indicators are selected because of their relationship to specific soil properties and soil quality. A quantitative assessment is the accurate measurement of an indicator than the qualitative assessment. Qualitative assessments have an element of subjectivity while quantitative methods have a precise, numeric value. Therefore, different people conducting the same measurement should be able to produce very similar results (Carter, 2002).

2.5.1. Physical soil quality indicators

In the case of soil physical properties, perceptive quality indicators are those related to soil aggregation, structure, macro- porosity and associated processes in soil such as water movement and air exchange (Shahab *et al*., 2013). The chemical and biological components are largely integrated by these physical properties and increase responses of soil to management, as well as associated plant productivity (Dexter 2004; Shukla *et al*., 2006).

Low bulk density indicates a good soil condition for crops and microorganisms in soil. It indicates that soil has good soil pore, aggregation, water and air circulation and helps in easy root penetration (Macci *et al.*, 2012; Mondal *et al*., 2015). Ghoshal (2004) reported that continuous submergence in paddy field increased bulk density and reduced hydraulic conductivity and resulted in subsequent deterioration of soil quality. Under a study of establishing critical limits for indicators in rice cropping system, Biswas *et al*. (2017) found that there was a strong negative correlation between bulk density and organic matter content due to the dilution effect of organic matter. Better aggregation and increased volume of soil pores also reduces bulk density (Hati *et al*., 2008; Bandyopadhyay *et al*., 2010) whereas soil compaction due to flood or agricultural activity such as tillage increased bulk density (Martinez and Zinck, 2004). Whereas particle density (PD) is a basic soil physical property which is determined by the mineral composition of soil and support soil fertility (Ruhlmann and Korschens, 2020).

Aggregate stability maintains the physical stability of soil and support crop growth by water storage regulation, aeration and biological activity, hence selected as an important soil physical quality indicator (Grandy and Robertson, 2006). Soil aggregate stability was also considered as an important indicator of degradation (Stavi *et al*., 2010). It was an important element of soil structure that affects hydrology, ecology, nutrient status and faunal activity of soil (Stavi *et al*., 2010). Mean weight diameter (MWD) of aggregates is another index which perfectly represents aggregate stability (Sarah, 2005). It has a positive effect on soil quality by improved soil infiltration capacity and resistance to erosion (Sarah, 2004). Short-term reducing conditions due to flooding change the chemistry of the soil and that may affect soil aggregation (De-Campose *et al*., 2009). Soils with well aggregation provides adequate habitat for soil microorganisms and increase soil porosity (Franzluebbers, 2002). Large well stabilized aggregates also have a role in carbon sequestration (Das *et al*., 2014).

Arshad and Coen (1992) found that there is a positive correlation between soil porosity and soil quality. Any modification in soil structutre involves changes in soil porosity. Hence Pagliai *et al.* (2004) considered soil porosity as a best indicator of soil structural quality. If a soil has less than 10 per cent porosity, they limit root penetration and imply poor soil structural quality. They also observed that information of pore system in soil provides knowledge about the retention and movement of water in soil. Sillon *et al*. (2003) considered soil porosity as one of the important component of fertility since it affects soil erosion, infiltration, water retention, soil evaporation and soil mechanical properties. Aprisal *et al*. (2019) also come with same result that soil porosity determines the movement of water into the soil and ease with which a plant root can penetrate in to soil, hence designated as a soil quality indicator. Xiao *et al*. (2016) reported that the lower value of bulk density relative to the particle density caused an increase in pore space and improved soil quality. Ubuoh *et al*. (2016) found that flooding have a negative effect on soil porosity.

Lin *et al.* (2017) expressed water holding capacity as a measure of soil quality since it determines the moisture content in soil. And moisture content gives a measure of water present in the soil. The water present in soil acts as a solvent to dissolve nutrients and makes up the soil solution, which act as a medium to support plant growth and thereby improve soil quality (Enyoh and Isiuku, 2020).

2.5.2. Chemical soil quality indicators

Chemical indicators can give information about the equilibrium that exist between soil solution and exchange sites (clay particles, organic matter); plant health; the nutritional requirements of plant and soil animal communities; and levels of soil contaminants and their availability for uptake by animals and plants (Adhikari and Hartemink, 2016). Soil pH, electrical conductivity, and extractable P and K are important chemical attributes associated with soil fertility and nutrient availability (Wienhold *et al*., 2009).

Shahid *et al*. (2013) selected pH as a soil quality indicator in lowland rice cultivation because of its ability to control the availability of various essential nutrients. Soil pH was a significant element which influences the microbial community (Wang *et al*., 2019). In acidic pH families such as Acidobacteriaceae, Hyrogenphilaceae, Beijerinckiaceae and Bradyrhizobiaceae are predominant. Soil acidity has very importance among chemical characters that influence the soil fertility. Not only pH but also organic carbon and nitrogen content also influenced the soil microbial diversity (Rousk *et al*., 2010). Any change in soil microbial diversity and their function is a result of varying soil properties. A shift in pH affects the abundance of various taxa in soil since some specific taxa are dominant in specific pH (Wang *et al*., 2020).

Akpoveta *et al*. (2014) conducted a study on soil quality after the flood in Nigeria in 2012 found that soil saturated with water causes pH reduction due to organic acid produced from fermentation. The pH of alkaline soils declined and pH of acid soils increased due to flooding. Soil pH is a major factor influencing the availability of elements in the soil for plant uptake. pH in acidic range affects the solubility of minerals and nutrient availability in flood affected soils.

Kalshetty *et al*. (2012) found that flooding from river Krishna in Bagalkot district in Karnataka state reduced pH of cultivated soil in riverbank areas. In acid soils an increase in pH is expected after flooding and that may lead to physicochemical changes in the soil (De-Campose *et al*., 2009). Beena and Thampatti (2013) conducted a study in acid sulphate soils Kerala found that pH was negatively correlated with exchangeable acidity. Exchangeable acidity varies with the nature of soil and base saturation.

Chan *et al*. (2010) reported that soil organic carbon is strong indicator of soil biological health and fertility. Soil organic carbon improves soil physical, chemical and biological properties like soil structure, buffering capacity and nutrient retention (Carson, 2013). Among chemical attributes, the soil organic carbon proved to be a very powerful indicator of soil quality. In subtropical region of India, poor soil quality due to depletion of soil organic carbon owing to high temperature and continuous cropping (Bhattacharyya *et al*., 2004; Mandal *et al*., 2008). Soil organic carbon is a key component of soil quality and its maintenance is vital for the sustainable productivity of agricultural systems (Carter, 2002). The biological, chemical and physical properties of soil were highly influenced by organic carbon through regulation of microbial activity, soil pH, nutrient availability and structural stability (Rahmanipour *et al*., 2014). Addition of different organic amendments in to soil stabilizes the soil organic carbon in aggregate fraction and physically protect in soil (Bandyopadhyay *et al*., 2010). Soil organic carbon also affects soil physical properties like aggregation, water-holding capacity and bulk density (Celik, 2005). Flood frequency appears to be a factor that limits natural soil developmental activities were inhibited by frequent floods and some studies conducted in wetlands have shown that the soils prone to successive floods resulted in depletion of organic carbon over time (Kayranli *et al*., 2010).

Fageria *et al*. (2011) studied the effect of submergence in nutrient availability. In flooded soils, both the concentration and forms of soil nutrients were affected by the reducing condition. Therefore, essential macro and micronutrients availability significantly affected by flooded condition. Nitrogen availability reduced due to denitrification whereas P availability increased due to reduction of ferric phosphate. They stated that flooding have less effect on potassium chemistry but some extent it helped to release potassium into soil solution from exchangeable complex. Potassium is displaced from exchangeable site by Fe and Mn released during flood. Deficiency of sulphur was noted in flooded soil due to reduction of sulphate ion into sulfide. Changes in availability of Ca and Mg were found to be less whereas the level of micronutrients like Fe and Mn are found to be toxic to plants. But the concentration of Zn and Cu reduced and boron concentration remain unchanged.

Dissolved soil nutrients in floodwaters were carried from floodplain surfaces into adjacent rivers or basin that are lying submerged and soil nutrients may also be transported from the river into floodplains through the lateral flow (Enyoh and Isiuku, 2020). Nitrogen dynamics in soil was highly affected by flooding (Hefting *et al*., 2004). Kalshetty *et al*. (2012) studied the effect of flood on soil properties in Bagalkot district of Karnataka State in India. They found that available nitrogen content reduced after flood might be due to increase in denitrification process. Available potassium showed an increment, whereas available phosphorus and magnesium got reduced in soil, and relative contribution of proton to effective cation exchange capacity was also reduced.

A decline of content in nutrients like potassium, phosphorus and manganese were found in flood affected farm fields of Abakaliki, Nigeria (Ubuoh *et al.,* 2016). Potassium is a major nutrient that is required for plants for healthy growth by resisting various diseases; therefore a reduction in potassium levels in the flood affected soils is a negative impact on soil quality. Flooding causes decrease in nutrient availability in soil due to increased solubility of mineral nutrients in water and loss through leaching (Conklin, 2005). Gallardo (2003) found an increase in the phosphorus availability after flooding due to release of phosphorus bound to iron during reduction of Fe (III) to Fe (II). Amarawansha *et al*. (2015) claimed that available manganese content increased due to flood and also interfere with Fe content in soil.

Amery and Smolders (2012) studied the behaviour of phosphorus release under water logging and came to a conclusion that the net P release in submerged soil was controlled by soil effective cation exchange capacity (ECEC). The ECEC gives an account of the available sites where positive ions can attach on clay surfaces and hence higher the value the greater the potential fertility of soil. They also stated that the reductive dissolution of the Fe (III) minerals during flooding can release the P adsorbed in iron (Fe) oxy-hydroxides in soil. And also increased pH values induce desorption of P from the soil surfaces as oxides.

Akpoveta *et al*. (2014) conducted a post flood study in Nigeria and arrived at a result that the flood led to decrease in soil pH, nitrate and phosphorus as well as exchangeable calcium, potassium and effective cation exchange capacity (ECEC). However, flood increased the exchangeable acidity which accounts the hydrogen and aluminium content in soil. There was no appreciable change found in total organic carbon, total nitrogen and sulphate contents whereas electrical conductivity showed an increment of 54 to 92 per cent in flood affected farmland compared to control. Moisture content varied from 17 to 45 per cent and micronutrient Mn showed a reduction of 25 to 49 per cent. They observed an increased concentration of Cu content in flood affected regions. They also observed that electrical conductivity being a measure of ionic concentration in the soils and are therefore related to dissolve solutes such as ions and salts. It is a measure of the soil salinity. Electrical conductivity of soil might be fluctuated if there is a chance of deposition of salts carried by flood from ocean.

Flooding for long-time increased ECEC due to strongly reducing conditions (Kirk *et al*., 2003; Favre *et al*., 2004). They attributed the increase is due to the reduction of structural Fe and the solubilisation of Fe (hydr)oxide coatings from clay surface. De-Campose *et al*. (2009) studied the effect of reducing condition due to flooding on various soil properties in the mid-western United States found that Fe, Mn, Ca and Mg contents were increased in the flooded soils. Antheunise and Verhoeven (2008) found a decrease in soil available Ca after flood occurrence.

In low land rice system available Zn plays an important role in soil quality maintenance (Shahid *et al.,* 2013). Zn is the most important micronutrient which defines the growth and yield of rice and rice is highly sensitive to the Zn deficiency (Alloway, 2004). Masto *et al*. (2007) also reported that available Zn status can be considered as a sensitive indicator of soil quality.

2.5.3. Biological soil quality indicators

Soil quality assessments can be improved by adding soil biological and biochemical indicators (Barrios, 2007). During soil quality evaluation, assessment of biological indicators is required to connect abiotic soil properties to soil functions in terms of various transformations (Lehman *et al*., 2015).

Paz-Ferreiro and Fu (2016) stated that soil microbial biomass carbon was regarded as one of the most sensitive indicators for the changes in soil quality. In reclaimed wetlands, low microbial biomass carbon (MBC) value act as evidence for minimum biological activity by influencing organic carbon content, total nitrogen and soil aggregation level in soil (Gupta and Germida, 2015). Soils collected from paddy fields of *kole* lands shown high microbial biomass and dehydrogenase activity (Amritha and Durga Devi, 2017). They also found that dehydrogenase activity and microbial biomass carbon are high in soils having high organic matter. This may be due to the supply of sufficient substrate to support microorganisms and their enzyme production (Yuan and Yue, 2012). Hojati and Nourbakhsh (2006) also found that microbial biomass carbon and dehydrogenase activity have strong positive correlation with soil organic carbon content. Better indication of soil microbial activity can be possible by measuring dehydrogenase activity since it has a close association with viable microbial population (Mijangos *et al*., 2006). Hence the assays of both microbial biomass carbon and dehydrogenase activity can explain the adverse effect of any change in soil.

In Entisols, dehydrogenase activity was considered as a powerful indicator of soil quality by Chaudhari *et al*. (2013) due to its role in oxidative activity. Schloter *et al*. (2003) claimed soil microbial biomass as a useful indicator since it is highly susceptible to soil pollution. Flooding occurred in city of Jena, Germany, alleviated microbial biomass carbon limitation, presumably due the input of nutrient-rich sediments (Mace *et al*., 2016). Flooding affect the nutrient availability, oxygen concentration in soil environment and shifts the microbial community composition and finally affects the soil enzymes activities (Burns and Ryder, 2001).

2.6. SOIL QUALITY ASSESSMENT

Since the soil properties are highly site specific, the major challenge of soil quality indexing is to select relevant indicators and score this indicators to evaluate the status of soils (Yu *et al*., 2018). Various concepts and methods have been proposed to find out the soil quality based on the fact that there is no universal method for assessing soil quality under different environment (Askari and Holden, 2014). Soil quality index is successfully used as an effective tool for quality assessment of soil, since it is quantitatively flexible, easy to use and very well correlated to the soil management practices (de Paul Obade and Lal, 2016). According to Zuber *et al*. (2017) the sensitivity of SQI towards soil quality changes reduced if there are no adequate indicators representing physical, chemical and biological properties. The indiscriminate and unscientific land uses and managements cause decline in soil quality by reducing soil organic matter content (Hall *et al*., 2017). Hence efficient land uses maintain and improve soil quality (Lal, 2015). Soil quality assessment is made by selecting a set of soil properties which are considered as soil quality indicators of particular area. Soil quality index is the result of product of selected soil quality indicator properties, which have dominant influence on soil functions (Vasu *et al*., 2016). Soil quality indexing not only helps to evaluate the ecological function of soils but also identify the individual soil properties that are important to the overall condition of soil (Beniston *et al*., 2016).

The three main steps for soil quality indexing are to (i) select a minimum data set (MDS) of indicators that best represent soil function, (ii) score the MDS indicators based on their performance of soil functions, and (iii) integrate the indicator scores into a comparative index of soil quality (Andrews *et al*., 2002).

2.6.1. Minimum data set

To avoid collinearity and limitation due to lack of fund, selection of a minimum data set is a necessary step in evaluation of soil quality (Bünemann *et al*., 2018). MDS varied significantly across various soil orders (Sharma *et al*., 2008). Statistical reduction of large set of data carried out by techniques such as principal component analysis (PCA), redundancy analysis (RDA) and discriminant analysis (Lima *et al*., 2013), and multiple regression (Kosmas *et al*., 2014). An appropriate MDS can be also defined using strategies like expert opinion and farmer knowledge (Cherubin *et al*., 2016). Minimum soil data set properties were selected based on the available soil data according to consensus of the authors, available literature in export opinion method. Soil quality index in semi arid Deccan plateau was studied by Vasu *et al*. (2016) using both PCA and expert opinion. They reported a large variation in soil quality in this area due to soil heterogeneity and soil degradation caused by subsoil sodicity. They found that 'expert opinion' method is comparatively better option for soil quality assessment in the semi arid tropical Deccan region since indicators were selected with due consideration of regressive pedogenic processes and their influence on soil properties. But it is not always possible because we should have adequate knowledge about the particular region where we are going to assess soil quality. They also found that PCA very well explained the variation in soil properties and their interaction.

A minimum data set (MDS) was proposed to measure soil quality and its changes due to management practices through selection of key indicators such as soil texture, organic matter, pH, nutrient status, bulk density, electrical conductivity and rooting depth (Larson and Pierce, 1994). Collecting a minimum data set helps to identify locally relevant soil indicators and to evaluate the link between selected indicators and significant soil and plant properties (Arshad and Martin, 2002).

2.6.2. Principal component analysis

To identify the potential indicators to represent a minimum data set, a principal component analysis was carried out in the total data set (Askari and Holden, 2015; Raiesi, 2017). Principal components (PCs) for a data set are defined as linear combinations of the variables that account for maximum variance within the set by describing vectors of closest fit to the n observations in p-dimensional space, subject to being orthogonal to one another (Andrews *et al*., 2002). All of physical, chemical, and biological data collected was evaluated by principal component analysis (PCA) (Thuithaisong *et al*., 2011). Pal *et al.* (2013) found that PCA reduces the dimension of large volume of data and facilitate the indicator selection by categorically grouping the soil properties into principal components. The system attributes are best represented by PCs receiving high values. Therefore, the PCs with eigen values greater than one are selected (Brejda *et al*., 2000). In order to maximize correlation, variables were subjected to varimax rotation between PCs and the measured attributes (Singh *et al*., 2016). While considering a particular PC, a weight or factor loading was received by each variable that represents its contribution to the PC. Only the highly weighted variables are retained from each PC for the MDS. Highly weighted variables are defined as that the factor loading lies within 10 per cent of the absolute values of highest factor loading. If more than one variable was retained within a PC, their linear correlations were checked to determine whether the variables could be considered redundant or dispensable and, therefore, eliminated from the MDS (Andrews *et al*, 2002). Among well-correlated variables within a PC, the variable with the highest loading factor was chosen for the MDS (Andrews and Carroll, 2001). If the highly weighted variables were not correlated, that their correlation coefficients are less than 0.60, then each was considered important indicator and was retained in the MDS.

After determining the MDS indicators, each of the variables in MDS were scored based on their performance of soil functions. Over a large range of indicator values measured in northern California, Andrews *et al*. (2002a) found that nonlinear scoring of indicators was more representative of system function than linearly scored indicators. Indicators were transformed in to unit less values by scoring.

2.6.3. Scoring or Indicator transformation

The selected variables for MDS are transformed by linear or non linear scoring. Each soil indicator was transformed into unit less combinable scores ranging from 0.00 to 1.00 (Askari and Holden, 2015; Raiesi, 2017). In both scoring methods the variables selected for MDS are categorised in to three groups such as more is better, less is better and optimum indicator based on soil function. The “scoring functions” can be subjective because this approach is based on perceived graphical relationships that may follow a normal distribution, with an upper asymptote, or a lower asymptote, determined through consensus or from literature review values (de Paul Obade and Lal, 2016).

2.6.3.1. Linear scoring

For ‘more is better’ indicators, each observation was divided by the highest observed value such that the highest observed value received a score of 1. For ‘less is better’ indicators, the lowest observed value was taken in numerator and divided by each observation such that the lowest observed value receives a score of 1 (Liebig *et al*., 2001). For linear scoring equation for more is better or less is better is used as follows;

$S_L=X/X_{max}$

$S_L=X_{min}/X$

Where S_L is the linear score, X is observed indicator value, X_{max} and X_{min} are maximum and minimum of observed indicator values (Askari and Holden, 2014; Raiesi, 2017). Both these equations are together used in optimum.

2.6.3.2. Non-linear scoring.

Indicators were transformed using sigmoid functions. Three curves are used for decision function, a sigmoid curve with an upper asymptote and lower asymptote was used for ‘more is better and less is better curve respectively. A bell-shaped curve was used for soil indicator depicts optimum soil function. The following equation was used for non linear scoring;

$$S_{NL}= a/(1 + \left(\frac{X}{Xm}\right)^{b})$$

Where S_{NL} is the non linear score, ‘a’ is the maximum score 1, X is the value of soil indicator, X_m is the mean value of each indicator and b is the slope of the curve. Slope of curve is set as -2.5 for more is better and 2.5 for less is better (Bastida *et al*., 2006; Raiesi, 2017)

A linear scoring method demands little prior knowledge of the system, and it is mostly relying on the observed values of the indicators to determine the variance, while a non-linear scoring approach requires an in-depth knowledge of each indicator's behaviour and has a much lower differences among the treatments than observed in its linearly scored counterparts (Andrews *et al*., 2002; Guo *et al*., 2017; Raiesi, 2017). Therefore, the non-linear scoring method was considered as the proper method for indexing soil quality indicators (Andrews *et al*., 2002, Mukhopadhyay *et al*., 2016; Zhao *et al.*, 2017). Yu *et al*. (2018) confirmed that the non-linear scoring indices presented soil function better than linear scoring indices due to its better differentiating ability among indicators. While linear methods are simple and user-friendly and require little knowledge of the indicator thresholds (Cherubin *et al*., 2016). The transformed indicators were integrated in to a soil quality index by additive or weighed additive methods.

2.6.4. Soil quality index

Many indexing strategies have been developed by scientists and tested for particular purposes under specific environmental conditions around the world. The easiest method to calculate a SQI is to simply add the scores of all indicators and then divide by the total number of indicators (Tesfahunegn *et al*., 2011). But the major defect regarding this method is that when the number of indicators among chemical, physical and biological attributes is unbalanced, then the overall SQI misrepresents the sector(s) having fewer indicators (Cherubin *et al*., 2016).

Based on the results of PCA the transformed indicator data was given weightage. A certain amount variation was explained by each PC in the total dataset. The weightage factor was derived by dividing the total percentage of variance from each PC with percentage of cumulative variance (Ray *et al*., 2014). The derived weightage factor for each PCs were multiplied with selected indicators from respective PCs. The weighted variables were then summed up to derive index value for all sites. However, the weighted additive approach was superior to the additive approach to show differences among the four land-use treatments carried out in alkaline soil of north east China (Yu *et al*., 2018).

On the other hand, several studies have used methods that assign weights for each indicator. Different criteria that have been used include soil function frameworks (Lima *et al*., 2013), principal component loading (Swanepoel *et al*., 2015), partial least squares regression coefficients (de Paul Obade and Lal, 2016) and correlation with crop yield (Liu *et al*., 2015). Simple and weighted additive SQ indexing strategies provide site-specific responses and influenced by existing dataset, soil type, and effects of land use and management practices (Askari and Holden, 2015).

Partoyo (2005) categorized soil in to five based on the soil quality index value. The soil quality index is a value calculated based on the score and weight of each indicator of soil quality. The classification by Partoyo (2005) shown in table below;

Sl No.	Range of SQI value	Soil quality class
1	0.80 - 1.00	Very good
2	0.60 - 0.79	Good
3	0.40 - 0.59	Fair

4	0.20 - 0.39	Bad
5	0.00 - 0.19	Very bad

Another rating of soil quality was by Xu *et al*. (2006), he classified quality of soil in to five grades such as high (0.8-1), higher (0.6-0.8), middle (0.4-0.6), lower (0.2-0.4) and low (0-0.2). They developed this rating for their specific study. Impact of land use on soil quality of eastern Himalayan region of India was studied by Singh *et al*. in 2018 and he classified the region in to three class namely low (<0.5), medium (0.5-0.75) and high (>0.75). In fact there is no standard rating for soil quality index; all the above ratings are developed by authors for their convenience and from the knowledge of existing soil quality of the particular area.

2.7. RELATIVE SOIL QUALITY INDEX (RSQI).

Relative soil quality index concept was put forwarded by Karlen and Stott (1994), as the percentage of ratio of soil quality index of a given site to maximum theoretical value of SQI for the same site.

$$\text{RSQI} = \frac{\text{SQI}}{\text{SQIm}} \times 100$$

According to the values of RSQI, soils were classified in to poor, medium and good as shown below.

Sl. No.	Range of RSQI	Soil quality class
1	<50%	Poor
2	50-70%	Medium
3	>70%	Good

2.8. NUTRIENT INDEX

Parker *et al*. (1951) introduced the concept of nutrient index. Nutrient index helps to compare the soil fertility of one region with another by converting soil test values in to a single unit less nutrient index (Singh *et al*., 2018). Nutrient index helps to measure capacity of soil to supply nutrients to plant and there support the growth (Singh *et al*., 2016). Hence it was a measure of soil fertility also (Ravikumar and Somashekhar, 2014). In order to develop a nutrient index soil test values are classified in to three such as low, medium and high (Pathak, 2010). Using this nutrient index was developed by the following equation.

$$\text{Nutrient index} = \frac{(1\times N1)+(2\times N2)+(3\times N3)}{N}$$

Whereas N1= Number of samples in low category

N2= Number of samples in medium category

N3= Number of samples in high category

N= Total number of samples

Ravikumar and Somashekhar (2014) divided the soil in to three category based on the value of nutrient index such as low (<1.67), medium (1.67-2.33) and high (>2.33). In India, Motsara (2002) developed a fertility map using nutrient index of N, P and K by collecting soil analysis data from 533 soil testing laboratories representing 450 districts.

Materials and methods

3. MATERIALS AND METHODS

The present study was carried out to assess the soil quality in *kole* lands of Thrissur and Malappuram districts of Kerala (AEU 6) in the post flood scenario and develop maps on soil characters and quality using GIS techniques. The soils were collected from different flood affected areas of AEU 6 and analysed at the College of Horticulture, Vellanikkara during 2018-2020.

3.1. DETAILS OF SURVEY AND SOIL COLLECTION

Kole lands with major crop rice, come under agro-ecological unit (AEU 6) with an area of 13,632 ha are distributed in Thrissur and Malappuram districts. The *kole* lands in Thrissur are distributed mainly among five block panchayats *viz*., Mullassery, Anthikkad, Cherpu, Irinjalakkuda and Puzhakkal while that in Malappuram are distributed among two block panchayats *viz*., Perumpadappu and Ponnani. Most of the paddy fields in *kole* lands were seriously affected by the flood. A total of 100 samples were collected, among which 75 were from *kole* lands of Thrissur district and 25 from *kole* lands of Malappuram district (Plate 3.1). GPS referenced surface (0 – 20 cm) soil samples were collected from different locations of *kole* padavu after the cropping season (Table 3.2). One or two samples were collected from each *kole* padavu according to the area of *kole* padavu. Thus, 15 samples from Mullassery block panchayat, 16 from Anthikkad block panchayat, 15 from Cherpu block panchayat, 15 from Irinjalakkuda block panchayat, 14 from Puzhakkal block panchayat, 12 from Perumpadappu block panchayat and 13 from Ponnani block panchayat were collected. Soil samples were collected from Elavally, Mullassery, Venkitengu panchayats from Mullassery block panchayat; Karalam, Kattoor, Muriyad, Parappookkara, Porathissery panchayats of Irinjalakkuda block panchayat; Cherpu, Paralam, Vallachira panchayats of Cherpu block panchayat; Adat, Arimbur, Avanoor, Kaiparambu, Mulamkunnathukavu, Tholur panchayats of Puzhakkal block panchayat; Anthikkad, Chazhoor, Manalur, Thanniyam panchayats of Anthikkad block panchayat; Maranchery, Perumpadappu, Nannamukk and Veliyamkode panchayats of Perumpadappu block panchayat and Thavanur and Ponnani panchayats of Ponnani block panchayat. The location map of of 100 geo referenced samples in AEU 6 was mapped (Fig. 3.1)

3.2. DETAILS OF LOCATIONS

Sl. no	Block panchayats	Name of *kole* padav	Longitude	Latitude
1	Mullassery (15 samples)	Ponnamutha	076° 32' 53.22" E	10° 16' 36053.63" N
2		Elamutha	076° 16' 58.54" E	10° 32' 36041.28" N
3		Mathukkara Thekk	076° 06' 59.27" E	10° 31' 36032.26" N
4		Pavudai	076° 06' 34.17" E	10° 32' 36038.61" N
5		Parappadam kizhakkethala	076° 06' 17.75" E	10° 32' 36035.91" N
6		Parappadam west	076° 06' 09.22" E	10° 32' 36038.59" N
7		Penakam	076° 06' 32.18" E	10° 32' 36043.97" N
8		Elavathur	076° 06' 42.77" E	10° 32' 36049.63" N
9		Cherotha akkarapadam	076° 06' 53.78" E	10° 34' 36008.97" N
10		Peruvalloor padav	076° 05' 40.67" E	10° 33' 36030.05" N
11		Kaniyamthuruth	076° 06' 14.78" E	10° 34' 36012.40" N
12		Annakkarachirakkal	076° 06' 29.15" E	10° 34' 36009.70" N
12		Annakkaravadakk	076° 06' 53.79" E	10° 33' 36022.44" N
14		Thanneerkayal	076° 04' 48.27" E	10° 31' 36043.68" N
15		Pulipandi	076° 03' 54.06" E	10° 32' 36002.57" N

16	Anthikkad	Chettupuzha west	076° 09' 51.95" E	10° 30' 36020.89" N
17	(16 samples)	Chaladipazhan *kole*	076° 08' 32.81" E	10° 30' 36012.78" N
18		Themalippuram	076° 07' 20.63" E	10° 29' 36045.60" N
19		Rajamukk	076° 07' 35.36" E	10° 29' 36050.56" N
20		Arumuri	076° 07' 34.13" E	10° 29' 36050.56" N
21		Manaloorthazham	076° 07' 29.96" E	10° 30' 36006.04" N
22		Kodayatti	076° 08' 09.85" E	10° 28' 36040.36" N
23		Ayyappan *kole*	076° 08' 10.35" E	10° 28' 36005.41" N
24		Pazhuvil bund *kole*	076° 09' 19.29" E	10° 24' 36033.69" N
25		Chennakaripuncha	076° 10' 34.49" E	10° 25' 36041.55" N
26		Jubilee thevarpadav	076° 10' 39.50" E	10° 25' 36046.41" N
27		Pallippuram	016° 10' 31.58" E	10° 27' 36017.53" N
28		Pullu	076° 09' 18.10" E	10° 28' 36004.86" N
29		Vilakkumadampadav	076° 09' 16.95" E	10° 28' 36007.08" N
30		Variyam *kole* padav	076° 09' 29.34" E	10° 28' 36005.05" N
31		Chettupuzha east	076° 10' 28.55" E	10° 29' 36053.74" N
32	Cherpu	Manakkal padavu	076° 11' 00.89" E	10° 29' 36012.45" N
33	(15 samples)	Madhammathopp	076° 10' 51.09" E	10° 29' 36010.57" N
34		Nerkathir	076° 11' 00.29" E	10° 29' 36012.25" N

35		Kanimangalam *kole* padav	076° 10' 55.48" E	10° 29' 36004.23" N
36		Karimbatta	076° 11' 35.10" E	10° 29' 36034.68" N
37		Kizhakkan *kole* padavu	076° 11' 47.55" E	10° 29' 36047.47" N
38		Cheeyaram samajam	076° 13' 14.98" E	10° 28' 36044.47" N
39		Avinissery samajam	076° 13' 01.94" E	10° 28' 36041.48" N
40		Kodannur *kole* farming society	076° 10' 08.75" E	10° 28' 36001.61" N
41		Pallippuram *kole* padav	076° 10' 34.78" E	10° 27' 36016.73" N
42		Pandaran *kole*	076° 10' 52.35" E	10° 27' 36033.70" N
43		Chovvoorthazham alukka padav	076° 11' 47.94" E	10° 27' 36003.75" N
44		Jubilee thevarpadav	076° 10' 39.50" E	10° 25' 36041.55" N
45		Perumkulam east	076° 11' 48.33" E	10° 27' 36001.15" N
46		Perumkulam west	076° 12' 30.97" E	10° 25' 36050.22" N
47	Irinjalakkuda	Painkilikayal	076° 12' 56.00" E	10° 24' 36002.34" N
48	(15 samples)	Chemmandakayal	076° 11' 37.75" E	10° 23' 36053.16" N
49		Vellani *kole*	076° 10' 01.68" E	10° 23' 36053.70" N
50		Thekkumoola	076° 09' 54.21" E	10° 21' 36054.75" N
51		Karppullithara kakkad	076° 13' 47.16" E	10° 21' 36040.15" N
52		Muriyaad	076° 13' 54.50" E	10° 21' 36044.42" N

53		Kalladithazham	076° 12' 25.43" E	10° 22' 36034.11" N
54		Chithravallipadam	076° 13' 26.60" E	10° 22' 36058.58" N
55		Kochipadam	076° 13' 10.22" E	10° 22' 36030.13" N
56		Kadumkadu	076° 14' 08.48" E	10° 22' 36050.82" N
57		Mothalakkulam	076° 14' 07.04" E	10° 22' 36048.00" N
58		Koda *kole*	076° 14' 16.94" E	10° 23' 36011.36" N
59		Konthikulam	076° 14' 24.80" E	10° 23' 36039.77" N
60		Parappookkara	076° 14' 55.42" E	10° 23' 36018.99" N
61		Nedumbal	016° 15' 24.73" E	10° 23' 36011.54" N
62	Puzhakkal	Pullazhi *kole* 1	076° 10' 50.62" E	10° 32' 36044.64" N
63	(14 samples)	Pullazhi *kole* 2	076° 10' 14.63" E	10° 32' 36007.44" N
64		Pannikkara kin *kole*	076° 10' 36.20" E	10° 31' 36046.59" N
65		Ombathumuri 1	076° 08' 21.36" E	10° 32' 36013.57" N
66		Ombathumuri 2	076° 07' 26.32" E	10° 32' 36017.16" N
67		Kadavil *kole*	076° 08' 12.98" E	10° 32' 36005.28" N
68		Pandaran *kole* 1	076° 08' 10.34" E	10° 32' 36000.22" N
69		Pandaran *kole* 2	076° 08' 09.97" E	10° 32' 36005.20" N
70		Sangham south *kole*	076° 07' 53.03" E	10° 32' 36038.91" N
71		Sangham north *kole*	076° 07' 55.39" E	10° 32' 36033.83" N

72		Chirukandathu *kole* 1	076° 08' 00.76" E	10° 33' 36044.80" N
73		Chirukandathu *kole* 2	076° 08' 04.41" E	10° 32' 36035.70" N
74		Karikkin *kole*	076° 08' 56.02" E	10° 34' 36007.19" N
75		Vadakke ponnur thazham	076° 08' 43.30" E	10° 35' 36030.97" N
76	Perumpadappu	Maradi *kole* padavu	075° 58' 56.30" E	10° 44' 36030.18" N
77	(12 samples)	Nadupotta *kole*	075° 58' 48.26" E	10° 45' 36000.97" N
78		Maradi *kole* padav, maranchery	075° 58' 36.27" E	10° 44' 36025.23" N
79		Kundamkuzhi 1	075° 58' 34.77" E	10° 45' 36006.16" N
80		Kundamkuzhi 2	075° 58' 18.97" E	10° 44' 36052.26" N
81		Mullamadu	075° 58' 14.00" E	10° 45' 36005.40" N
82		Arimbinkundu	075° 57' 50.28" E	10° 45' 36017.46" N
83		Irumbayil *kole*	075° 58' 11.58" E	10° 45' 36056.71" N
84		Aana *kole* 1	075° 58' 35.44" E	10° 43' 36025.63" N
85		Aana *kole* 2	075° 58' 44.42" E	10° 43' 36025.63" N
86		Kolothupadavu 1	076° 00' 48.95" E	10° 44' 36036.06" N
87		Kolothupadavu 2	076° 01' 28.20" E	10° 44' 36047.40" N
88	Ponnani	Ponnani *kole* padavu 1	075° 59' 08.49" E	10° 44' 36019.83" N
89	(13 samples)	Ponnani *kole* padavu 2	075° 59' 02.35" E	10° 44' 36027.29" N

90		Ponnani *kole* padavu 3	075° 59' 18.01" E	10° 44' 36038.17" N
91		Kanniyam kayal 1	075° 58' 59.37" E	10° 46' 36034.72" N
92		Puzhangad *kole* 1	075° 58' 55.36" E	10° 46' 36029.37" N
93		Kanniyam kayal 2	075° 58' 49.13" E	10° 46' 36039.46" N
94		Anthalachira 1	075° 58' 46.66" E	10° 46' 36048.61" N
95		Anthalachira 2	075° 58' 45.69" E	10° 46' 36052.86" N
96		Puzhangad	075° 58' 48.69" E	10° 46' 36036.46" N
97		Panthavoor 1	076° 01' 13.40" E	10° 45' 36007.38" N
98		Panthavoor 2	076° 01' 50.33" E	10° 45' 36043.38" N
99		Moochikkal kadavu 1	075° 59' 46.31" E	10° 44' 36004.49" N
100		Moochikkal kadavu 2	075° 59' 11.40" E	10° 44' 36054.96" N

3.3. CHARACTERIZATION OF SOIL SAMPLES

The physical, chemical and biological attributes were analysed using standard procedures. The soil samples were kept as wet samples without drying. Moisture content of soil at the time of analysis was measured gravimetrically which was used for moisture correction.

3.3.1. Characterization of physical properties

3.3.1.1. Bulk density

Bulk density was determined using Keen Raczkowski (KR) box method, where soil was directly collected from the field filled in to a KR box which had a known volume. Soil was oven dried at 105 ^{0}C to obtain a constant weight. Then, the bulk density (Mg m^{-3}) was calculated by dividing the dry mass of soil by volume of the KR box (Keen and Raczkowski, 1921).

3.3.1.2. Particle density

Particle density was determined by Keen Raczkowski (KR) box method (Keen and Raczkowski, 1921). Filled the KR box with soil until the box was nearly full. Particle density calculated using the formula;

PD = Weight of soil / Volume of soil excluding pore space

3.3.1.3. Porosity

Porosity was calculated using bulk density and particle density (Danielson and Sutherland, 1986).

Porosity = (1-(bulk density/particle density)) x100

3.3.1.4. Maximum water holding capacity

Maximum water holding capacity was determined using Keen Raczkowski (KR) box method (Keen and Raczkowski, 1921). The KR box was filled with soil and placed in a water filled tray and difference in weight was noted after overnight. Maximum water holding capacity was calculated using the formula,

Maximum water holding capacity= $((C - B)/(B - A))$ x 100

Plate 3.1. Collection of soil samples from paddy field

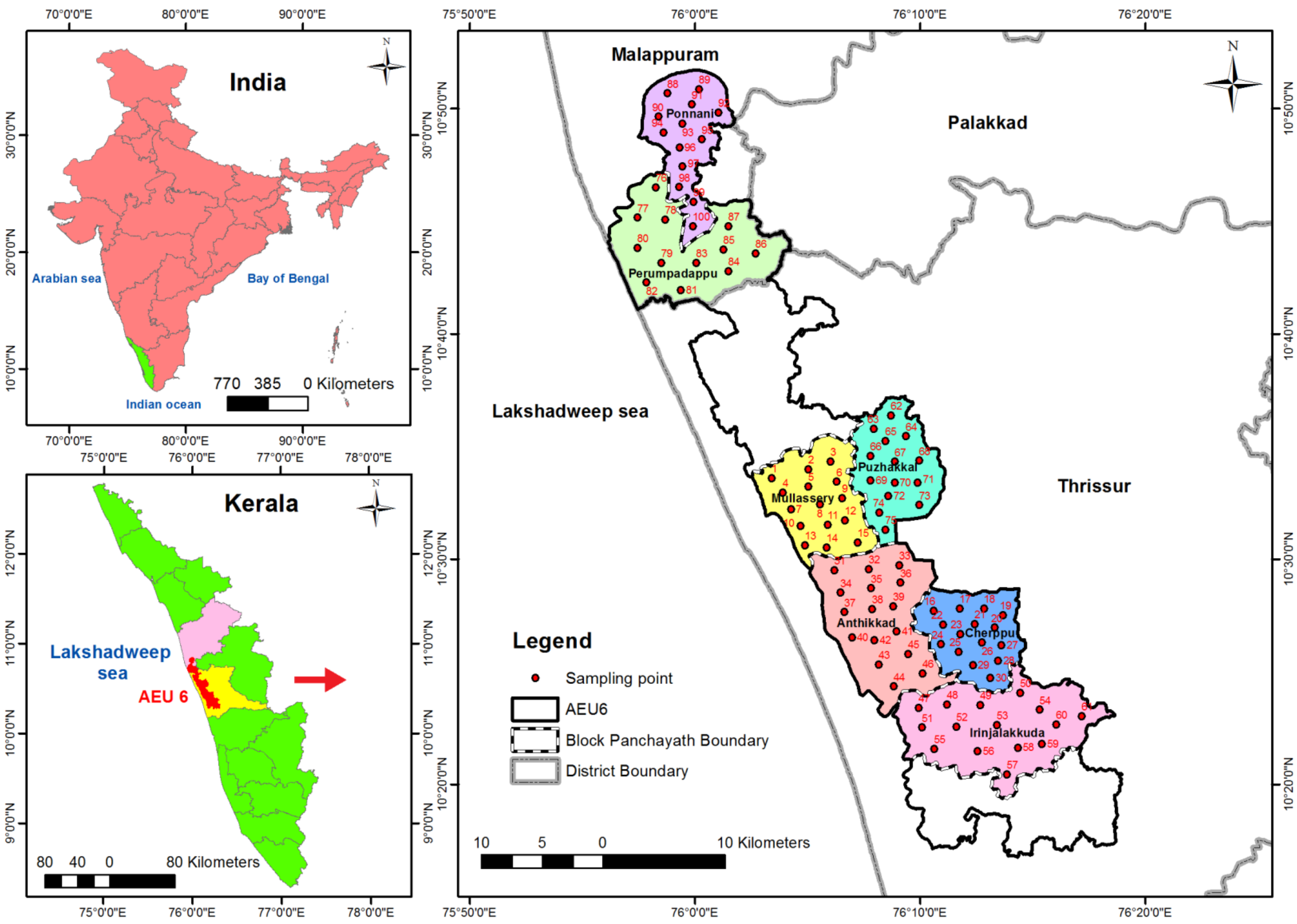

Fig. 3.1. Location of soil samples collected from flood affected areas of AEU 6

Where,

C = weight of KR box + saturated soil

B= weight of KR box + dry soil

A = weight of KR box + filter paper

3.3.1.5. Soil moisture

Soil moisture was measured by gravimetric method. The weight difference between fresh soil (W_1) and oven dried soil at 105 ^{0}C (W_2) gave the water content in soil.

Soil moisture content (%) = $[(W_1 - W_2)/ W_1] \times 100$

3.3.1.6. Aggregate stability

Yoder's wet sieving method (Yoder, 1936) was used for determination of aggregate stability. Yoder's apparatus is a nest of sieves with 5.0, 2.0, 1.0, 0.5 and 0.25 mm diameter. 50 g of soil was placed in the top of sieves and wet sieved for 30 minutes. The soil retained in each sieve was transferred and dried at 105 ^{0}C. The aggregate stability for each soil sample was then expressed by mean weight diameter (MWD) using the equation shown below (Van Bavel, 1949).

Mean weight diameter = $\sum di \times wi$

Where *di* and *wi* are the mean diameter in each fraction and proportion of total sample weight respectively.

3.3.2. Characterization of chemical properties

3.3.2.1. pH

The pH of soil was determined potentiometrically using a pH meter. A 1:2.5 soil water suspension was used for determination of soil pH (Jackson, 1958).

3.3.2.2. Electrical conductivity

A supernatant liquid of 1:2.5 soil water suspension was used for estimation of electrical conductivity by a conductivity meter (Jackson, 1958).

3.3.2.3. Organic carbon

Wet digestion method was used for determination of organic carbon content in soil samples (Walkley and Black, 1934).

3.3.2.4. Exchangeable acidity

Exchangeable acidity (Al^{+3} and H^{+}) was determined by the titration method (McLean, 1965). Extraction was carried out using 1.0 M KCl (1:2.5) and a known quantity of extract was titrated against a 0.01 M NaOH.

3.3.2.5. Available nitrogen

Available Nitrogen was determined by alkaline potassium permanganate method by Subbiah and Asija (1956). The soil was distilled with alkaline permanganate solution to liberate ammonia which was collected in boric acid. This ammonia was determined volumetrically.

3.3.2.6. Available phosphorus

Available phosphorus was extracted using Bray No.1 extractant (Bray and Kurtz, 1945), and the P content in the extract was determined using ascorbic acid as reducing agent which yielded a blue colour (Watanabe and Olsen, 1965). The intensity of blue colour was measured using a spectrophotometer.

3.3.2.7 Available potassium

Available K was estimated by flame photometer using the extract neutral normal ammonium acetate (Hanway and Heidel, 1952; Jackson, 1958).

3.3.2.8. Available calcium and magnesium

Available calcium and magnesium was extracted using neutral normal ammonium acetate and its amount in extract was estimated using atomic absorption spectrometer (Jackson, 1958).

3.3.2.9. Available sulphur

Available S was extracted using 0.15% $CaCl_2$ solution (Tabatabai, 1996). Concentration of available S was estimated by measuring the turbidity in spectrophotometer.

3.3.2.10. Available micro nutrients

Available micronutrients were analysed using 0.1M HCl extractant and concentration of micronutrients (Fe, Mn, Zn and Cu) were measured using AAS (Sims and Johnson, 1991).

3.3.2.11. Available boron

Available boron was found by hot water extraction followed by addition of Azomethyl-H and quantified by spectrophotometer (Gupta, 1972).

3.3.2.12. Effective cation exchange capacity

The effective cation exchange capacity in soil was estimated by method proposed by Hendershot and Duquette (1986). The cations (Na, K, Ca, and Mg) present in the exchangeable sites in the soil were replaced by 0.1 M $BaCl_2$ solution and cations in the extract were estimated using AAS. Effective cation exchange capacity was calculated using the formula shown below,

ECEC = Exchangeable (Na + K + Ca + Mg + acidity)

3.3.3. Characterization of biological properties

3.3.3.1. Dehydrogenase activity

Dehydrogenase activity in soil was estimated based on rate of reduction of 2,3,5 triphenyltetrazolium chloride (TTC) to triphenylformazan (TPF) (Klein *et al.*, 1971). The red colour of triphenylformazan was estimated colorimetrically using a spectrophotometer.

3.3.3.2. Microbial biomass carbon

Soil microbial biomass carbon (MBC) was determined by the chloroform fumigation and extraction method (Jenkinson and Powlson, 1976); consisting of 0.5 M K_2SO_4 extraction of both fumigated and unfumigated soils. Fumigations were carried out in a vacuum desiccator with alcohol free chloroform. Fumigated and unfumigated extracts were filtered (Whatman Filter Papers 42, CAT No. 1442-150). In both extracts, dissolved organic carbon was measured by Walkley and Black method (Walkley and Black, 1934).

3.4. SOIL QUALITY INDEX ASSESSMENT

Evaluation of soil quality was carried out by the method proposed by Andrews *et al*. (2002). A minimum dataset (MDS) was selected by principal component analysis of soil quality indicators using SPSS version 16 statistical package.

Principal components (PC) with eigen values greater than one were selected for MDS. Only the highly weighted variables were retained from each PC for the MDS. If more than one variable was retained within a principal component, their linear correlations were checked to determine whether the variables could be considered redundant and, therefore, eliminated from the MDS. Among well-correlated variables within a principal component, the variable with the highest loading factor was chosen for the MDS. If the highly weighted variables were not correlated, that their correlation coefficients were less than 0.60, then each was considered important indicator and was retained in the MDS. The selected variables in each MDS were categorized in to three groups *viz*., more is better, less is better, optimum based on the performance on soil functions. Subsequently, the indicators were scored by non-linear scoring method. The weightage of each principal component was calculated using the variance obtained from principal component analysis. Weight of each PCs were determined by dividing the per cent variance of each PC with the cumulative variance explained by all the PCs having eigen vectors >1. The SQI was calculated by aggregating the product of score of each indicator with its weightage factor. Since there is no standard rating for SQI, relative soil quality index (RSQI) was computed using the formula proposed by Karlen and Stott (1994).

$$\text{RSQI} = \frac{\text{SQI}}{\text{SQIm}} \times 100$$

Where,

SQI = soil quality index of particular area

SQIm = theoretical maximum soil quality index of that area

3.5. PREPARATIONS OF GIS MAPS.

Geo referenced thematic maps of relative soil quality index was developed by Arc GIS software. Major nutrients like N, P, K and pH of the soils of AEU 6 were also mapped.

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Results

4. RESULTS

The experimental results obtained during the course of the investigation are presented below-

4.1. SOIL QUALITY ASSESSMENT

Soil quality was assessed by analyzing soil physical, chemical and biological characteristics. A minimum data set was selected from this and used for working out soil quality index.

4.1.1. Physical attributes

Soil samples collected from different location of flood affected *kole* lands were analyzed for various physical properties.

4.1.1.1. Bulk density

Bulk density of the soil varied from 0.53 Mg m^{-3} to 1.34 Mg m^{-3} in different sites of *kole* lands. The lowest bulk density was recorded in Puzhangad of Ponnani block panchayat and the highest in Kundamkuzhi *kole* padav of Perumpadappu block panchayat. The highest mean (1.02 Mg m^{-3}) bulk density was recorded in Anthikkad block panchayat. Bulk density varied from 0.75 Mg m^{-3}(Chaladi pazhan *kole*) to 1.13 Mg m^{-3}(Kodayatti) in Anthikkad block panchayat. The lowest mean (0.86 Mg m^{-3}) bulk density was recorded in Puzhakkal block panchayat. It ranged from 0.72 Mg m^{-3} (Karikkin *kole*) to 1.08 Mg m^{-3} (Chirukandathu *kole* 2) in Puzhakkal block panchayat. Bulk density extended from 0.72 Mg m^{-3} (Parappadam kizhakkethala) to 1.16 Mg m^{-3} (Annakkara chirakkal) in Mullassery block panchayat. It ranged from 0.64 Mg m^{-3} (Avinissery samajam) to 1.07 Mg m^{-3} (Kizhakkan *kole* padavu) in Cherpu block panchayat and it varied from 0.72 Mg m^{-3} (Koda *kole*) to 1.07 Mg m^{-3} (Kalladi thazham) in Irinjalakkuda block panchayat. Bulk density varied from 0.65 Mg m^{-3} to 1.34 Mg m^{-3} in Perumpadappu block panchayat and from 0.53 Mg m^{-3} to 1.22 Mg m^{-3} in Ponnani block panchayat. There was no significance difference between bulk densities in different block panchayats. Bulk density in Mullassery block panchayat was on par with Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani block panchayats (Table 4.1).

Table 4.1. Bulk density ($Mg\ m^{-3}$) of soils in the block panchayats of AEU 6

Block panchayats	Bulk density	
	Mean ± SD	Range
Mullassery	$0.86^{a} \pm 0.14$	0.72 - 1.16
Cherpu	$0.90^{a} \pm 0.13$	0.64 - 1.07
Anthikkad	$1.02^{a} \pm 0.12$	0.75 - 1.13
Irinjalakkuda	$0.91^{a} \pm 0.13$	0.72 - 1.07
Puzhakkal	$0.82^{a} \pm 0.23$	0.72 - 1.08
Perumpadappu	$0.90^{a} \pm 0.21$	0.65 - 1.34
Ponnani	$0.91^{a} \pm 0.21$	0.53 - 1.22
CD = Non significant		

4.1.1.2. Particle density

Particle density of the soil varied from 2.05 $Mg\ m^{-3}$ to 2.67 $Mg\ m^{-3}$. The highest particle density was recorded in Mothalakkulam of Irinjalakkuda block panchayat whereas lowest particle density in Kadavil *kole* of Puzhakkal block panchayat. The highest mean (2.56 $Mg\ m^{-3}$) particle density was observed in Irinjalakkuda block panchayat. Particle density in Irinjalakkuda block panchayat ranged from 2.24 $Mg\ m^{-3}$ (Vellani *kole*) to 2.67 $Mg\ m^{-3}$ (Mothalakkulam). The lowest mean (2.32 $Mg\ m^{-}$3) particle density was recorded in Puzhakkal block panchayat. Particle density in Puzhakkal block panchayat varied from 2.05 $Mg\ m^{-3}$ (Kadavil *kole*) to 2.63 $Mg\ m^{-3}$ (Pullazhi *kole* 1). The lowest particle density and the highest particle density were recorded in Cherotha akkarapadam (2.08 $Mg\ m^{-3}$) and Peruvalloor padav (2.66 $Mg\ m^{-3}$) respectively in Mullassery block panchayat. Particle density in Cherpu block panchayat extended from 2.11 $Mg\ m^{-3}$ (Pallippuram *kole* padav) to 2.65 $Mg\ m^{-3}$ (Kodannur *kole* farming society). In Anthikkad block panchayat, it varied from 2.11 $Mg\ m^{-3}$ (Ayyappan *kole*) to 2.64 $Mg\ m^{-3}$ (Kodayatti). Particle density in Perumpadappu block panchayat ranged from 2.30 $Mg\ m^{-3}$ to 2.59 $Mg\ m^{-3}$ and in Ponnani block panchayat varied from 2.13 $Mg\ m^{-3}$ to 2.65 $Mg\ m^{-3}$. There was no significant difference in particle density of different block panchayats. Particle density in all the block panchayats were on par (Table 4.2).

Table 4.2. Particle density (Mg m^{-3}) of soils in the block panchayats of AEU 6

Block panchayats	Particle density	
	Mean ± SD	Range
Mullassery	$2.43^a \pm 0.19$	2.08 - 2.66
Cherpu	$2.39^a \pm 0.20$	2.11 - 2.65
Anthikkad	$2.43^a \pm 0.15$	2.11 - 2.64
Irinjalakkuda	$2.56^a \pm 0.19$	2.24 - 2.67
Puzhakkal	$2.33^a \pm 0.18$	2.05 - 2.63
Perumpadappu	$2.43^a \pm 0.14$	2.30 - 2.59
Ponnani	$2.43^a \pm 0.15$	2.13 - 2.65
CD = Non significant		

4.1.1.3. Porosity

Porosity of the soil samples varied from 44.34 per cent to 78.21 per cent. The highest mean (64.17 %) porosity was recorded in Mullassery block panchayat. It varied from 51.09 per cent (Annakkara vadakk) to 71 per cent (Elamutha). The lowest mean (57.26 %) was recorded in Anthikkad block panchayat. The porosity in Anthikkad block panchayat varied from 44.34 per cent (Arumuri) to 63.94 per cent (Chettupuzha east). In Cherpu block panchayat, the highest porosity was observed in Nerkathir (72.06 %) and lowest in Pallippuram *kole* padav (52.3 %). Porosity in Puzhakkal block panchayat ranged from 56.61 per cent (Sangham north *kole*) to 70.77 per cent (Pullazhi *kole*). In Perumpadappuu block panchayat, it varied between 50.25 to 69.25 per cent. Ponnani *kole* showed a wide variation ranging from 49.33 per cent (Panthavoor) to 78.21 per cent (Puzhangad *kole*). Porosity in Mullassery block panchayat was on par with Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani block panchayats (Table 4.3).

Table 4.3. Porosity (%) of soils in the block panchayat of AEU 6

Block panchayats	Porosity	
	Mean ± SD	Range
Mullassery	64.17[a] ± 6.54	51.09 - 71.00
Cherpu	64.26[a] ± 5.49	52.30 - 72.06
Anthikkad	57.26[a] ± 4.63	44.34 - 63.94
Irinjalakkuda	64.01[a] ± 6.83	54.11 - 75.74
Puzhakkal	65.23[a] ± 5.20	56.61 - 70.77
Perumpadappu	62.58[a] ± 7.64	50.25 - 69.25
Ponnani	62.57[a] ± 9.02	49.33 - 78.21
CD = Non significant		

4.1.1.4. Maximum water holding capacity

Maximum water holding capacity of the soil ranged from 28.11 per cent to 73.49 per cent. The highest mean (69.76 %) maximum water holding capacity was observed in Puzhakkal block panchayat. Maximum water holding capacity ranged from 49.17 per cent (Vadakke ponnur thazham) to 73.45 per cent (Ombathumuri 1) in Puzhakkal block panchayat. The lowest mean (51.23 %) was recorded from Mullassery block panchayat. It exhibited a range of 28.44 per cent (Pulipandi) to 62.95 per cent (Elamutha) in Mullassery block panchayat. Maximum water holding capacity showed a range of 48.76 per cent (Perumkulam east) to 71.29 per cent (Cheeyaram samajam) in Cherpu block panchayat. In Anthikkad block panchayat, it varied from 21.09 per cent (Chaladi pazhan *kole*) to 72.13 per cent (Jubilee thevar padav). Maximum water holding capacity varied from 33.96 per cent (Nedumbal) to 73.49 per cent (Painkili kayal) in Irinjalakkuda block panchayat. It exhibited a range of 28.11 per cent (Nadupotta *kole*) to 49.66 per cent (Kundamkuzhi 1) in Perumpadappu block panchayat. In Ponnani block panchayat, it varied from 32.92 per cent (Moochikkal kadavu 2) to 71.30 per cent (Puzhangad *kole*). Maximum water holding capacity of Mullassery, Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu block panchayats were on par with Ponnani block panchayat (Table 4.4).

Table 4.4. Maximum water holding capacity (%) of soils in the block panchayats of AEU 6

Block panchayats	Maximum water holding capacity	
	Mean ± SD	Range
Mullassery	51.24[a] ± 9.58	28.44 - 62.95
Cherpu	63.94[a] ± 17.48	48.76 - 71.29
Anthikkad	63.90[a] ± 16.31	21.09 - 72.13
Irinjalakkuda	65.55[a] ± 37.92	33.96 - 73.49
Puzhakkal	69.76[a] ± 19.67	49.17 - 73.45
Perumpadappu	62.87[a] ± 16.86	28.11 - 49.66
Ponnani	66.17[a] ± 27.21	32.92 - 71.36
CD = Non significant		

4.1.1.5. Soil moisture

The soil moisture content ranged from 12.00 per cent to 41.6 per cent. The highest mean (35.45 %) moisture content was recorded in Anthikkad block panchayat. Moisture content of soil samples of Anthikkad block panchayat ranged from 32 per cent (Variyam *kole* padavu) to 41.3 per cent (Themalippuram). The lowest mean of 17.49 per cent was recorded from Cherpu block panchayat. In Cherpu block panchayat, it varied from 12 per cent to 20.97 per cent. Soil moisture content varied between 21.90 to 38.38 per cent in Mullassery block panchayat, 27.88 to 40.60 per cent in Irinjalakkuda block panchayat, 20.70 to 36.00 per cent in Puzhakkal block panchayat, 19.10 to 40.30 per cent in Perumpadappu block panchayat, 26.50 to 41.60 per cent in Ponnani block panchayat. Soil moisture in Anthikkad and Irinjalakkuda were significantly different from other block panchayats. Soil moisture content recorded from Mullassery, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu block panchayats were on par with Ponnani block panchayat. There was no significant difference between the moisture content in Perumpadappu and Ponnani block panchayats (Table 4.5).

Table 4.5. Moisture content (%) of soils in the block panchayats of AEU 6

Block panchayats	Soil moisture	
	Mean ± SD	Range
Mullassery	$33.62^{ab} \pm 5.58$	21.90 - 38.80
Cherpu	$17.50^{d} \pm 4.63$	12.00 - 20.97
Anthikkad	$35.45^{a} \pm 6.02$	32.00 - 41.30
Irinjalakkuda	$35.09^{a} \pm 4.50$	27.88 - 40.60
Puzhakkal	$26.56^{c} \pm 5.50$	20.70 - 36.00
Perumpadappu	$29.62^{bc} \pm 9.19$	19.10 - 40.30
Ponnani	$30.51^{bc} \pm 6.47$	26.50 - 41.60
CD (0.01) = 6.77	CD (0.05) = 4.58	

4.1.1.6. Aggregate stability

Aggregate stability of soil was measured by mean weight diameter (mm). The highest soil mean weight diameter (MWD) was shown by Anthalachira in Ponnani block panchayat and the lowest by Pannikkarakin *kole* in Puzhakkal block panchayat. The highest mean (3.24 mm) for MWD was recorded from Mullassery block panchayat and the lowest mean (2.54 mm) was from Cherpu block panchayat. Mean weight diameter range shown in Mullassery, Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal and Ponnani block panchayats were from 1.93 mm (Parappadam west) to 5.87 mm (Kaniyamthuruth), 1.8 mm (Jubilee thevar padavu) to 3.63 mm (Nerkathir), 1.85 mm (Chaladipazhan *kole*) to 3.98 mm (Ayyappan *kole*), 1.95 mm (Chithravallipadam) to 4.01 mm (Koda *kole*), 0.70 mm (Pannikkarakin *kole*) to 3.83 mm (Ombathumuri 1), 2.01 mm (Arimbinkundu) to 4.39 mm (Irumbayil *kole*) and 2.22 mm (Moochikkal kadavu 2) to 6.95 mm (Anthalachira), respectively. Mean weight diameter in all the block panchayats were on par and no significant difference was observed between them (Table 4.6).

Table 4.6. Mean weight diameter (mm) of soils in the block panchayats of AEU 6

Block panchayats	Mean weight diameter	
	Mean ± SD	Range
Mullassery	3.24a ± 1.18	1.93 - 5.87
Cherpu	2.54a ± 0.54	1.80 - 3.63
Anthikkad	2.62a ± 0.57	1.85 - 3.98
Irinjalakkuda	2.96a ± 0.78	1.95 - 4.01
Puzhakkal	2.74a ± 0.77	0.70 - 3.83
Perumpadappu	2.82a ± 0.76	2.01 - 4.39
Ponnani	3.22a ± 1.20	2.22 - 6.95
CD = Non significant		

4.1.2. Chemical attributes

4.1.2.1. pH

The highest pH was observed in Pannikkara kin *kole* (6.35) of Puzhakkal block panchayat and the lowest in Arimbinkundu (3.51) of Perumpadappu block panchayat. The highest mean (5.21) was recorded from Cherpu block panchayat and the lowest mean (4.45) from Mullassery block panchayat. In Mullassery block panchayat, pH varied from 4.02 (Parappadam west) to 5.06 (Thanneerkayal). In Cherpu block panchayat, it extended from 3.61 (Perumkulam west) to 6.23 (Chovvoorthazham alukka padav). It showed a range of 3.97 (Pazhuvil bund *kole*) to 5.80 (Vilakkumadam padav) in Anthikkad block panchayat. Soil pH ranged from 3.94 (Parappookkara and Karpullithara kakkad) to 5.98 (Muriyad) in Irinjalakkuda block panchayat and from 4.1 (Pullazhi *Kole* 1) to 6.35 (Pannikkara kin *kole*) in Puzhakkal block panchayat, while in Perumpadappu block panchayat, pH varied from 3.51 (Arimbinkundu) to 6.13 (Mullamadu). In Ponnani block panchayat, it varied from 3.85 (Ponnani *kole* padavu 2) to 5.67 (Panthavoor 1). The pH recorded from Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani block panchayats were on par and it was significantly different from Mullassery block panchayat (Table 4.7).

Table 4.7. pH of soils in the block panchayats of AEU 6

Block panchayats	pH	
	Mean ± SD	Range
Mullassery	$4.46^{b} \pm 0.29$	4.02 - 5.06
Cherpu	$5.22^{a} \pm 0.78$	3.61 - 6.23
Anthikkad	$4.88^{a} \pm 0.81$	3.97 - 5.80
Irinjalakkuda	$5.01^{a} \pm 0.62$	3.94 - 5.98
Puzhakkal	$5.22^{a} \pm 0.72$	4.10 - 6.35
Perumpadappu	$4.96^{a} \pm 0.95$	3.51 - 6.13
Ponnani	$5.06^{a} \pm 0.58$	3.85 - 5.67
CD (0.05) = 0.395		

4.1.2.2. Electrical conductivity (EC)

Electrical conductivity in *kole* lands varied from 0.01 dS m^{-1} to 0.38 dS m^{-1}. The highest mean (15 dS m^{-1}) electrical conductivity was recorded in Mullassery block panchayat. In Mullassery block panchayat, electrical conductivity ranged from 0.09 dS m^{-1} (Kaniyamthuruth) to 0.27 dS m^{-1} (Pavudai). The lowest mean (0.05 dS m^{-1}) electrical conductivity was recorded in Irinjalakkuda block panchayat. In Cherpu block panchayat, electrical conductivity extended from 0.08 dSm^{-1} (Madhammathopp) to 0.03 dS m^{-1} (Pandaran *kole*). Electrical conductivity varied from 0.01 dS m^{-1} (Chennakari puncha) to 0.17 dS m^{-1} (Chettupuzha east) in Anthikkad block panchayat and 0.01 dS m^{-1} (Thekkumoola, Muriyaad, Kochipadam, Kadumkadu, Koda *kole*) to 0.07 dS m^{-1} (Kalladi thazham) in Irinjalakkuda block panchayat. In Puzhakkal block panchayat, it varied from 0.05 dS m^{-1} (Karikkin *kole*) to 0.08 dS m^{-1} (Pandaran *kole* 2, Sangham south *kole*, Pannikkara kin *kole*, Sangham north *kole*, Chirukandathu *kole* 1). In Perumpadappu block panchayat, electrical conductivity ranged from 0.05 dS m^{-1} (Nadupotta) to 0.015 dS m^{-1} (Irumbayil *kole*) and while in Ponnani block panchayat, it varied from 0.06 dS m^{-1} (Ponnani *Kole* padavu 2) to 0.38 dS m^{-1} (Anthalachira 2). Electrical conductivity recorded in Cherpu, Anthikkad, Puzhakkal and Ponnani block panchayats were on par. Electrical conductivity in Mullassery, Irinjalakkuda and Perumpadappu block panchayats were significantly different from other block panchayats. Electrical conductivity in different block panchayats were found significant both at 1 per cent and 5 per cent level of significance (Table 4.8).

Table 4.8. Electrical conductivity (dS m^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Electrical conductivity	
	Mean ± SD	Range
Mullassery	$0.15^{a} \pm 0.05$	0.09 - 0.27
Cherpu	$0.07^{bc} \pm 0.05$	0.03 - 0.08
Anthikkad	$0.06^{bc} \pm 0.02$	0.01 - 0.17
Irinjalakkuda	$0.05^{c} \pm 0.04$	0.01 - 0.07
Puzhakkal	$0.06^{bc} \pm 0.01$	0.05 - 0.08
Perumpadappu	$0.08^{b} \pm 0.05$	0.05 - 0.15
Ponnani	$0.06^{bc} \pm 0.25$	0.06 - 0.38
CD (0.01) = 0.05	CD (0.05) = 0.03	

4.1.2.3. Organic carbon

The highest (3.47 %) and the lowest (0.28 %) organic carbon content was recorded in soil samples collected from Perumpadappu block panchayat and Ponnani block panchayat respectively. The highest mean (1.21 %) was recorded from Irinjalakkuda block panchayat and the lowest (0.78 %) was from Mullassery block panchayat. In Mullassery block panchayat, organic carbon varied from 0.39 per cent (Penakam) to 1.31 per cent (Parappadam west). Organic carbon varied from 0.37 per cent (Perumkulam west) to 1.65 (Jubilee thevar padav) per cent in Cherpu block panchayat. In Anthikkad block panchayat, organic carbon content showed a variation from 0.42 per cent (Chettupuzha east) to 1.87 per cent (Chaladi pazhan *kole*) whereas in Irinjalakkuda block panchayat, it varied from 0.51 per cent (Chithravallipadam) to 2.2 per cent (Vellani *kole*). Soils collected from Puzhakkal block panchayat showed organic carbon ranging from 0.72 per cent (Karikkin *kole*) to 1.65 per cent (Pannikkara kin *kole*). In Perumpadappu block panchayat, organic carbon ranged from

0.61 per cent (Kundamkuzhi 2) to to 3.47 per cent (Irumbayil *kole*) and in Ponnani block panchayat, it was from 0.28 per cent (Ponnani *kole* padavu 1) to 2.89 per cent (Moochikkal kadavu 2). The organic carbon content in all the block panchayats were on par and there is no significant difference between block panchayats (Table 4.9).

Table 4.9. Organic carbon (%) of soils in the block panchayats of AEU 6

Block panchayats	Organic carbon	
	Mean ± SD	Range
Mullassery	$0.78^a \pm 0.33$	0.39 - 1.31
Cherpu	$1.00^a \pm 0.37$	0.37 - 1.65
Anthikkad	$1.18^a \pm 0.37$	0.42 - 1.87
Irinjalakkuda	$1.21^a \pm 0.48$	0.51 - 2.20
Puzhakkal	$1.02^a \pm 0.28$	0.72 - 1.65
Perumpadappu	$1.04^a \pm 0.84$	0.69 - 3.47
Ponnani	$1.11^a \pm 0.83$	0.28 - 2.89
CD = Non significant		

4.1.2.4. Exchangeable acidity

The lowest (0.05 cmol (+) kg^{-1}) exchangeable acidity was recorded from Irinjalakkuda, Puzhakkal and Ponnani block panchayats respectively and the highest (2.2 cmol (+) kg^{-1}) was from Ponnani block panchayat. The highest mean (1.14 cmol (+) kg^{-1}) was recorded from Puzhakkal block panchayat and the lowest mean (0.76 cmol (+) kg^{-1}) was from Mullassery block panchayat. The range of exchangeable acidity recorded were from 0.2 to 1.62 cmol (+) kg^{-1}, 0.17 to 1.53 cmol (+) kg^{-1}, 0.27 to 2.07 cmol (+) kg^{-1}, 0.05 to 1.42 cmol (+) kg^{-1}, 0.05 to 1.64 cmol (+) kg^{-1}, 0.05 to 1.83 cmol (+) kg^{-1} and 0.35 to 2.2 cmol (+) kg^{-1} in Mullassery, Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani block panchayats respectively. Exchangeable acidity in different block panchayats were significantly different at 5 per cent level of significance (Table 4.10).

Table 4.10. Exchangeable acidity (cmol (+) kg^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Exchangeable acidity	
	Mean ± SD	Range
Mullassery	$0.76^{c} \pm 0.45$	0.20 - 1.62
Cherpu	$0.89^{bc} \pm 0.51$	0.17 - 1.53
Anthikkad	$0.98^{ab} \pm 0.54$	0.27 - 2.07
Irinjalakkuda	$0.78^{bc} \pm 0.48$	0.05 - 1.42
Puzhakkal	$1.14^{a} \pm 0.41$	0.05 - 1.64
Perumpadappu	$0.91^{bc} \pm 0.67$	0.05 - 1.83
Ponnani	$0.94^{abc} \pm 0.53$	0.35 - 2.20
CD (0.05) = 0.21		

4.1.2.5. Available nitrogen

The highest available N was observed in Chaladi pazhan *kole* (1113.62 kg ha^{-1}) in Anthikkad block panchayat and the lowest in Manakkal padavu (92.13 kg ha^{-1}) in Cherpu block panchayat. The highest mean (811.08 kg ha^{-1}) was recorded from Irinjalakkuda and the lowest (479.50 kg ha^{-1}) was from Cherpu block panchayat. In Mullassery block panchayat, all the soil samples showed high available N and it ranged from 553.67 kg ha^{-1} (Cherotha akkarapadam) to 931.00 kg ha^{-1} (Thanneerkayal). In Cherpu block panchayat, the lowest available N was observed in Manakkal padavu (92.13 kg ha^{-1}) and the highest in Jubilee thevar padav (745.99 kg ha^{-1}). In Anthikkad block panchayat, the highest available N was found in Chaladi pazhan *kole* (1113.62 kg ha^{-1}) and the lowest in Chennakari puncha (612.38 kg ha^{-1}). Available N ranged from 644.2 kg ha^{-1} (Koda *kole*) to 972.91 kg ha^{-1} (Kochipadam) in Irinjalakkuda block panchayat and from 506.16 kg ha^{-1} (Vadakke ponnur thazham) to 942.63 kg ha^{-1} (Pannikkara kin *kole*) in Puzhakkal block panchayat, while in Perumpadappu block panchayat, available N showed a variation from 217.08 kg ha^{-1} (Nadupotta *kole*) to 1085.54 kg ha^{-1} (Maradi *kole* padavu) and in Ponnani block panchayat it varied from 364.92 kg ha^{-1} (Ponnani *kole* padavu 2) to 1033.04 kg ha^{-1}

(Puzhangad *kole*). In most of the soil samples, available nitrogen was high, but few soils showed low available N (Manakkal padavu, Karimbatta, Pallippuram *kole* padav, Nadupotta *kole*). Available nitrogen in Mullassery, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappuu and Ponnani block panchayats were on par and significantly different from Cherpu block panchayat (Table 4.11). Available nitrogen in all block panchayats was found significant at both 1 per cent and 5 per cent level of significance.

Table 4.11. Available nitrogen (kg ha^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Available nitrogen	
	Mean ± SD	Range
Mullassery	743.19^{a} ± 113.34	553.67 - 931.00
Cherpu	479.50^{b} ± 204.13	92.13 - 745.99
Anthikkad	795.22^{a} ± 196.17	612.38 - 1113.62
Irinjalakkuda	811.08^{a} ± 105.69	644.20 - 972.91
Puzhakkal	760.77^{a} ± 117.57	506.16 - 942.63
Perumpadappu	717.95^{a} ± 277.47	217.08 - 1085.54
Ponnani	754.67^{a} ± 227.75	364.92 - 1065.83
CD (0.01) = 174.51	CD (0.05) = 117.95	

4.1.2.6. Available phosphorus

Available P ranged from 2.17 kg ha^{-1} (Jubilee thevar padav) to 101.39 kg ha^{-1} (Peruvalloor padav). The highest mean (35.44 kg ha^{-1}) was recorded in Mullassery block panchayat. The range of available P varied from 9.28 to 101.39 kg ha^{-1} in Mullassery block panchayat. The lowest mean (9.47 kg ha^{-1}) was recorded from Irinjalakkuda block panchayat. Available P showed a range of 2.17 to 43.00 kg ha^{-1} in Cherpu block panchayat and 3.51 to 29.65 kg ha^{-1} in Anthikkad block panchayat. In Irinjalakkuda block panchayat, the highest available P was observed from Chemmanda kayal (17.89 kg ha^{-1}) and the lowest from Kadumkadu (2.23 kg ha^{-1}). In Puzhakkal block panchayat, available P varied from 12.71 kg ha^{-1} (Karikkin *kole*) to 22.43 kg ha^{-1} (Chirukandathu *kole* 1). The range of available P observed in

Perumpadappu block panchayat varied from 12.81 kg ha^{-1} (Arimbinkundu) to 40.55 kg ha^{-1} (Aana *kole* 2) and in Ponnani block panchayat, it varied from 12.56 kg ha^{-1} (Ponnani *kole* padavu 2) to 36.26 kg ha^{-1} (Panthavoor 2). Available phosphorus was found significant at both 1 per cent and 5 per cent level of significance. Available phosphorus in Mullassery block panchayat was found significantly different from other block panchayats. Available phosphorus in Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani block panchayats were on par (Table 4.12).

Table 4.12. Available phosphorus (kg ha^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Avialable phosphorus	
	Mean ± SD	Range
Mullassery	35.44^{a} ± 27.11	9.28 - 101.39
Cherpu	14.13^{b} ± 11.05	2.17 - 43.00
Anthikkad	14.05^{b} ± 8.94	3.51 - 29.65
Irinjalakkuda	9.47^{b} ± 6.60	2.23 - 17.89
Puzhakkal	14.27^{b} ± 4.58	12.71 - 22.43
Perumpadappu	17.47^{b} ± 4.48	12.81 - 40.55
Ponnani	13.72^{b} ± 9.24	12.56 - 36.26
CD (0.01) = 12.11	CD (0.05) = 8.18	

4.1.2.7. Available potassium

Available potassium varied from 30.42 kg ha^{-1} to 684.03 kg ha^{-1}. The highest mean of 224.22 kg ha^{-1} was observed in Cherpu block panchayat and the lowest mean of 107.5 kg ha^{-1} was observed in Puzhakkal block panchayat. In Cherpu block panchayat, the highest available potassium was observed in Kanimangalam *kole* padav (460.89 kg ha^{-1}) and the lowest in Avinissery samajam (72.99 kg ha^{-1}). Available potassium varied from 55.14 kg ha^{-1} (Arumuri) to 278.57 kg ha^{-1} (Themalippuram) in Anthikkad block panchayat whereas it was from 30.42 kg ha^{-1} (Vellani *kole*) to 405.96 kg ha^{-1}(Mothalakkulam) in Irinjalakkuda block panchayat. In Puzhakkal block panchayat, it varied from 81.58 kg ha^{-1} (Pullazhi *kole*) to 122.22 kg ha^{-1} (Kadavil *kole*). In Perumpadappu block panchayat, available K varied from 89.48 kg ha^{-1} (Kundamkuzhi) to 379.85 kg ha^{-1} (Aana *kole* 1). The highest available K was observed in Anthalachira (684.03 kg ha^{-1}) and the lowest in Ponnani *kole* padavu 2 (96.13 kg ha^{-1}) in Ponnani block panchayat. Available potassium in Mullassery, Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani block panchayats were on par (Table 4. 13) and there was no significant difference.

Table 4.13. Available potassium (kg ha^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Available potassium	
	Mean ± SD	Range
Mullassery	142.80^{a} ± 72.36	63.95 - 338.33
Cherpu	224.22^{a} ± 123.20	72.99 - 460.89
Anthikkad	177.56^{a} ± 70.65	55.14 - 278.57
Irinjalakkuda	111.93^{a} ± 92.41	30.42 - 405.96
Puzhakkal	107.50^{a} ± 13.92	81.58 - 122.22
Perumpadappu	152.80^{a} ± 85.15	89.48 - 379.85
Ponnani	136.37^{a} ± 184.03	96.13 - 684.03
CD = Non significant		

4.1.2.8. Available calcium

The highest available calcium was recorded from Anthalachira (1600.92 mg kg^{-1}) in Ponnani block panchayat and the lowest was from Kodannur *kole* farming society (5.29 mg kg^{-1}) in Cherpu block panchayat. The highest mean (487.56 mg kg^{-1}) was observed in Anthikkad block panchayat. The lowest mean (242.51 mg kg^{-1}) was observed in Cherpu block panchayat. In Anthikkad block panchayat, available calcium varied from 170.52 mg kg^{-1} (Manaloorthazham) to 863.71 mg kg^{-1} (Pullu) and it varied from 5.29 mg kg^{-1} (Kodannur *kole* farming society) to 403.42 mg kg^{-1} (Karimbatta) in Cherpu block panchayat. In Mullassery block panchayat, it showed a range of 213.95 mg kg^{-1} (Peruvalloor padav) to 575.98 mg kg^{-1} (Elamutha). The highest available calcium in Irinjalakkuda block panchayat was recorded from

Chemmanda kayal (935.9 mg kg^{-1}) and the lowest was from Konthikulam (227.59 mg kg^{-1}). In Puzhakkal, Perumpadappu and Ponnani block panchayats, available calcium showed a range of 281.97 mg kg^{-1} (Ombathumuri 1) to 479.23 mg kg^{-1} (Chirukandathu *kole* 1), 178.28 mg kg^{-1} (Irumbayil *kole*) to 1112.23 mg kg^{-1} (Mullamadu), 213.15 mg kg^{-1} (Ponnani *kole* padavu 2) to 1600.92 mg kg^{-1} (Anthalachira) respectively. There was no significance difference in available calcium among the block panchayats (Table 4.14).

Table 4.14. Available calcium (mg kg^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Available calcium	
	Mean ± SD	Range
Mullassery	308.10^{a} ± 91.53	213.95 - 575.98
Cherpu	242.51^{a} ± 110.27	5.29 - 403.42
Anthikkad	487.55^{a} ± 196.41	170.52 - 863.71
Irinjalakkuda	399.05^{a} ± 217.29	227.59 - 935.90
Puzhakkal	376.60^{a} ± 55.46	281.97 - 479.23
Perumpadappu	362.77^{a} ± 262.20	178.28 - 1112.23
Ponnani	394.52^{a} ± 406.63	213.15 - 1600.92
CD = Non significant		

4.1.2.9. Available magnesium

Available magnesium in *kole* lands varied from 3.61 mg kg^{-1} to 374.46 mg kg^{-1}. The highest mean of 131.55 mg kg^{-1} was recorded from Anthikkad block panchayat and the lowest mean of 40.36 mg kg^{-1} was from Cherpu block panchayat. The range of available magnesium in Mullassery, Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani block panchayats were 73.26 to 224.6 mg kg^{-1}, 3.61 to 103.2 mg kg^{-1}, 11.12 to 236.35 mg kg^{-1}, 45.36 to 334.70 mg kg^{-1}, 30.19 to 49.38 mg kg^{-1}, 46.15 to 104.69 mg kg^{-1} and 27.70 to 274.46 mg kg^{-1} respectively. There was no significant difference found among block panchayats in available magnesium (Table 4.15).

Table 4.15. Available magnesium (mg kg^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Available magnesium	
	Mean ± SD	Range
Mullassery	116.76^{a} ± 47.09	73.26 - 224.60
Cherpu	58.47^{a} ± 51.13	3.61 - 103.20
Anthikkad	131.55^{a} ± 116.74	11.12 - 236.35
Irinjalakkuda	105.98^{a} ± 175.60	45.36 - 334.70
Puzhakkal	40.36^{a} ± 30.12	30.19 - 49.38
Perumpadappu	79.50^{a} ± 54.39	46.15 - 104.69
Ponnani	104.90^{a} ± 108.95	27.7 - 274.46
CD = Non significant		

4.1.2.10. Available sulphur

Available sulphur varied from 4.46 mg kg^{-1} to 53.16 mg kg^{-1}. The highest mean (24.96 mg kg^{-1}) was observed in Perumpadappu block panchayat. The lowest mean of 9.10 mg kg^{-1} was recorded in Cherpu block panchayat. In Mullassery block panchayat, available sulphur varied from 4.91 mg kg^{-1} (Kaniyamthuruth) to 16.95 mg kg^{-1} (Parappadam kizhakkethala). In Cherpu block panchayat, available sulphur was high in Chovvoorthazham alukka padav (21.67 mg kg^{-1}) and low in Manakkal padavu (4.46 mg kg^{-1}). In Anthikkad block panchayat, it varied from 8.69 mg kg^{-1} (Manaloorthazham) to 29.67 mg kg^{-1} (Themalippuram) and in Irinjalakkuda block panchayat, it varied from 5.51 mg kg^{-1} (Chithravallipadam) to 19.68 mg kg^{-1} (Konthikulam). In Puzhakkal block panchayat, it ranged from 4.81 mg kg^{-1} (Vadakke ponnur thazham) to 21.58 mg kg^{-1} (Sangham south *kole*). The range of available sulphur in Perumpadappu block panchayat was from 4.97 mg kg^{-1} (Maradi *kole* padav, maranchery) to 17.00 mg kg^{-1} (Kolothupadavu 1) and in Ponnani block panchayat, it was from 4.65 mg kg^{-1} (Ponnani *kole* padavu) to 53.16 mg kg^{-1} (Puzhangad *kole*). Available sulphur in all block panchayats was found to be significant at both 1 per cent and 5 per cent level of significance. Available sulphur in Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal and Ponnani block panchayats were on par (Table 4.16).

Table 4.16. Available sulphur (mg kg^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Available sulphur	
	Mean ± SD	Range
Mullassery	9.72^{a} ± 16.82	4.91 – 16.95
Cherpu	9.10^{c} ± 7.84	4.46 - 21.67
Anthikkad	12.53^{c} ± 6.07	8.69 - 29.67
Irinjalakkuda	10.10^{c} ± 4.80	5.51 - 19.68
Puzhakkal	10.08^{c} ± 5.04	4.81 - 21.58
Perumpadappu	24.96^{b} ± 2.85	4.97 - 17.00
Ponnani	11.26^{c} ± 12.74	4.65 - 53.16
CD (0.01) = 9.78	CD (0.05) = 6.61	

4.1.2.11. Available iron

The available iron content ranged from 15.06 mg kg^{-1} to 3851.06 mg kg^{-1}. The highest mean (1571.16 mg kg^{-1}) was recorded from Puzhakkal block panchayat and the lowest mean (100.45 mg kg^{-1}) was from Mullassery block panchayat. In Mullassery block panchayat available iron varied from 33.35 mg kg^{-1} (Mathukkara thekk) to 187.46 mg kg^{-1} (Elavathur). In Cherpu block panchayat, available iron varied from 15.06 mg kg^{-1} (Karimbatta) to 1077.05 mg kg^{-1} (Cheeyaram samajam). In Anthikkad block panchayat, available iron ranged from 33.68 mg kg^{-1} (Pullu) to 686.2 mg kg^{-1} (Themalippuram). In Irinjalakkuda block panchayat, it ranged from 48.75 mg kg^{-1} (Chemmanda kayal) to 2930.72 mg kg^{-1} (Kochipadam). The highest available iron in Puzhakkal block panchayat was found from Sangham north *kole* (3312.83 mg kg^{-1}) and the lowest from Pandaran *kole* 1 (101.75 mg kg^{-1}). In Perumpadappu and Ponnani block panchayats, available iron ranged from 98.76 mg kg^{-1} (Nadupotta *kole*) to 3361.26 mg kg^{-1} (Kundamkuzhi 2) and from 195.8 mg kg^{-1} (Puzhangad *kole* 1) to 3851.06 mg kg^{-1} (Kanniyamkayal) respectively. Available iron in all blocks was found significant at both 1 per cent and 5 per cent level of significance. Available iron in Mullassery, Cherpu and Anthikkad were on par (Table 4.17).

Table 4.17. Available iron (mg kg^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Available iron	
	Mean ± SD	Range
Mullassery	100.45^{d} ± 49.57	33.35 - 187.46
Cherpu	208.71^{d} ± 303.07	15.06 - 1077.05
Anthikkad	204.10^{d} ± 181.51	33.68 - 686.20
Irinjalakkuda	808.97^{bc} ± 1170.60	48.75 - 2930.72
Puzhakkal	1571.16^{a} ± 1544.12	101.75 - 3312.83
Perumpadappu	578.86^{cd} ± 1320.36	98.76 - 3361.26
Ponnani	1111.59^{ab} ± 943.25	195.80 - 3851.06
CD (0.01) = 716.22	CD (0.05) = 484.10	

4.1.2.12. Available manganese

The available manganese content ranged from 3.20 mg kg^{-1} to 73.76 mg kg^{-1}. The highest mean (28.75 mg kg^{-1}) was observed in Irinjalakkuda block panchayat and the lowest mean (12.56 mg kg^{-1}) was in Mullassery block panchayat. The highest available manganese in Mullassery block panchayat was found from Elavathur (19.25 mg kg^{-1}) and the lowest from Kaniyamthuruth (4.47 mg kg^{-1}). Available manganese in Cherpu block panchayat varied from 4.28 mg kg^{-1} (Kanimangalam *kole* padav) to 51.40 mg kg^{-1} (Kizhakkan *kole* padavu). In Anthikkad block panchayat, available manganese ranged from 4.12 mg kg^{-1} (Chaladi pazhan *kole*) to 73.76 mg kg^{-1} (Manaloorthazham). In Irinjalakkuda block panchayat, it ranged from 4.98 mg kg^{-1} (Kalladi thazham) to 57.32 mg kg^{-1} (Karppullithara kakkad). The highest available manganese in Puzhakkal block panchayat was found from Sangham north *kole* (37.30 mg kg^{-1}) and the lowest from Kadavil *kole* (9.66 mg kg^{-1}). In Perumpadappu block panchayat, available manganese ranged from 3.20 mg kg^{-1} (Nadupotta *kole*) to 57.42 mg kg^{-1} (Mullamadu), while in Ponnani block panchayat, it varied from 2.47 mg kg^{-1}

(Ponnani *kole* padavu 2) to 40.95 mg kg^{-1} (Panthavoor 2). There was no significant difference in available manganese in all the block panchayats (Table 4.18).

Table 4.18. Available manganese (mg kg^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Available manganese	
	Mean ± SD	Range
Mullassery	12.56^a ± 5.96	4.47 - 19.25
Cherpu	16.00^a ± 16.05	4.28 - 51.40
Anthikkad	19.07^a ± 16.94	4.12 - 73.76
Irinjalakkuda	28.75^a ± 24.26	4.98 - 57.32
Puzhakkal	22.72^a ± 10.52	9.66 - 37.30
Perumpadappu	19.82^a ± 16.36	3.20 - 57.42
Ponnani	17.87^a ± 12.07	2.47 - 40.95
CD = Non significant		

4.1.2.13. Available zinc

Available zinc ranged from 1.02 mg kg^{-1} to 9.93 mg kg^{-1}. The highest mean of 4.52 mg kg^{-1} was found in Puzhakkal block panchayat and the lowest mean of 1.68 mg kg^{-1} in Cherpu block panchayat. The range of available Zn varied from 1.04 to 3.14 mg kg^{-1} in Mullassery block panchayat, 1.05 to 2.95 mg kg^{-1} in Cherpu block panchayat and 1.03 to 6.83 mg kg^{-1} in Anthikkad block panchayat. The highest available Zn was observed from Karppullithara kakkad (9.37 mg kg^{-1}) and the lowest from Koda *kole* (1.08 mg kg^{-1}) in Irinjalakkuda block panchayat. In Puzhakkal block panchayat, available Zn varied from 1.24 mg kg^{-1} (Kadavil *kole*) to 9.93 mg kg^{-1} (Sangham north *kole*). The range of available Zn observed in Perumpadappu block panchayat varied from 1.02 mg kg^{-1} (Maradi *kole* padav, maranchery) to 3.59 mg kg^{-1} (Aana *kole* 2) and in Ponnani block panchayat, it varied from 1.28 mg kg^{-1} (Moochikkal kadavu 2) to 4.74 mg kg^{-1} (Ponnani *kole* padavu). Available Zn was found significant among all block panchayats at 5 per cent level of significance. It is found that available zinc in Mullassery block panchayat was on par with Cherpu, Anthikkad, Irinjalakkuda, Perumpadappuu and Ponnani block panchayats (Table 4.19).

Table 4.19. Available zinc (mg kg^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Available zinc	
	Mean ± SD	Range
Mullassery	1.97^{cd} ± 0.68	1.04 - 3.14
Cherpu	1.68^{d} ± 0.74	1.05 - 2.95
Anthikkad	2.72^{bcd} ± 1.53	1.03 - 6.83
Irinjalakkuda	3.38^{ab} ± 2.11	1.08 - 9.37
Puzhakkal	4.52^{a} ± 3.32	1.24 - 9.93
Perumpadappu	2.85^{bcd} ± 1.85	1.02 - 3.59
Ponnani	3.04^{bc} ± 0.61	1.28 - 4.74
CD (0.05) = 1.27		

4.1.2.14. Available copper

The available Cu content ranged from 0.44 mg kg^{-1} to 14.77 mg kg^{-1}. The highest mean (4.03 mg kg^{-1}) was recorded from Mullassery block panchayat and the lowest (1.88 mg kg^{-1}) was in Puzhakkal block panchayat. Available Cu in Mullassery block panchayat varied from 1.87 mg kg^{-1} (Pulipandi) to 6.50 mg kg^{-1} (Parappadam west). Available Cu in Cherpu block panchayat varied from 0.58 mg kg^{-1} (Kanimangalam *kole* padav) to 3.85 mg kg^{-1} (Avinissery samajam). In Anthikkad block panchayat, available Cu ranged from 1.29 mg kg^{-1} (Chaladi pazhan *kole*) to 6.66 mg kg^{-1} (Vilakkumadam padav). In Irinjalakkuda block panchayat, it ranged from 0.45 mg kg^{-1} (Kochipadam) to 5.04 mg kg^{-1} (Parappookkara). Available Cu in Puzhakkal block panchayat extended from 0.46 mg kg^{-1} (Ombathumuri 1) to 5.00 mg kg^{-1} (Chirukandathu *kole*). In Perumpadappu block panchayat, available Cu varied from 0.65 mg kg^{-1} (Kundamkuzhi 2) to 14.77 mg kg^{-1} (Kolothupadavu 1). In Ponnani block panchayat, available Cu ranged from 0.44 mg kg^{-1} (Kanniyamkayal) to 4.79 mg kg^{-1} (Panthavoor 1). Available copper was found significant at both 1 per cent and 5 per cent level of significance. Available Cu in Mullassery block panchayat was found on par with other block panchayats (Table 4.20).

Table 4.20. Available copper (mg kg^{-1}) of soils in the block panchayat of AEU 6

Block panchayats	Available copper	
	Mean ± SD	Range
Mullassery	$4.03^{a} \pm 1.30$	1.87 - 6.50
Cherpu	$1.89^{d} \pm 1.04$	0.58 - 3.85
Anthikkad	$3.69^{ab} \pm 1.41$	1.29 - 6.66
Irinjalakkuda	$3.23^{abc} \pm 1.41$	0.45 - 5.04
Puzhakkal	$1.88^{d} \pm 1.67$	0.46 - 5.00
Perumpadappu	$2.94^{bc} \pm 4.13$	0.65 - 14.77
Ponnani	$2.48^{cd} \pm 3.91$	0.44 - 4.79
CD (0.01) = 1.41	CD (0.05) = 0.95	

4.1.2.15. Available boron

Available B was found deficient in all the soil samples. The highest available B was recorded from Chithravallipadam (0.27 mg kg^{-1}) in Irinjalakkuda block panchayat and the lowest in Elamutha (0.01 mg kg^{-1}) of Mullassery block panchayat. The highest mean (0.10 mg kg^{-1}) was observed in Anthikkad block panchayat and the lowest mean (0.07 mg kg^{-1}) was from Puzhakkal and Cherpu block panchayats. In Mullassery block panchayat, available B ranged from 0.01 mg kg^{-1} (Elamutha) to 0.15 mg kg^{-1} (Pavudai). Available B varied from 0.02 mg kg^{-1} (Perumkulam east, Nerkathir) to 0.25 mg kg^{-1} (Kizhakkan *kole* padavu) in Cherpu block panchayat and it varied from 0.02 mg kg^{-1} (Themalippuram) to 0.29 mg kg^{-1} (Chaladi pazhan *kole*) in Anthikkad block panchayat. In Irinjalakkuda block panchayat, it varied from 0.04 mg kg^{-1} (Chemmanda kayal, Kalladi thazham, Parappookkara) to 0.27 mg kg^{-1} (Chithravallipadam). Available B varied from 0.02 mg kg^{-1} (Vadakke ponnur thazham) to 0.18 mg kg^{-1} (Pandaran *kole* 1) in Puzhakkal block panchayat, from 0.05 mg kg^{-1} (Aana *kole* 1, Maradi *kole* padavu) to 0.19 mg kg^{-1} (Kolothupadavu 2) in Perumpadappu block panchayat and from 0.06 mg kg^{-1} (Ponnani *kole* padavu 3) to

0.12 mg kg^{-1} (Kanniyamkayal 1) in Ponnani block panchayat. It was found that there was no significant difference in available boron among the block panchayats (Table 4.21).

Table 4.21. Available boron (mg kg^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Available boron	
	Mean ± SD	Range
Mullassery	$0.09^a \pm 0.04$	0.01 - 0.15
Cherpu	$0.07^a \pm 0.05$	0.02 - 0.25
Anthikkad	$0.10^a \pm 0.06$	0.02 - 0.29
Irinjalakkuda	$0.09^a \pm 0.07$	0.04 - 0.27
Puzhakkal	$0.07^a \pm 0.04$	0.02 - 0.18
Perumpadappu	$0.08^a \pm 0.04$	0.05 - 0.19
Ponnani	$0.08^a \pm 0.04$	0.06 - 0.12
CD = Non significant		

4.1.2.16. Effective cation exchange capacity (ECEC)

The ECEC ranged from 0.62 cmol (+) kg^{-1} to 9.00 cmol (+) kg^{-1}. The highest mean of 3.95 cmol (+) kg^{-1} was recoded in Mullassery block panchayat and the lowest mean of 2.77 cmol (+) kg^{-1} in Irinjalakkuda block panchayat. The highest ECEC in Mullassery block panchayat was found from Thanneerkayal and Pulipandi (7.03 cmol (+) kg^{-1}) and the lowest from Elamutha (2.82 cmol (+) kg^{-1}). Effective cation exchange capacity in Cherpu block panchayat varied from 2.49 cmol (+) kg^{-1} (Manakkal padavu) to 4.51 cmol (+) kg^{-1} (Cheeyaram samajam, Pandaran *kole*). In Anthikkad block panchayat, it ranged from 1.55 cmol (+) kg^{-1} (Chettupuzha east) to 6.28 cmol (+) kg^{-1} (Pazhuvil bund *kole*). In Irinjalakkuda block panchayat, ECEC ranged from 0.62 cmol (+) kg^{-1} (Chemmanda kayal) to 4.09 cmol (+) kg^{-1} (Kalladi thazham). The ECEC in Puzhakkal block panchayat varied from 2.25 cmol (+) kg^{-1} (Ombathumuri 2) to 4.42 cmol (+) kg^{-1} (Pandaran *kole* 1and 2). In Perumpadappuu block panchayat, ECEC varied from 2.86 cmol (+) kg^{-1} (Kundamkuzhi 2) to 4.93 cmol (+) kg^{-1} (Kolothupadavu). In Ponnani block panchayat, ECEC ranged from 2.68

cmol (+) kg^{-1} (Panthavoor 1) to 9 cmol (+) kg^{-1} (Kanniyamkayal 1). There was no significant difference in ECEC among the block panchayats (Table 4.22).

Table 4.22. Effective cation exchange capacity (cmol (+) kg^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Effective cation exchange capacity	
	Mean ± SD	Range
Mullassery	$3.95^a \pm 1.07$	2.82 - 7.03
Cherpu	$3.91^a \pm 1.06$	2.49 - 4.51
Anthikkad	$3.73^a \pm 1.11$	1.55 - 6.28
Irinjalakkuda	$2.77^a \pm 0.99$	0.62 - 4.09
Puzhakkal	$2.83^a \pm 0.62$	2.25 - 4.42
Perumpadappu	$3.63^a \pm 0.75$	2.86 - 4.93
Ponnani	$3.88^a \pm 1.60$	2.68 - 9.00
CD = Non significant		

4.1.3. Biological attributes

4.1.3.1. Dehydrogenase activity

Dehydrogenase activity ranged from 65.54 µg TPF g^{-1} 24 hr^{-1} to 1909.59 µg TPF g^{-1} 24 hr^{-1}. The highest mean (873.58 µg TPF g^{-1} 24 hr^{-1}) was in Irinjalakkuda block panchayat and the lowest mean (364.33 µg TPF g^{-1} 24 hr^{-1}) was in Mullassery block panchayat. In Mullassery block panchayat, the highest dehydrogenase activity was recorded from Kaniyamthuruth (1040.51 µg TPF g^{-1} 24 hr^{-1}) and the lowest dehydogenase activity was in Parappadam west (65.54 µg TPF g^{-1} 24 hr^{-1}). The lowest dehydrogenase activity in Cherpu block panchayat was exhibited by Chovvoorthazham alukka padav (79.26 µg TPF g^{-1} 24 hr^{-1}) and the highest in Cheeyaram samajam (1081.73 µg TPF g^{-1} 24 $hr^{-1)}$. Dehydrogenase activity of Anthikkad block panchayat was ranged from 244.78 µg TPF g^{-1} 24 hr^{-1} (Jubilee thevar padav) to 1315.96 µg TPF g^{-1} 24 hr^{-1} (Ayyappan *kole*). Soil samples from Irinjalakkuda block panchayat showed variation of dehydrogenase activity from 104.58 µg TPF g^{-1} 24 hr^{-1} (Chemmanda kayal) to 1909.59 µg TPF g^{-1} 24 hr^{-1}

(Mothalakkulam). The lowest dehydrogenase activity in Puzhakkal block panchayat was indicated by Chirukandathu *kole* 2 (274.91 µg TPF g^{-1} 24 hr^{-1}) and the highest in Pannikkara kin *kole* (1147.82 µg TPF g^{-1} 24 hr^{-1}). In Perumpadappu block panchayat, dehydrogenase activity ranged from 66.69 µg TPF g^{-1} 24 hr^{-1} (Maradi *kole* padavu) to 1358.93 µg TPF g^{-1} 24 hr^{-1} (Arimbinkundu). In Ponnani block panchayat, it varied from 147.06 µg TPF g^{-1} 24 hr^{-1} (Ponnani *kole* padavu 2) to 784.8 µg TPF g^{-1} 24 hr^{-1} (Kanniyamkayal 1). There was no significant difference in dehydrogenase activity in different block panchayats (Table 4.23).

Table 4.23. Dehydrogenase activity (µg TPF g^{-1} 24 hr^{-1}) of soils in the block panchayats of AEU 6

Block panchayats	Dehydrogenase activity	
	Mean ± SD	Range
Mullassery	364.33^{a} ± 266.96	65.54 - 1040.51
Cherpu	535.07^{a} ± 305.04	79.26 - 1081.73
Anthikkad	766.59^{a} ± 392.83	244.78 - 1315.96
Irinjalakkuda	873.58^{a} ± 536.14	104.58 - 1909.59
Puzhakkal	721.72^{a} ± 373.53	274.91 - 1147.82
Perumpadappu	652.23^{a} ± 365.17	66.69 - 1358.93
Ponnani	744.04^{a} ± 256.41	147.06 - 784.80
CD = Non significant		

4.1.3.2. Microbial biomass carbon

Microbial biomass carbon content ranged from 6.47 µg g^{-1} soil to 383.26 µg g^{-1} soil. The highest mean (280.29 µg g^{-1} soil) was seen in Mullassery block panchayat and the lowest mean (110.81 µg g^{-1} soil) was in Cherpu block panchayat. The highest microbial biomass carbon in Mullassery block panchayat was found from Pavudai (383.26 µg g^{-1} soil) and the lowest from Parappadam west (158.01 µg g^{-1} soil). Microbial biomass carbon in Cherpu block panchayat varied from 12.62 µg g^{-1} soil (Kodannur *kole* farming society) to 199.3 µg g^{-1} soil (Perumkulam west). In Anthikkad block panchayat, microbial biomass carbon ranged from 31.89 µg g^{-1} soil

(Chettupuzha east) to 269.44 µg g^{-1} soil (Variyam *kole* padav). In Irinjalakkuda block panchayat, it ranged from 6.47 µg g^{-1} soil (Kalladi thazham) to 224.72 µg g^{-1} soil (Kadumkadu). The highest microbial biomass carbon content in Puzhakkal block panchayat was found from Kadavil *kole* (289.06 µg g^{-1} soil) and the lowest from Sangham north *kole* (62.19 µg g^{-1} soil). In Perumpadappu block panchayat, it varied from 32.97 µg g^{-1} soil (Kolothupadavu 1) to 374.98 µg g^{-1} soil (Aana *kole* 1). In Ponnani block panchayat, it ranged from 15.51 µg g^{-1} soil (Moochikkal kadavu) to 341.35 µg g^{-1} soil (Puzhangad *kole* 1). Microbial biomass carbon in different block panchayats were significantly different at both 1 per cent and 5 per cent level of significance. Microbial biomass carbon in Ponnani block panchayat was on par with Cherpu, Anthikkad, Irinjalakkuda, Puzhakkal and Perumpadappu block panchayats (Table 4.24).

Table 4.24. Microbial biomass carbon (µg g^{-1} soil) of soils in the block panchayats of AEU 6

Block panchayats	Microbial biomass carbon	
	Mean ± SD	Range
Mullassery	280.29^{a} ± 80.22	158.01 - 383.26
Cherpu	110.81^{b} ± 55.32	12.62 - 199.30
Anthikkad	157.40^{b} ± 54.77	31.89 - 269.44
Irinjalakkuda	123.63^{b} ± 69.58	6.47 - 224.72
Puzhakkal	129.48^{b} ± 74.13	62.19 - 289.06
Perumpadappu	160.32^{b} ± 81.41	32.97- 374.98
Ponnani	160.34^{b} ± 113.45	15.51 - 341.35
CD (0.01) = 92.86	CD (0.05) = 62.77	

4.2. COMPUTATION OF SOIL QUALITY INDEX

4.2.1. Development of minimum data set

Principal component analysis (PCA) was carried out with 24 soil variables to derive a suitable minimum data set. The variables included bulk density, particle density, porosity, maximum water holding capacity, soil moisture, aggregate stability, pH, electrical conductivity (EC), organic carbon, effective cation exchange capacity (ECEC), exchangeable acidity, available N, P, K, Ca, Mg, S, B, Fe, Mn, Zn, Cu, dehydrogenase activity and microbial biomass carbon (MBC).

The analysis of variables by principal component analysis resulted in eight principal components (PCs) (Table 4.25) and only the highly weighted variables, factor loading within 10 per cent of the absolute values of the highest factor loading, were retained from each PC for the MDS. Thus the variables *viz*., available Ca, available S, available N, porosity, exchangeable acidity, available Fe, available Zn, particle density, available B were selected for MDS (Table 4.26).

Table 4.25. Results of principal component analysis (PCA)

Particulars	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Eigen value	3.39	2.95	2.31	2.03	1.66	1.53	1.31	1.09
Variance (%)	14.14	12.32	9.66	8.48	6.95	6.38	5.48	5.03
Cumulative variance (%)	14.14	26.46	36.12	44.60	51.55	57.93	63.41	68.44
Factor loadings								
Bulk density	-.036	-.042	-.037	-.944	-.004	-.003	.215	.021
Particle density	-.001	-.119	.078	-.148	-.122	.026	.707	.128
Porosity	.025	.041	.079	.948	-.016	.025	-.015	-.072
Maximum water holding capacity	.111	-.142	.092	.173	-.187	.323	-.502	-.238
Aggregate stability	.509	.290	-.221	.089	.028	.063	.096	.145
Soil moisture	.306	.098	.785	.090	-.020	.048	.204	.017
pH	-.089	-.296	-.113	-.014	-.306	.052	-.543	.310

EC	.707	.172	.001	.130	.429	-.119	.063	.074
Organic carbon	.083	-.422	.428	.196	.242	-.248	-.172	.112
Exchangeable acidity	.010	-.131	.216	-.059	.823	.172	-.070	-.039
Available N	.042	-.070	.825	.082	.079	.196	.058	-.072
Available P	-.032	.695	.043	.080	.064	-.181	-.114	.029
Available K	.627	-.163	-.146	.082	.369	-.277	.011	.203
Available Ca	.812	-.105	.195	-.127	-.061	.045	-.102	-.114
Available Mg	.714	-.016	.320	.021	.006	-.067	-.023	-.149
Available S	.020	.781	.190	.252	.011	-.061	.123	.023
Available B	-.028	.073	.001	-.060	.014	-.026	.152	.797
Available Fe	-.074	-.105	-.200	-.080	.264	.733	.063	-.056
Available Mn	.117	-.243	.201	-.053	-.086	.527	-.116	.542
Available Cu	-.142	.186	.630	-.088	.027	-.375	-.121	.183
Available Zn	-.144	-.108	.134	.096	.021	.790	-.123	.081
ECEC	.236	.071	-.064	.014	.806	.056	.099	.004
MBC	.141	.667	-.054	-.129	-.293	-.048	.201	.067
Dehydrogenase activity	.025	-.559	.136	.191	-.216	.165	.315	.214

Table 4.26. Minimum data set (MDS)

PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Avail. Ca	Avail. S	Avail. N	Porosity	Ex. acidity	Avail. Fe Avail. Zn	Particle density	Avail. B

4.2.2. Scoring of MDS indicators

The MDS variables were normalised using non linear scoring functions, *viz*., more is better, less is better and optimum functions where scores ranged from 0 to 1 and the indicators in MDS were transformed in to unitless data (Table 4.27).

4.2.2.1 More is better function

This function was used for attributes like available calcium (Fig. 4.1), available sulphur (Fig. 4.2), available nitrogen (Fig. 4.3), available zinc (Fig. 4.4) and available boron (Fig. 4.5), since they influence soil quality in a positive manner. Non linear scoring for 'more is better' function was carried out using the formula put forward by Bastida *et al.* (2006) and Raiesi (2017).

$$S_{NL} = a/(1 + \left(\frac{X}{Xm}\right)^b)$$

Where S_{NL} is the non linear score, 'a' is the maximum score 1, X is the value of soil indicator, X_m is the mean value of each indicator and b is the slope of the curve. Slope of curve is set as -2.5 for more is better function.

4.2.2.2 Less is better function

This function was used for variables like exchangeable acidity (Fig. 4.6) and available iron (Fig. 4.7). Since available iron was in toxic level in most of the soil samples, less is better function was used.

$$S_{NL}= a/(1 + \left(\frac{X}{Xm}\right)^b)$$

Where S_{NL} is the non linear score, 'a' is the maximum score 1, X is the value of soil indicator, X_m is the mean value of each indicator and b is the slope of the curve. Slope of curve is set as 2.5 for less is better function.

4.2.2.3 Optimum function

This function was used for particle density (Fig. 4.8) and porosity (Fig. 4.9). For optimum function scoring, equation of "more is better" and "less is better" was used jointly in decreasing and increasing part of curve respectively.

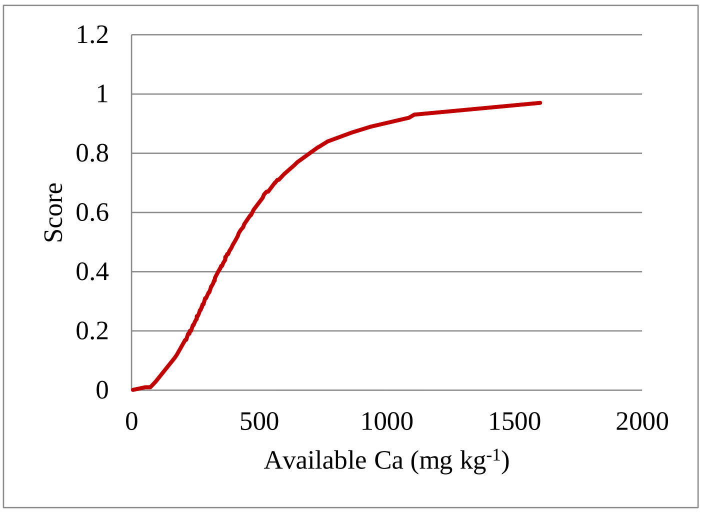

Fig. 4.1. More is better curve of available Ca

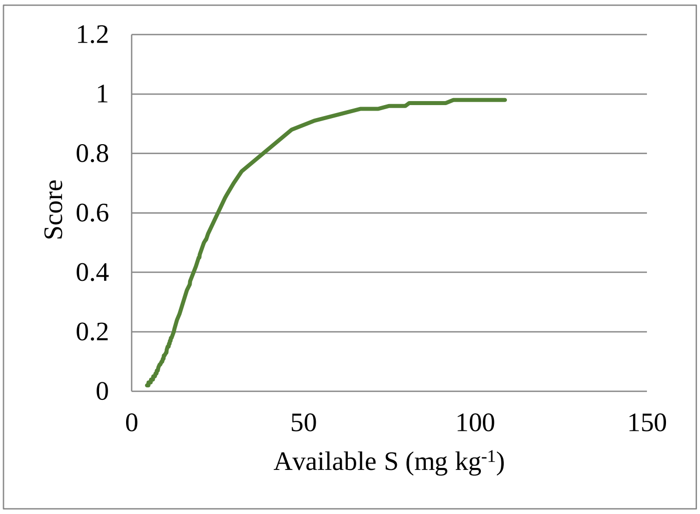

Fig. 4.2. More is better curve of available S

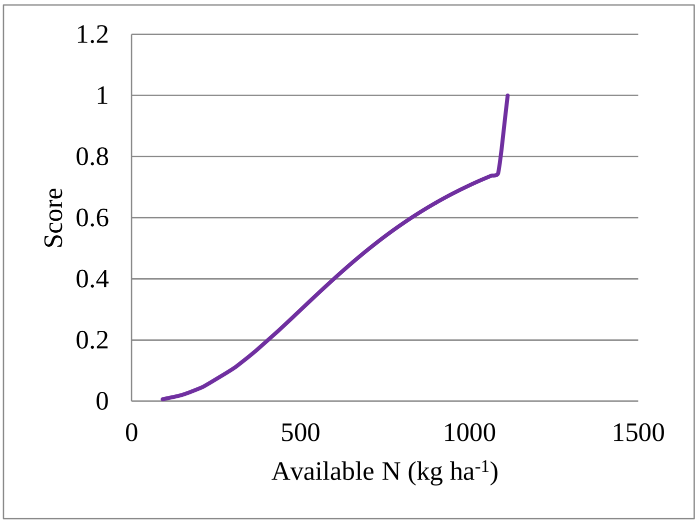

Fig. 4.3. More is better curve of available N

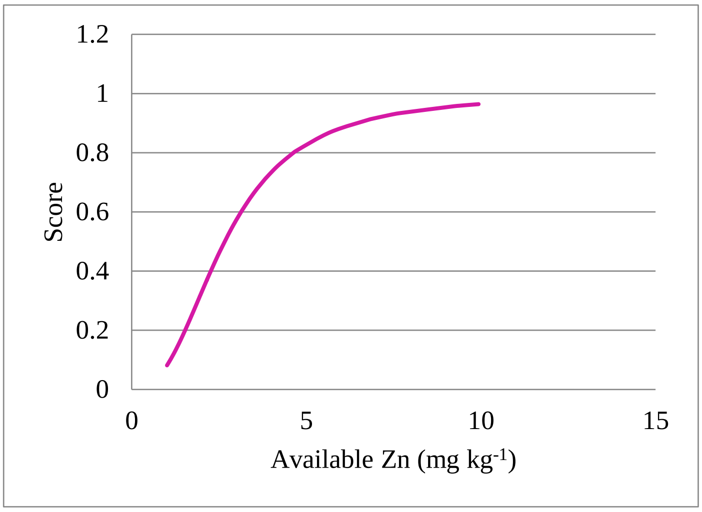

Fig. 4.4. More is better curve of available Zn

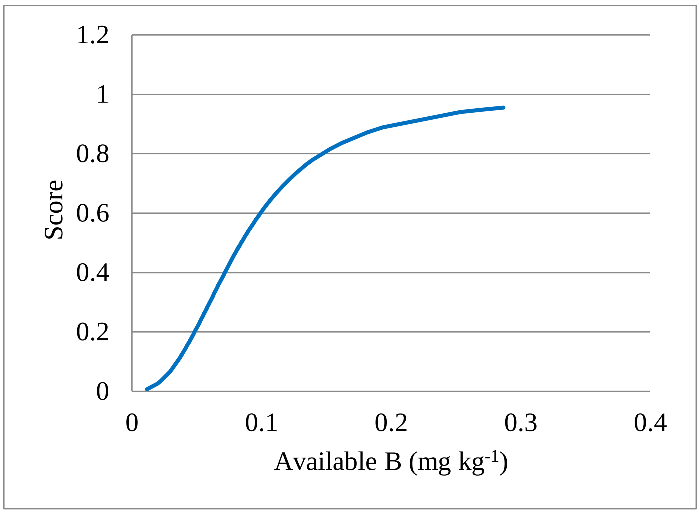

Fig. 4.5. More is better curve of available B

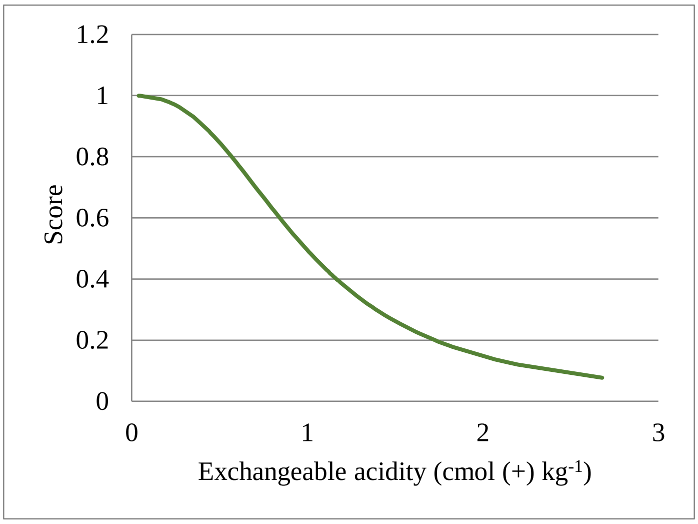

Fig. 4.6. Less is better curve of exchangeable acidity

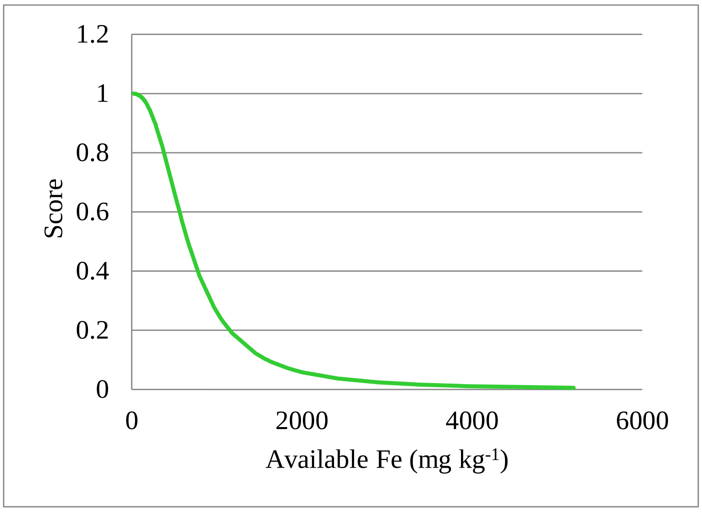

Fig. 4.7. Less is better curve of available Fe

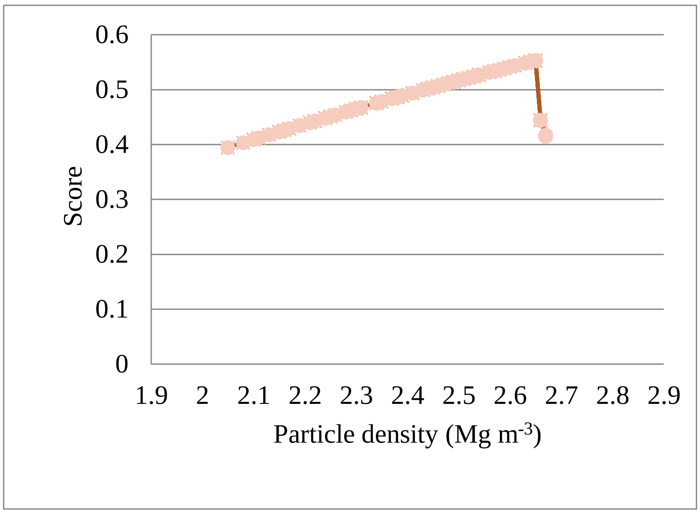

Fig. 4.8. Optimum curve of particle density

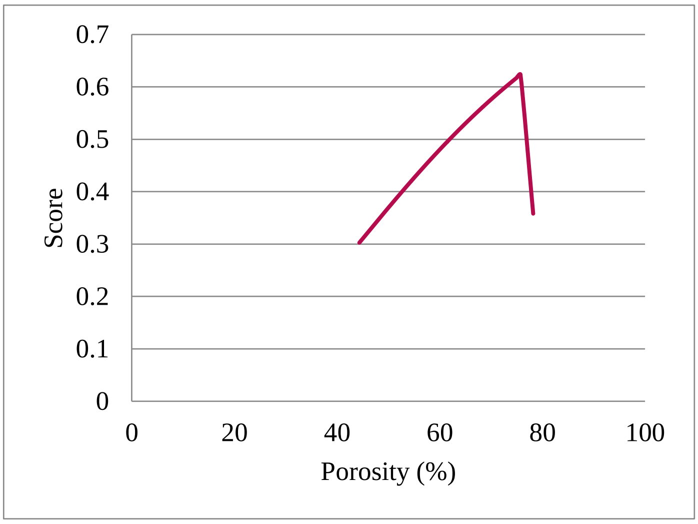

Fig. 4.9. Optimum curve of porosity

Table 4.27. Non-linear scores for each variable in MDS

Sl No	Name of *kole* padavu	Avail. Ca	Avail. S	Avail. N	Porosity	Exchangeable acidity	Avail Fe	Avail. Zn	Particle density	Avail. B
	Mullassery									
1	Ponnamutha	0.38	0.95	0.57	0.50	0.39	1.00	0.41	0.41	0.41
2	Elamutha	0.71	0.96	0.46	0.58	0.97	1.00	0.35	0.44	0.44
3	Mathukkara thekk	0.44	0.95	0.52	0.55	0.97	1.00	0.32	0.50	0.50
4	Pavudai	0.34	0.98	0.65	0.57	0.48	0.99	0.60	0.55	0.55
5	Parappadam kizhakkethala	0.35	0.98	0.56	0.57	0.35	0.98	0.52	0.48	0.48
6	Parappadam west	0.28	0.98	0.61	0.53	0.39	0.99	0.16	0.52	0.52
7	Penakam	0.33	0.96	0.57	0.55	0.67	0.99	0.31	0.51	0.51
8	Elavathur	0.19	0.97	0.43	0.56	0.51	0.96	0.54	0.47	0.47
9	Cherotha akkarapadam	0.31	0.97	0.35	0.51	0.91	0.99	0.12	0.40	0.40
10	Peruvalloor padav	0.17	0.97	0.58	0.58	0.94	0.99	0.21	0.42	0.42
11	Kaniyamthuruth	0.19	0.98	0.47	0.45	0.83	1.00	0.22	0.49	0.49
12	Annakkara chirakkal	0.22	0.95	0.45	0.41	0.84	0.99	0.32	0.51	0.51
13	Annakkara vadakk	0.22	0.97	0.41	0.38	0.23	0.97	0.03	0.48	0.48
14	Thanneerkayal	0.35	0.88	0.67	0.46	0.98	0.96	0.19	0.50	0.50

15	Pulipandi	0.25	0.74	0.45	0.52	0.41	0.99	0.04	0.51	0.51
	Cherpu									
16	Manakkal padavu	0.42	0.02	0.01	0.55	0.88	0.99	0.37	0.45	0.45
17	Madhammathopp	0.03	0.02	0.23	0.53	0.46	0.98	0.44	0.49	0.49
18	Nerkathir	0.24	0.02	0.28	0.59	0.62	1.00	0.04	0.53	0.53
19	Kanimangalam *kole* padav	0.17	0.02	0.24	0.48	0.69	1.00	0.08	0.44	0.44
20	Karimbatta	0.50	0.03	0.02	0.50	0.99	1.00	0.10	0.53	0.53
21	Kizhakkan *kole* padavu	0.23	0.02	0.37	0.45	0.25	0.39	0.35	0.52	0.52
22	Cheeyaram samajam	0.20	0.03	0.46	0.44	0.26	0.23	0.56	0.46	0.46
23	Avinissery samajam	0.24	0.05	0.35	0.59	0.27	0.98	0.56	0.45	0.45
24	Kodannur *kole* farming society	0.001	0.05	0.4	0.52	0.73	0.99	0.43	0.40	0.40
25	Pallippuram *kole* padav	0.28	0.03	0.04	0.40	0.82	0.95	0.24	0.41	0.41
26	Pandaran *kole*	0.46	0.17	0.5	0.45	0.31	0.99	0.16	0.49	0.49
27	Chovvoorthazham alukka padav	0.31	0.51	0.17	0.50	0.97	1.00	0.11	0.44	0.44
28	Jubilee thevar padav	0.31	0.09	0.54	0.47	0.98	1.00	0.10	0.43	0.43
29	Perumkulam east	0.01	0.2	0.41	0.51	0.25	0.98	0.2	0.45	0.45
30	Perumkulam west	0.22	0.03	0.16	0.47	0.77	0.99	0.16	0.54	0.54
	Anthikkad									
31	Chaladi pazhan *kole* 1	0.65	0.53	1.00	0.42	0.78	1.00	0.02	0.44	0.44

32	Themalippuram	0.77	0.70	0.57	0.51	0.59	0.48	0.71	0.48	0.48
33	Rajamukk	0.67	0.11	0.67	0.42	0.2	0.88	0.54	0.48	0.48
34	Arumuri	0.55	0.13	0.46	0.30	0.20	1.00	0.21	0.48	0.48
35	Manaloorthazham	0.11	0.10	0.68	0.47	0.36	0.98	0.53	0.52	0.52
36	Kodayatti	0.67	0.36	0.62	0.45	0.4	0.98	0.74	0.55	0.55
37	Ayyappan *kole*	0.25	0.14	0.65	0.42	0.81	0.76	0.55	0.41	0.41
38	Pazhuvil bund *kole*	0.82	0.16	0.59	0.46	0.14	1.00	0.02	0.52	0.52
39	Chaladi pazhan *kole* 2	0.41	0.18	0.41	0.51	0.53	0.89	0.91	0.53	0.53
40	Chennakari puncha	0.70	0.18	0.41	0.43	0.87	0.98	0.37	0.48	0.48
41	Jubilee thevar padav	0.73	0.18	0.72	0.45	0.78	0.82	0.41	0.48	0.48
42	Pallippuram	0.33	0.18	0.42	0.45	0.78	0.99	0.53	0.52	0.52
43	Pullu	0.87	0.17	0.64	0.51	0.88	1.00	0.6	0.49	0.49
44	Vilakkumadam padav	0.37	0.11	0.64	0.46	0.96	0.93	0.56	0.53	0.53
45	Variyam *kole* padav	0.82	0.16	0.5	0.45	0.19	0.94	0.55	0.52	0.52
46	Chettupuzha east	0.01	0.45	0.49	0.52	0.30	1.00	0.06	0.48	0.48
	Irinjalakkuda									
47	Painkili kayal	0.34	0.21	0.62	0.54	0.49	0.09	0.87	0.49	0.49
48	Chemmanda kayal	0.89	0.11	0.6	0.55	1.00	1.00	0.36	0.53	0.53
49	Vellani *kole*	0.71	0.13	0.69	0.56	0.39	0.99	0.76	0.45	0.45

50	Thekkumoola	0.84	0.15	0.56	0.42	1.00	0.99	0.44	0.55	0.55
51	Karppullithara kakkad	0.37	0.34	0.62	0.58	0.49	0.19	0.96	0.53	0.53
52	Muriyaad	0.37	0.07	0.6	0.47	0.32	0.02	0.79	0.54	0.54
53	Kalladi thazham	0.36	0.03	0.46	0.47	0.76	0.97	0.37	0.54	0.54
54	Chithravallipadam	0.48	0.03	0.49	0.50	1.00	0.60	0.47	0.49	0.49
55	Kochipadam	0.45	0.05	0.69	0.43	0.29	0.01	0.40	0.43	0.43
56	Kadumkadu	0.42	0.05	0.65	0.58	0.83	0.93	0.42	0.53	0.53
57	Mothalakkulam	0.41	0.07	0.61	0.57	0.81	0.99	0.64	0.38	0.38
58	Koda *kole*	0.24	0.05	0.44	0.62	0.87	0.98	0.1	0.51	0.51
59	Konthikulam	0.20	0.45	0.5	0.45	0.65	0.38	0.71	0.42	0.42
60	Parappookkara	0.45	0.05	0.65	0.50	0.42	0.98	0.57	0.55	0.55
61	Nedumbal	0.53	0.04	0.66	0.51	0.75	0.99	0.20	0.55	0.55
	Puzhakkal									
62	Pullazhi *kole* 1	0.42	0.10	0.49	0.58	0.26	0.01	0.96	0.55	0.55
63	Pullazhi *kole* 2	0.40	0.10	0.44	0.58	0.22	0.04	0.93	0.42	0.42
64	Pannikkara kin *kole*	0.31	0.11	0.67	0.56	0.28	0.9	0.32	0.46	0.46
65	Ombathumuri 1	0.29	0.12	0.45	0.57	0.26	0.10	0.55	0.43	0.43
66	Ombathumuri 2	0.48	0.12	0.44	0.57	1.00	0.07	0.56	0.41	0.41
67	Kadavil *kole*	0.50	0.24	0.35	0.53	0.49	0.12	0.13	0.39	0.39

68	Pandaran *kole* 1	0.45	0.21	0.55	0.52	0.41	0.99	0.27	0.45	0.45
69	Pandaran *kole* 2	0.46	0.5	0.54	0.54	0.41	0.99	0.34	0.48	0.48
70	Sangham south *kole*	0.46	0.51	0.59	0.49	0.45	0.02	0.96	0.43	0.43
71	Sangham north *kole*	0.46	0.03	0.6	0.44	0.41	0.02	0.96	0.50	0.50
72	Chirukandathu *kole* 1	0.61	0.05	0.59	0.45	0.41	0.96	0.57	0.52	0.52
73	Chirukandathu *kole* 2	0.59	0.05	0.65	0.45	0.43	0.51	0.93	0.45	0.45
74	Karikkin *kole*	0.52	0.03	0.54	0.56	0.30	0.28	0.44	0.52	0.52
75	Vadakke ponnur thazham	0.49	0.02	0.30	0.52	0.35	0.64	0.91	0.47	0.47
	Perumpadappu									
76	Maradi *kole* padavu	0.66	0.05	0.75	0.39	0.18	0.06	0.53	0.42	0.42
77	Nadupotta *kole*	0.28	0.10	0.05	0.39	0.71	0.99	0.41	0.54	0.54
78	Maradi *kole* padav, maranchery	0.29	0.03	0.44	0.41	0.55	0.99	0.01	0.44	0.44
79	Kundamkuzhi 1	0.54	0.11	0.1	0.37	0.49	0.02	0.31	0.47	0.47
80	Kundamkuzhi 2	0.56	0.03	0.13	0.42	1.00	0.02	0.52	0.51	0.51
81	Mullamadu	0.93	0.07	0.66	0.47	0.78	0.97	0.67	0.48	0.48
82	Arimbinkundu	0.59	0.08	0.71	0.57	0.42	0.99	0.21	0.49	0.49
83	Irumbayil *kole*	0.12	0.15	0.42	0.60	0.63	0.99	0.39	0.48	0.48
84	Aana *kole* 1	0.48	0.16	0.28	0.50	0.81	0.95	0.31	0.42	0.42
85	Aana *kole* 2	0.19	0.16	0.15	0.55	0.22	0.57	0.68	0.48	0.48

86	Kolothupadavu 1	0.27	0.37	0.74	0.54	0.12	0.48	0.13	0.47	0.47
87	Kolothupadavu 2	0.26	0.06	0.55	0.40	0.13	0.53	0.08	0.53	0.53
	Ponnani									
88	Ponnani *kole* padavu 1	0.54	0.04	0.26	0.48	0.81	0.10	0.18	0.51	0.51
89	Ponnani *kole* padavu 2	0.17	0.02	0.16	0.38	0.46	0.10	0.32	0.53	0.53
90	Ponnani *kole* padavu 3	0.76	0.26	0.65	0.52	0.08	0.07	0.81	0.51	0.51
91	Kanniyamkayal	0.47	0.46	0.53	0.56	0.18	0.01	0.40	0.55	0.55
92	Puzhangad *kole* 1	0.70	0.65	0.54	0.61	0.93	0.93	0.37	0.42	0.42
93	Kanniyamkayal 2	0.93	0.42	0.31	0.45	0.29	0.91	0.24	0.50	0.50
94	Anthalachira 1	0.97	0.46	0.49	0.50	0.19	0.98	0.23	0.50	0.50
95	Anthalachira 2	0.92	0.66	0.44	0.62	0.35	0.81	0.24	0.50	0.50
96	Puzhangad *kole* 2	0.43	0.91	0.72	0.36	0.19	0.95	0.17	0.42	0.42
97	Panthavoor 1	0.66	0.11	0.35	0.46	0.43	0.59	0.21	0.44	0.44
98	Panthavoor 2	0.67	0.06	0.34	0.36	0.46	0.24	0.23	0.51	0.51
99	Moochikkal kadavu 1	0.29	0.08	0.64	0.43	0.46	0.53	0.15	0.49	0.49
100	Moochikkal kadavu 2	0.27	0.09	0.68	0.48	0.32	0.66	0.14	0.49	0.49

4.2.3. Computation of SQI

The SQI of different sites of *kole* lands in block panchayats of AEU 6 (Table 4.29) was calculated using the formula

SQI = $\sum_{i=1}^{n} wi \times si$

Where, Si was the score of subscripted variable and Wi was weighing factor (Table 4. 28) derived from PCA.

Table 4.28. Weight of each PC derived from PCA

PCs	1	2	3	4	5	6	7	8
Weights(Wi)	0.21	0.18	0.14	0.12	0.10	0.09	0.08	0.07

Table 4.29. SQI of different sites of *kole* lands in AEU 6

Sl No.	Block panchayats	Name of *Kole* padavu	SQI
1	Mullassery	Ponnamutha	0.63
2		Elamutha	0.78
3		Mathukkara thekk	0.76
4		Pavudai	0.77
5		Parappadam kizhakkethala	0.66
6		Parappadam west	0.59
7		Penakam	0.67
8		Elavathur	0.61
9		Cherotha akkarapadam	0.63
10		Peruvalloor padav	0.65
11		Kaniyamthuruth	0.61
12		Annakkara chirakkal	0.59
13		Annakkara vadakk	0.52
14		Thanneerkayal	0.67
15		Pulipandi	0.50

16	Cherpu	Manakkal padavu	0.43
17		Madhammathopp	0.33
18		Nerkathir	0.37
19		Kanimangalam *kole* padav	0.36
20		Karimbatta	0.44
21		Kizhakkan *kole* padavu	0.36
22		Cheeyaram samajam	0.31
23		Avinissery samajam	0.43
24		Kodannur *kole* farming society	0.41
25		Pallippuram *kole* padav	0.37
26		Pandaran *kole*	0.45
27		Chovvoorthazham alukka padav	0.50
28		Jubilee thevar padav	0.48
29		Perumkulam east	0.33
30		Perumkulam west	0.42
31	Anthikkad	Chaladi pazhan *kole* 1	0.68
32		Themalippuram	0.64
33		Rajamukk	0.54
34		Arumuri	0.44
35		Manaloorthazham	0.45
36		Kodayatti	0.65
37		Ayyappan *kole*	0.50
38		Pazhuvil bund *kole*	0.51
39		Chaladi pazhan *kole* 2	0.57
40		Chennakari puncha	0.58
41		Jubilee thevar padav	0.58
42		Pallippuram	0.51
43		Pullu	0.66
44		Vilakkumadam padav	0.54
45		Variyam *kole* padav	0.57
46		Chettupuzha east	0.42

47	Irinjalakkuda	Painkili kayal	0.48
48		Chemmanda kayal	0.64
49		Vellani *kole*	0.60
50		Thekkumoola	0.63
51		Karppullithara kakkad	0.53
52		Muriyaad	0.41
53		Kalladi thazham	0.46
54		Chithravallipadam	0.54
55		Kochipadam	0.37
56		Kadumkadu	0.55
57		Mothalakkulam	0.54
58		Koda *kole*	0.47
59		Konthikulam	0.52
60		Parappookkara	0.50
61		Nedumbal	0.53
62	Puzhakkal	Pullazhi *kole* 1	0.42
63		Pullazhi *kole* 2	0.39
64		Pannikkara kin *kole*	0.43
65		Ombathumuri 1	0.36
66		Ombathumuri 2	0.47
67		Kadavil *kole*	0.41
68		Pandaran *kole* 1	0.53
69		Pandaran *kole* 2	0.54
70		Sangham south *kole*	0.51
71		Sangham north *kole*	0.45
72		Chirukandathu *kole* 1	0.53
73		Chirukandathu *kole* 2	0.52
74		Karikkin *kole*	0.43
75		Vadakke ponnur thazham	0.44
76	P erumpadapp	Maradi *kole* padavu	0.42
77		Nadupotta *kole*	0.41

78		Maradi *kole* padav, maranchery	0.40
79		Kundamkuzhi 1	0.34
80		Kundamkuzhi 2	0.43
81		Mullamadu	0.68
82		Arimbinkundu	0.55
83		Irumbayil *kole*	0.44
84		Aana *kole* 1	0.51
85		Aana *kole* 2	0.35
86		Kolothupadavu 1	0.41
87		Kolothupadavu 2	0.36
88	Ponnani	Ponnani *kole* padavu 1	0.39
89		Ponnani *kole* padavu 2	0.28
90		Ponnani *Kole* padavu 3	0.51
91		Kanniyamkayal 1	0.47
92		Puzhangad *kole* 1	0.70
93		Kanniyamkayal 2	0.58
94		Anthalachira 1	0.62
95		Anthalachira 2	0.66
96		Puzhangad *kole* 2	0.59
97		Panthavoor 1	0.46
98		Panthavoor 2	0.40
99		Moochikkal kadavu 1	0.41
100		Moochikkal kadavu 2	0.40

4.2.4. Comparison of SQI

SQI in different block panchayats of AEU 6 were compared using one way ANOVA with DMRT. The SQI values varied from 0.28 to 0.78. The highest SQI was showed by Elamutha in Mullassery block panchayat and the lowest by Ponnani *kole* padavu 2 in Ponnani block panchayat. The highest mean (0.64) was recorded in Mullassery block panchayat and the lowest (0.39) was in Cherpu block panchayat. SQI was found significant at both 1 per cent and 5 per cent level of significance. The soils of Mullassery block panchayats showed significantly superior soil quality compared to all other blocks. On the basis of decreasing SQI, the block panchayats were arranged in following order:

Mullassery > Anthikkad > Irinjalakkuda > Ponnani > Puzhakkal > Perumpadappu > Cherpu.

Table 4.30. SQI of soils in block panchayats of AEU 6

Block panchayats	SQI	
	Mean ± SD	Range
Mullassery	$0.64^{a} \pm 0.06$	0.63 - 0.78
Cherpu	$0.39^{e} \pm 0.06$	0.31 - 0.50
Anthikkad	$0.55^{b} \pm 0.08$	0.42 - 0.68
Irinjalakkuda	$0.51^{bcd} \pm 0.07$	0.37 - 0.64
Puzhakkal	$0.45^{de} \pm 0.06$	0.36 - 0.54
Perumpadappu	$0.44^{cde} \pm 0.07$	0.34 - 0.68
Ponnani	$0.50^{bcd} \pm 0.11$	0.28 - 0.70
CD (0.01) = 0.09	CD (0.05) = 0.07	

4.3. COMPUTATION OF RSQI (RELATIVE SOIL QUALITY INDEX)

The RSQI of different sites of *kole* lands in block panchayats of AEU 6 (Table 4.31) was calculated using the equation proposed by Karlen and Stott (1994),

$$\mathrm{RSQI} = \frac{\mathrm{SQI}}{\mathrm{SQIm}} \times 100$$

Where SQI is observed soil quality index and SQIm is the theoretical maximum soil quality. The soils were rated based on RSQI as poor (RSQI<50 %), medium (50-70 %) and high (RSQI>70 %). SQI_m was calculated by multiplying the weight factor of each indicator in MDS with the maximum score 1.

The highest RSQI was recorded in Elamutha (72.22) of Mullassery block panchayat and the lowest in Ponnani *kole* padavu 2 (25.93) of Ponnani block panchayat (Table 4.31).

Table 4.31. Computed RSQI values in different site of *kole* land soils

Sl No.	Block panchayats	Name of *kole* padavu	RSQI
1	Mullassery	Ponnamutha	58.33
2		Elamutha	72.22
3		Mathukkara thekk	70.37
4		Pavudai	71.30
5		Parappadam kizhakkethala	61.11
6		Parappadam west	54.63
7		Penakam	62.04
8		Elavathur	56.48
9		Cherotha akkarapadam	58.33
10		Peruvalloor padav	60.19
11		Kaniyamthuruth	56.48
12		Annakkara chirakkal	54.63
13		Annakkara vadakk	48.15
14		Thanneerkayal	62.04
15		Pulipandi	46.30
16	Cherpu	Manakkal padavu	39.81
17		Madhammathopp	30.56
18		Nerkathir	34.26
19		Kanimangalam *kole* padav	33.33
20		Karimbatta	40.74
21		Kizhakkan *kole* padavu	33.33
22		Cheeyaram samajam	28.70
23		Avinissery samajam	39.81
24		Kodannur *kole* farming society	37.96
25		Pallippuram *kole* padav	34.26
26		Pandaran *kole*	41.67
27		Chovvoorthazham alukka	46.30

		padav	
28		Jubilee thevar padav	44.44
29		Perumkulam east	30.56
30		Perumkulam west	38.89
31	Anthikkad	Chaladi pazhan *kole* 1	62.96
32		Themalippuram	59.26
33		Rajamukk	50.00
34		Arumuri	40.74
35		Manaloorthazham	41.67
36		Kodayatti	60.19
37		Ayyappan *kole*	46.30
38		Pazhuvil bund *kole*	47.22
39		Chaladi pazhan *kole* 2	52.78
40		Chennakari puncha	53.70
41		Jubilee thevar padav	53.70
42		Pallippuram	47.22
43		Pullu	61.11
44		Vilakkumadam padav	50.00
45		Variyam *kole* padav	52.78
46		Chettupuzha east	38.89
47	Irinjalakkuda	Painkili kayal	44.44
48		Chemmanda kayal	59.26
49		Vellani *kole*	55.56
50		Thekkumoola	58.33
51		Karppullithara kakkad	49.07
52		Muriyaad	37.96
53		Kalladi thazham	42.59
54		Chithravallipadam	50.00
55		Kochipadam	34.26
56		Kadumkadu	50.93
57		Mothalakkulam	50.00

58		Koda *kole*	43.52
59		Konthikulam	48.15
60		Parappookkara	46.30
61		Nedumbal	49.07
62	Puzhakkal	Pullazhi *kole* 1	38.89
63		Pullazhi *kole* 2	36.11
64		Pannikkara kin *kole*	39.81
65		Ombathumuri 1	33.33
66		Ombathumuri 2	43.52
67		Kadavil *kole*	37.96
68		Pandaran *kole* 1	49.07
69		Pandaran *kole* 2	50.00
70		Sangham south *kole*	47.22
71		Sangham north *kole*	41.67
72		Chirukandathu *kole* 1	49.07
73		Chirukandathu *kole* 2	48.15
74		Karikkin *kole*	39.81
75		Vadakke ponnur thazham	40.74
76	Perumpadappu	Maradi *kole* padavu	38.89
77		Nadupotta *kole*	37.96
78		Maradi *kole* padav, maranchery	37.04
79		Kundamkuzhi 1	31.48
80		Kundamkuzhi 2	39.81
81		Mullamadu	62.96
82		Arimbinkundu	50.93
83		Irumbayil *kole*	40.74
84		Aana *kole* 1	47.22
85		Aana *kole* 2	32.41
86		Kolothupadavu 1	37.96
87		Kolothupadavu 2	33.33
88	Ponnani	Ponnani *kole* padavu 1	36.11

89		Ponnani *kole* padavu 2	25.93
90		Ponnani *Kole* padavu 3	47.22
91		Kanniyamkayal 1	43.52
92		Puzhangad *kole* 1	64.81
93		Kanniyamkayal 2	53.70
94		Anthalachira 1	57.41
95		Anthalachira 2	61.11
96		Puzhangad *kole* 2	54.63
97		Panthavoor 1	42.59
98		Panthavoor 2	37.04
99		Moochikkal kadavu 1	37.96
100		Moochikkal kadavu 2	37.04

The RSQI was found significant at both 1 per cent and 5 per cent level of significance. The highest significant RSQI was recorded in Mullassery block panchayat (71.84 %) and the lowest RSQI (24.07 %) in Perumpadappu block panchayat. The RSQI in Anthikkad block panchayat ranked second while RSQI in Ponnani block panchayat was found on par with irinjalakkuda, Perumpadappu and Puzhakkal block panchayats.

Table 4.32. RSQI of soils in block panchayats of AEU 6

Block panchayats	RSQI	
	Mean ± SD	Range
Mullassery	$59.50^{a} \pm 7.59$	46.30 - 72.22
Cherpu	$36.97^{e} \pm 5.28$	28.70 - 46.30
Anthikkad	$51.15^{b} \pm 7.34$	38.89 - 62.96
Irinjalakkuda	$47.96^{bcd} \pm 8.98$	34.26 - 59.26
Puzhakkal	$42.52^{de} \pm 7.34$	33.33 - 50.00
Perumpadappu	$40.89^{cde} \pm 8.95$	31.48 - 62.96
Ponnani	$46.08^{bc} \pm 11.22$	25.93 - 64.81
CD (0.01) = 8.493	CD (0.05) = 6.414	

4.4. NUTRIENT INDEX OF N, P, K AND ORGANIC CARBON

Nutrient index was calculated as per Parker *et al*. (1951) using the formula

$$\text{Nutrient index} = \frac{(1\times N1)+(2\times N2)+(3\times N3)}{N}$$

Whereas N1= Number of samples in low category

N2= Number of samples in medium category

N3= Number of samples in high category

N= Total number of samples

The three classes nutrient index classes are: low (<1.67), medium (1.67 - 2.33) and high (>2.33) (Ravikumar and Somashekar, 2013).

Nutrient index of nitrogen varied from 2.2 to 3. Nitrogen nutrient index was found high in Mullassery, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappuu and Ponnani block panchayats whereas it was medium in Cherpu block panchayat.

Nutrient index of phosphorus varied from 1.53 to 2.60. Phosphorus nutrient index found low in both Irinjalakkuda and Cherpu block panchayats, medium in Anthikkad, Puzhakkal, Perumpadappu and Ponnani block panchayats and high in Mullassery block panchayat.

Nutrient index of potassium varied from 1.33 to 2.69. Potassium nutrient index was high in Ponnani block panchayat and medium in Mullassery, Anthikkad, Irinjalakkuda and Perumpadappu block panchayats and low in Cherpu and Puzhakkal block panchayats.

Nutrient index of organic carbon varied from 1.53 to 2.13. Organic carbon nutrient index was found medium in all block panchayats except in Mullassery block panchayat where it was found low.

Table 4.33. Nutrient index of N, P, K and organic carbon in block panchayats of AEU 6

Block panchayats	Nutrient index			
	N	P	K	OC
Mullassery	3.00	2.60	1.73	1.53
Cherpu	2.20	1.60	1.33	1.87
Anthikkad	3.00	1.69	1.94	2.12
Irinjalakkuda	3.00	1.53	2.00	2.13
Puzhakkal	2.64	2.00	1.36	2.00
Perumpadappu	2.58	1.78	2.08	2.08
Ponnani	2.78	2.23	2.69	2.00

4.5. CORRELATION BETWEEN PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS

Correlation between soil quality indicators *viz*., physical, chemical and biological were carried out in SPSS statistical package. Significant positive correlation existed between bulk density and particle density, soil moisture content and organic carbon, soil moisture content and electrical conductivity, organic carbon and available nitrogen, available iron and available zinc, available zinc and manganese, available sulphur and microbial biomass carbon. Significant negative correlation was observed between bulk density and porosity, bulk density and organic carbon, bulk density and water holding capacity, available iron and sulphur.

Table 4.34 Correlation between soil quality indicators

	BD	PD	Poro	WHC	Moist	MWD	pH	EC	OC	EA	N	P	K	Ca	Mg	S	B	Fe	Mn	Cu	Zn	ECEC	MBC	DHA
BD	1																							
PD	.294**	1																						
Porosity	-.897**	-0.1	1																					
WHC	-.228*	-.222*	0.18	1																				
Moist	-0.08	0.11	0.16	-0.06	1																			
MWD	-0.05	0.05	0.06	-0.03	0.05	1																		
pH	-0.1	-0.1	-0	0.155	-0.19	-0.13	1																	
EC	-0.12	-0	0.13	-0.08	.235*	.337**	-.273**	1																
OC	-.213*	-0.1	0.14	0.02	.276**	-0.06	0.057	0.098	1															
EA	0.01	-0.1	-0	0	0.12	-0	-0.16	.244*	.218*	1														
N	-0.1	0.05	0.12	0.192	.639**	-0.13	-0.08	0.055	.307**	.241*	1													
P	-0.1	-0.1	0.12	-.200*	0.09	0.147	-0.09	0.115	-0.16	-0.09	-0.08	1												
K	-0.07	0.01	0.04	-0.09	0.1	.226*	-0.05	.642**	0.179	0.173	-0.08	-0.03	1											
Ca	0.02	0	-0	0.103	.336**	.205*	0	.490**	0.132	0.057	0.166	-0.04	.371**	1										
Mg	-0.07	-0	0.09	0.075	.397**	.203*	-0.12	.380**	.220*	0.125	.207*	0.033	.295**	.583**	1									
S	-.224*	-0	.203*	-0.06	.232*	0.154	-.294**	.235*	-0.19	-0.09	0.117	.444**	-0.07	-0.11	0.06	1								
B	0.09	0.13	-0.1	-0.18	0.04	0.045	0.015	0.021	0.007	-0.04	-0.02	-0.02	0.047	-0.06	-0.066	0.045	1							
Fe	0.08	0.04	-0.1	0.012	-0.08	0.005	0.071	-0.05	-0.09	.244*	0	-0.12	-0.05	-0.04	-0.155	-.223*	-0.1	1						
Mn	0.06	0.07	-0.1	.209*	0.14	0.019	.213*	0	0.111	0.097	0.192	-.248*	0.026	0.051	0.028	-0.15	.221*	.197*	1					
Cu	0.03	0.1	0.01	-0.1	.342**	-0.07	-0.02	0.02	0.194	0.079	.294**	.220*	-0.01	0.002	0.071	0.196	0.05	-.356**	-0.03	1				
Zn	-0.12	-0	0.13	0.194	0.05	-0.11	0.121	-0.17	-0.01	0.131	0.152	-0.16	-.240*	0.023	-0.097	-0.15	-0	.515**	.419**	-0.08	1			
ECEC	-0	-0	-0	-0.08	-0.01	0.14	-.248*	.449**	0.093	.603**	0.085	0.045	.365**	0.102	.208*	0.107	0.04	0.134	-0.05	-0.12	-0.04	1		
MBC	0.09	0.04	-0.1	-0.19	0.06	0.173	-0.16	0.043	-.286**	-.294**	-0.09	.280**	-0.09	0.013	0.074	.480**	0.12	-0.15	-0.14	0.013	-.215*	-0.046	1	
DHA	-0.07	0.13	0.07	0.021	0.12	-0.12	0.133	-0.15	0.118	-0.02	.200*	-.329**	0	0.026	0.056	-.241*	0.1	0.042	.338**	-0.12	0.129	-0.07	-.212*	1

Discussion

5. DISCUSSION

The results obtained during the present investigations were discussed and the interpretations were made under the following sections.

5.1. SOIL QUALITY ASSESSMENT

5.1.1. Physical attributes

5.1.1.1. Bulk density

Bulk density of the soil varied from 0.53 Mg m^{-3} to 1.34 Mg m^{-3} with a mean of 0.91 Mg m^{-3} in AEU 6 (*Kole* lands). Ninety six per cent of soil samples showed bulk density less than 1.2 Mg m^{-3} and the remaining 4 per cent showed a bulk density in between 1.2 Mg m^{-3} to 1.4 Mg m^{-3}. The result revealed that most of the soil had low bulk density (Fig. 5.1). This might be due to presence of high organic matter content. Johnkutty and Venugopal (1993) reported that soils in *kole* lands have high organic matter content and it varied from 2.07 to 4.16 per cent. In a study of establishing critical limits for indicators in rice cropping system, Biswas *et al*. (2017) found that there was a strong negative correlation between bulk density and organic matter content due to the dilution effect of organic matter. Similar results were also observed by Papini *et al*. (2011), Karami *et al*. (2012) and Sakin (2012).

It was also found that there was significant strong correlation between bulk density and porosity. This was in conformity with the results obtained by Bandyopadhyay *et al*. (2010). He also observed that increased volume of soil pore reduced bulk density. Low BD indicates a good soil condition for crops and microorganisms in soil. It indicates that soil has good soil pore, aggregation, water and air circulation and helps in easy root penetration (Macci *et al*., 2012).

5.1.1.2. Particle density

Particle density of soil varied from 2.05 Mg m^{-3} to 2.67 Mg m^{-3} with an average of 2.43 Mg m^{-3}. Among the 100 soil samples collected from AEU 6, 12 per cent had a particle density of 2.2 Mg m^{-3}, 34 per cent in between 2.2 to 2.4 Mg m^{-3}. Particle density varied from 2.4 to 2.6 Mg m^{-3} in 37 per cent of soil whereas only 17 per cent soil had particle density greater than 2.6 Mg m^{-3} (Fig. 5.2). The variation in particle density might be due to its variation in mineral composition or textural difference or due to mixing with organic matter.

Skopp (2000) found that all mineral soils were best represented by a standard particle density of 2.65 Mg m^{-3} and was equal to the mean density of quartz. Ruhlmann *et al*. (2006) observed that particle density of mineral soil ranged from 2.4 to 2.9 Mg m^{-3} and reported that any variation of particle density from this value might be due to the mixing of organic matter or due to change in mineral composition. Ball *et al*. (2000) observed that particle density of soil with clay and heavy minerals varied between 2.2 to 2.9 Mg m^{-3} and 2.9 to 4.0 Mg m^{-3}, respectively. Hassink (1995) found that particle density of organic matter varied from 1.0 to 1.5 Mg m^{-3} and mixing ratio of organic matter with soil alters its particle density. The increased particle density of these soils might be due to high clay content and decreased particle density may be due to mixing with organic matter.

5.1.1.3. Porosity

Porosity of soil samples varied from 44.34 per cent to 78.21 per cent with a mean of 61.93 per cent. Eighty five per cent of soil samples collected from AEU 6 had a porosity of 50 to 70 per cent, 13 per cent had porosity greater than 70 per cent and only 2 per cent had porosity in between 30 to 50 per cent. In AEU 6, 98 per cent of soils have high porosity (Fig. 5.3). This might be due to high organic matter content and low bulk density of soil.

Haynes and Swift (1990) stated that higher organic matter content in soil increased soil porosity. Kay and Bygaart (2002) observed positive effect of organic matter on soil porosity and reported that organic matter would stabilize soil pores and increase its persistence under any environmental or anthropogenic stresses.

5.1.1.4. Maximum water holding capacity

Maximum water holding capacity varied from 18.11 per cent to 73.49 per cent with a mean of 58.68 per cent. Among 100 samples collected from AEU 6, about one by third sample (34 %) had maximum water holding capacity of 50 to 70 per cent and another one by third (36 %) had 30 to 50 per cent maximum water holding capacity (Fig. 5.4). Most of the soils in AEU 6 had high water holding capacity. This might be

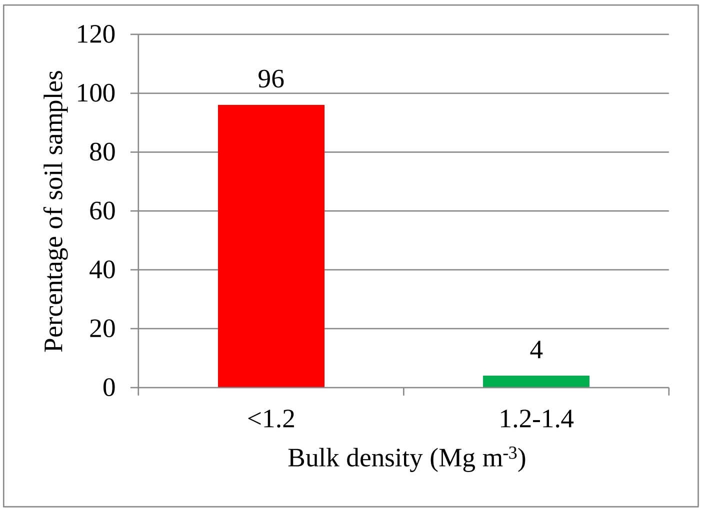

Fig. 5.1. Percentage distribution of bulk density (Mg m^{-3}) in AEU 6

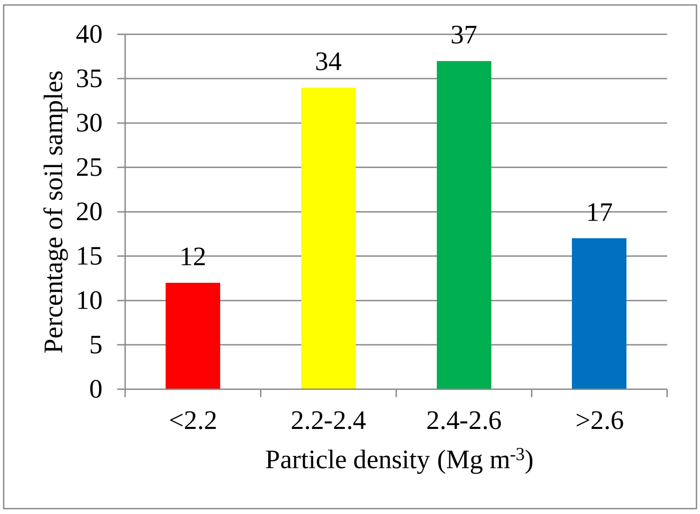

Fig. 5.2. Percentage distribution of particle density (Mg m^{-3}) in AEU 6

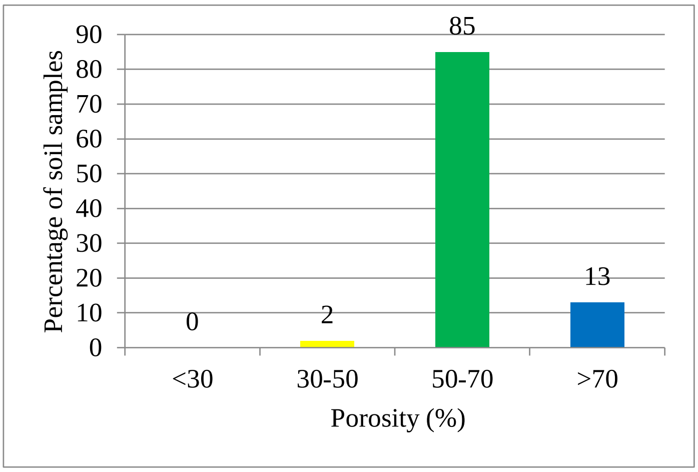

Fig. 5.3. Percentage distribution of porosity (%) in AEU 6

due to high organic matter content and clayey texture of soil. Only 5 per cent of soil showed less than 30 per cent of water holding capacity and this might be due to the presence of sand in coastal *kole* lands. Srinivasan (2012) reported clayey texture of soils in *kole* flood plains and sandy in coastal areas. Content of clay in soil increased water holding capacity whereas more coarse textured soils had low water retention capacity (Hudson, 1994). He also reported that increase in organic matter had positive effect in increasing water holding capacity regardless of texture. Wu *et al*. (2013) observed that organic matter application in to soil increased its water holding capacity by enhancing soil porosity.

5.1.1.5. Soil moisture

Soil moisture ranged from 12.00 per cent to 41.60 per cent with a mean of 30.32 per cent. It was found that 69 per cent of soil samples had greater than 25 per cent moisture content in soil (Fig. 5.5). This might be due to high organic matter content and clay content. About 31 per cent of soils have less than 25 per cent soil moisture content this might be due to high sand content in soils of coastal area. Papini *et al*. (2011) reported that organic matter addition and high clay content in soil increased soil moisture and similar results were reported by Ponizovsky *et al.* (1999) and McLauchlan (2006).

5.1.1.6. Aggregate stability

Mean weight diameter of AEU 6 showed a range from 0.70 mm to 6.95 mm with a mean of 3.02 mm. More than 92 per cent of samples had mean weight diameter more than 2 mm (Fig. 5.6). This increased mean weight diameter indicated high aggregate stability and it might be due to high organic matter content in soils.

Degens *et al*. (2000) reported that addition of organic matter increased soil aggregation and the size of aggregate would vary from 1 to 10 mm. Tejada *et al*. (2006) found that organic matter acted as a cementing factor for flocculating soil particles and forming stable aggregates. Greater aggregate stability was contributed by increased hydrogen bonding between polar groups of the organic molecules and adsorbed water molecules or oxygen of the silicate surface. McLauchlan (2006) reported that increased clay content also improved aggregation in soil.

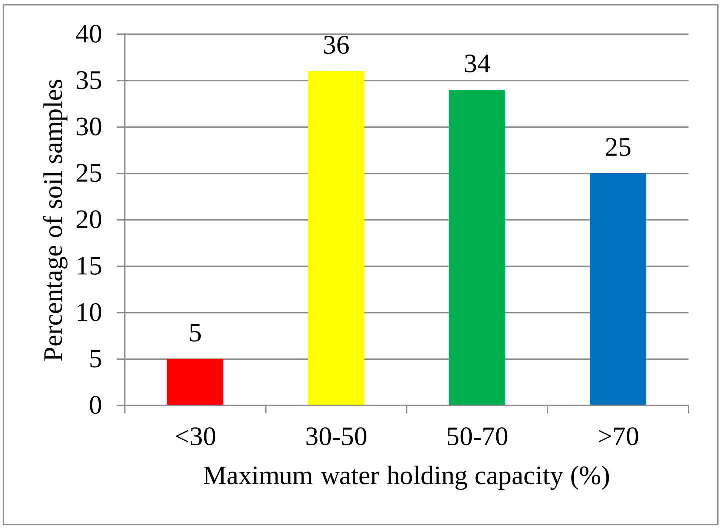

Fig. 5.4. Percentage distribution of maximum water holding capacity (%) in AEU 6

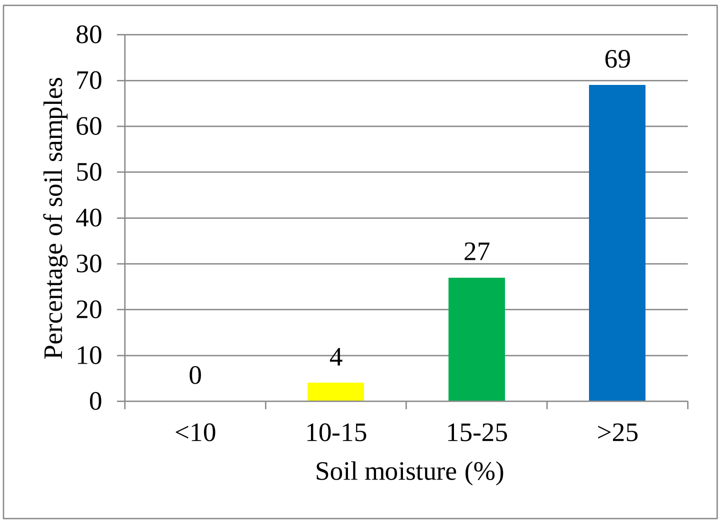

Fig. 5.5. Percentage distribution of soil moisture (%) in AEU 6

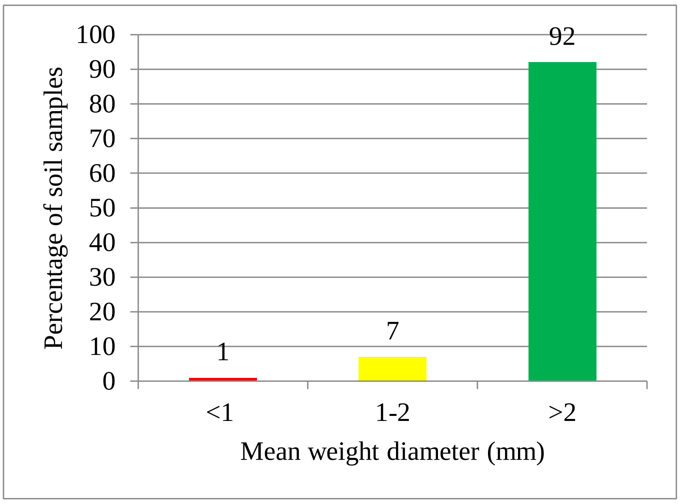

Fig. 5.6. Percentage distribution of mean weight diameter (mm) in AEU 6

5.1.2. Chemical attributes

5.1.2.1. pH

pH of soil samples in AEU 6 varied from 3.51 to 6.35 with a mean value of 4.92. All the soil samples showed an acidic soil reaction. Thirty four per cent of soils in AEU 6 were extremely acidic, 22 per cent very strongly acidic, 17 per cent strongly acidic, 21 per cent moderately acidic and 6 per cent slightly acidic (Fig. 5.7). This is in conformity with findings of Johnkutty and Venugopal (1993). They reported that soils in *kole* area were generally acidic with a pH varied from 2.6 to 6.3. The extreme acidity of these soils due to the presence of organic peat layer in subsurface.

5.1.2.2. Electrical conductivity (EC)

Electrical conductivity in *kole* lands varied from 0.01 dS m^{-1} to 0.27 dS m^{-1} with a mean of 0.11 dS m^{-1}. All the soil samples collected from *kole* lands have an electrical conductivity less than 1 dS m^{-1} (Fig. 5.8). Swarajyalakshmi *et al*. (2003) observed that EC of these soils during the growing season ranged from 0.1 to 2 dS m^{-1}. Irene (2014) reported that electrical conductivity of *kole* lands before cropping season had a mean value of 0.39 dS m^{-1}. This variation in EC might be due to loss of soluble salt during flooding, variation in mineralogy of soil and high soil moisture content present in soil (Brevik *et al*, 2006). The low EC value might be due to the effect of flood. Lavado and Taboada (1987) found that occurrences of flooding in Pampean plain in Argentina reduced electrical conductivity of soil by washing out the salts from soil.

5.1.2.3. Organic carbon

Organic carbon content varied from 0.28 per cent to 3.47 per cent with a mean of 1.1 per cent. About 64 per cent of soil samples had medium organic carbon content (Fig. 5.9). These results are in agreement with findings of Muraleedharan (1984) and Amritha and Durga Devi (2017), who found that organic carbon content in *kole* lands varied from 0.85 to 2.47 per cent. It was found that before flood organic carbon was low to medium in AEU 6 (GoK, 2013). After flood organic carbon was found medium to high and this may be due to deposition of silt or due to accumulation of organic

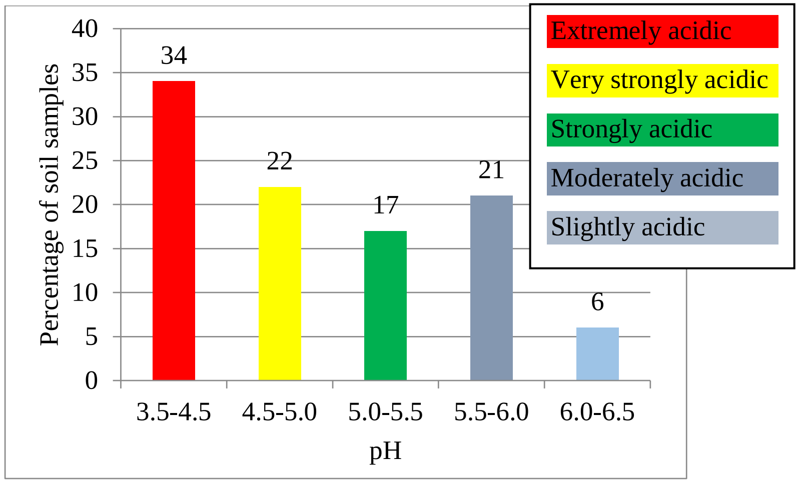

Fig 5.7. Percentage distribution of pH in AEU 6

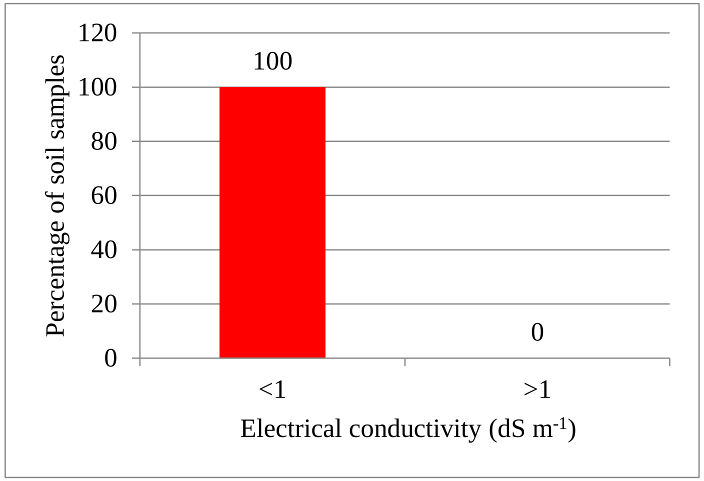

Fig. 5.8. Percentage distribution of electrical conductivity (dS m^{-1}) in AEU 6

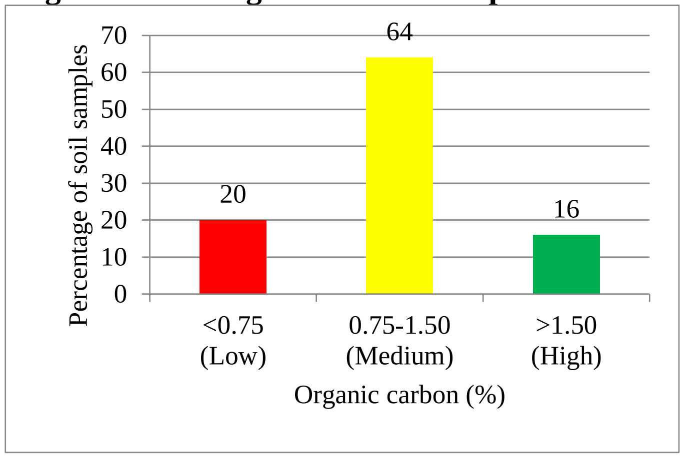

Fig. 5.9. Percentage distribution of organic carbon (%) in AEU 6

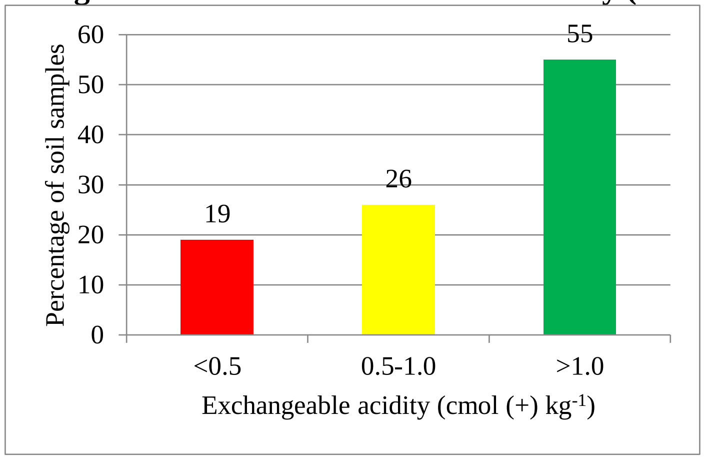

Fig. 5.10. Percentage distribution of exchangeable acidity (cmol (+) kg^{-1}) in AEU 6

matter after flood. Muraleedharan (1984) and Kavitha and Sujatha (2015) claimed that the high organic carbon content of *kole* land soils was due to high deposition of silt material washed down by rivers from the mountains. Yuana *et al*. (2020) observed extremely significant positive correlation with silt content, which showed that silt can contribute to organic carbon deposition. Dexter (2004) found that increased organic matter content also support increment in organic carbon content in soil.

5.1.2.4. Exchangeable acidity

Exchangeable acidity varied from 0.05 cmol (+) kg^{-1} to 2.2 cmol (+) kg^{-1} with a mean of 0.99 cmol (+) kg^{-1}. Fifty five per cent of soil collected from AEU 6 had exchangeable acidity more than 1 cmol (+) kg^{-1} (Fig. 5.10). The variation in exchangeable acidity might be due to high exchangeable hydrogen and aluminium ions in soil (Amalu and Okon, 2013). He also reported that in sandy soil with acidic reaction, exchangeable acidity was high due to excess aluminium. Beena and Thampatti (2013) found that exchangeable acidity varied with the nature of soil and base saturation. Low pH and high content of exchangeable aluminium contribute to high exchangeable acidity in *kole* lands. Similar findings were also done by Spears and Lajtha (2004).

5.1.2.5. Available nitrogen

Available N in AEU 6 ranged from 92.13 kg ha^{-1} to 1113.62 kg ha^{-1} with a mean of 704.59 kg ha^{-1}. Seventy seven per cent of soil samples collected from *kole* lands showed high content of available nitrogen (Fig. 5.11). The high content of nitrogen in *kole* lands might be due to the occurrence of high organic matter. This was in accordance with findings of Batjes (1996) and Morisada and Kanomata (2004). Amritha and Durga Devi (2017) observed that *kole* lands show superiority in available nitrogen due to high content of organic matter.

5.1.2.6. Available phosphorus

Available P ranged from 2.17 kg ha^{-1} to 101.39 kg ha^{-1} with a mean 17.81 kg ha^{-1}. Fifty five per cent of soils had medium in available P and 21 per cent showed high available P content, but 24 per cent of soils showed deficiency in phosphorus

(Fig. 5.12). Gallardo (2003) and Amery and Smolders (2012) found that flooding increased the phosphorus availability due to release of phosphorus bound to iron during reduction of Fe (III) to Fe (II). According to Stewart and Sharpley (1987) fixation of P occurs in soils having toxic Al and Fe contents. Same trend was also reported by Mamathashree *et al.* (2018). Penn and Camberato (2019) agreed with these results and also stated that low pH contribute to P fixation. The deficiency of P might be due to fixation of phosphorus or loss of available P by washing out during flood.

The phosphorus was found high before flood (GoK, 2013). But after the flood, the status of phosphorus changed to medium to high. Kalshetty *et al*. (2012) found a decline in P availability after flooding. This may be due to loss of P by dissolution in flood water. Similar findings were done by Djodjic *et al*. (2004).

5.1.2.7. Available potassium

Available potassium varied from 30.42 kg ha^{-1} to 684.03 kg ha^{-1} with an average of 196.04 kg ha^{-1}. Among the 100 soil samples, 44 per cent had medium potassium content and 21 per cent had high available potassium content. Low available potassium was observed in 39 per cent of soils in AEU 6 (Fig. 5.13). Potassium deficiency in *kole* lands were reported by Johnkutty and Venugopal (1993). Out of six samples collected from *kole* lands, four samples showed potassium deficiency. Ubuoh *et al.* (2016) found that flood affected farm fields of Abakaliki, Nigeria, showed a decline in availability of potassium content. About 65 per cent of soils were adequate in available potassium. This might be due to variation in mineral compostion, high cation exchange capacity and clayey texture of soil. Similar finding was reported by Afari-Sefa (2004).

No significant difference was found in available potassium status in soil after the incidence of flood (GoK, 2013).

5.1.2.8. Available calcium

Available calcium varied from 5.29 mg kg^{-1} to 1600.92 mg kg^{-1} with a mean of 400.97 mg kg^{-1}. Among the total 100 samples, 64 per cent of soils were sufficient in available calcium (Fig. 5.14). However, 36 per cent of soil showed deficiency in

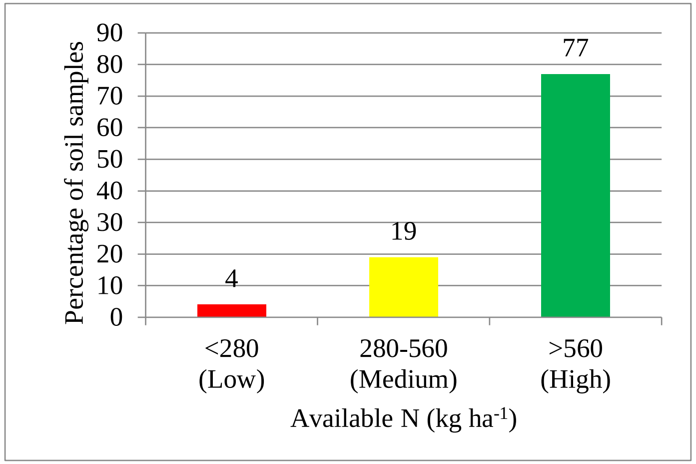

Fig. 5.11. Percentage distribution of available N (kg ha^{-1}) in AEU 6

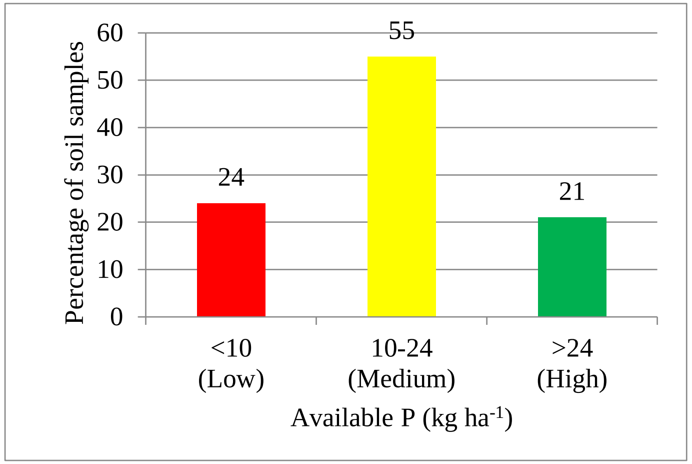

Fig. 5.12. Percentage distribution of available P (kg ha^{-1}) in AEU 6

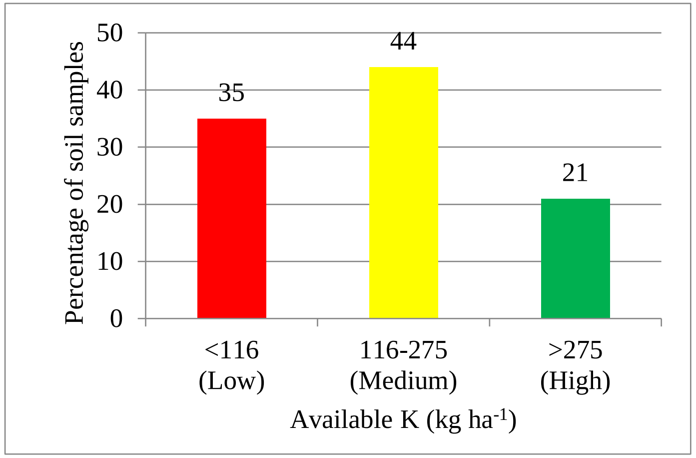

Fig. 5.13. Percentage distribution of available K (kg ha^{-1}) in AEU 6

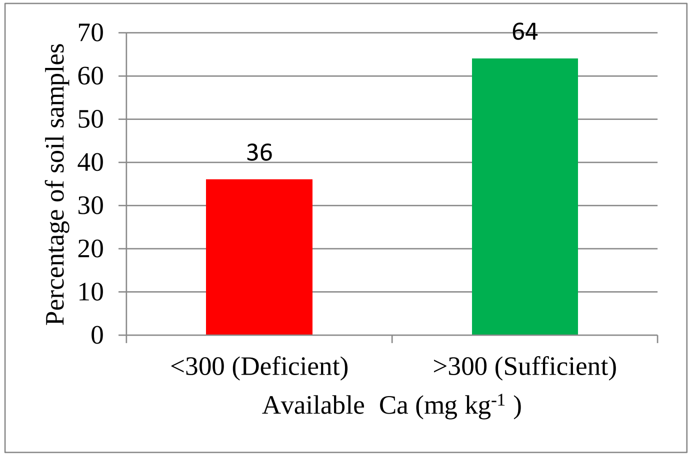

Fig. 5.14. Percentage distribution of available Ca (mg kg^{-1}) in AEU 6

available Ca. This may be due to the low pH associated with sandy texture of soil which promotes leaching of calcium (Zharare *et al*., 2009).

5.1.2.9. Available magnesium

Available Mg in *kole* lands varied from 3.61 mg kg^{-1} to 374.46 mg kg^{-1} with a mean of 103.41 mg kg^{-1}. Seventy three per cent of soil samples collected from AEU 6 was deficient in available Mg (Fig. 5.15). This is in conformity with findings of Irene (2014). She reported that available magnesium showed extreme deficiency in AEU 6. Since magnesium is deficient in soil, application of magnesium fertilizers are recommended after every cropping season. The deficiency of magnesium might be due to low soil reaction. Sureshkumar and Sandeep (2015) reported that magnesium solubility was higher when pH of soil fell below 7.5. They found that magnesium depletion was a common occurrence in acidic soils due to higher instability of magnesium minerals in acidic condition.

5.1.2.10. Available sulphur

Available sulphur varied from 4.46 mg kg^{-1} to 53.16 mg kg^{-1} with a mean of 21.20 mg kg^{-1}. Available sulphur was found sufficient in 88 per cent of soil samples in AEU 6 (Fig. 5.16). Rajasekharan *et al.* (2014) reported that available sulphur was sufficient in Kerala soil except coastal soils which showed deficiency. Sufficiency of sulphur in Kerala soils is due to excess application of sulphur fertilizers in fields. Irene (2014) observed a mean value of 34.28 mg kg^{-1} of sulphur in *kole* lands before cropping season and no sulphur deficiency was reported. Sureshkumar and Sandeep (2015) stated that soils with high organic matter provide sufficient level of sulphur. However, 11 per cent of soils showed sulphur deficiency. This might be due to formation of insoluble FeS in reduced condition (Fageria *et al.,* 2011) or due to increased leaching of sulphur in sandy soils (Camberato and Casteel, 2017).

5.1.2.11. Available iron

The available iron content ranged from 15.06 mg kg^{-1} to 3851.06 mg kg^{-1} with a mean of 660.72 mg kg^{-1}. Available Fe content was very high in AEU 6 (Fig. 5.17). The results support the findings of Muraleedharan (1984), who reported iron toxicity

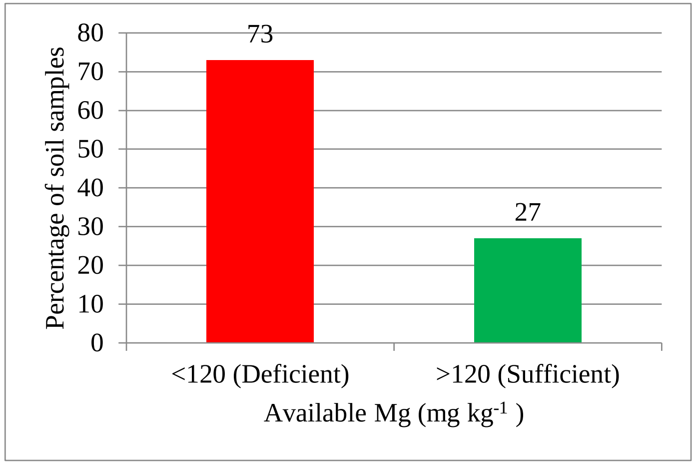

Fig. 5.15. Percentage distribution of available Mg (mg kg^{-1}) in AEU 6

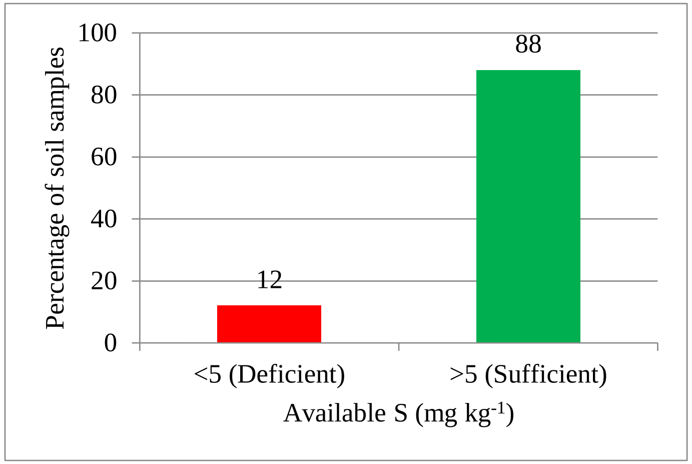

Fig. 5.16. Percentage distribution of available S (mg kg^{-1}) in AEU 6

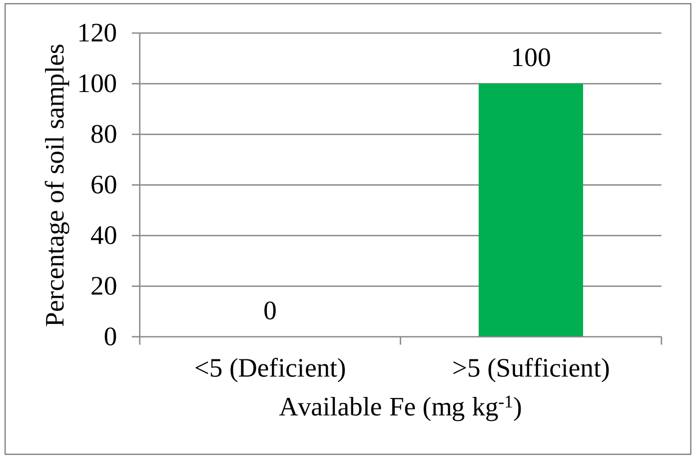

Fig. 5.17. Percentage distribution of available Fe (mg kg^{-1}) in AEU 6

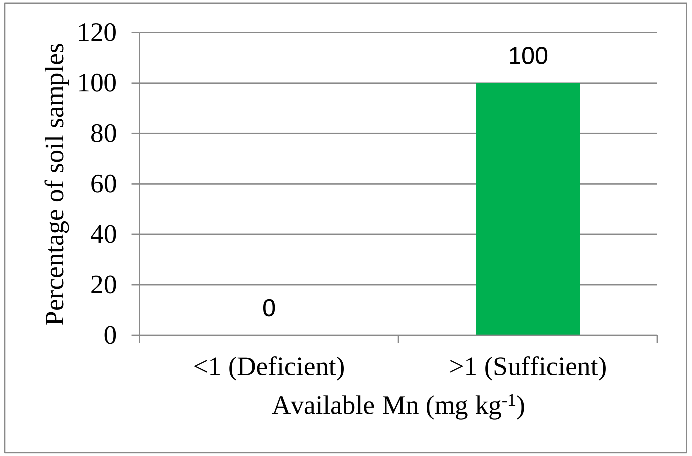

Fig. 5.18. Percentage distribution of available Mn (mg kg^{-1}) in AEU 6

in *kole* lands. Fageria *et al*. (2011) observed that submergence occurred by flooding increased the Fe content in soil by its reduction. Hike in Fe concentration (up to 500 mg kg^{-1}) and development of bronzing symptom in rice was also observed by Sahrawat (2004) under submergence.

5.1.2.12. Available manganese

The available manganese content ranged from 3.2 mg kg^{-1} to 73.76 mg kg^{-1} with a mean of 19.26 mg kg^{-1}. Available Mn status was found sufficient in soils of AEU 6 (Fig. 5.18). This may be due to release of available Mn during flood. Amarawansha *et al*. (2015) claimed that available manganese content increased due to flood. During flooding Mn^{4+} reduced to Mn^{2+} and this leads to increased solubilisation of manganese in soil.

5.1.2.13. Available zinc

Available zinc ranged from 1.02 mg kg^{-1} to 9.93 mg kg^{-1} with an average of 2.66 mg kg^{-1}. There was no Zn deficiency in AEU 6 (Fig. 5.19). Available Zn was adequate in 89 per cent of soil before flood (GoK, 2013), after flood it was found that available zinc status increased to 100 per cent of samples. The sufficiency in zinc availability might be due to low pH and high organic matter content in soil. Flooding might had been increased organic matter content in soil by deposition carried from higher elevations. This is in agreement with findings of Robertson and Lucas (1981).

5.1.2.14. Available copper

The available Cu content ranged from 0.44 mg kg^{-1} to 14.77 mg kg^{-1} with a mean of 2.99 mg kg^{-1}. Among the 100 samples, 83 per cent of soils had sufficient available Cu (Fig. 5.20). The increased availability of copper might be due to the effect of flooding. During flooding, reduction of hydrous oxides of Fe and Mn and the production of organic complexing agents would have increased the solubility of copper. This corroborated the findings of Sahrawat (2004) and Akpoveta *et al*. (2014).

5.1.2.15. Available boron

Available B was found deficient in all the soil samples (Fig. 5.21). It ranged from 0.01 mg kg^{-1} to 0.27 mg kg^{-1} with a mean of 0.08 mg kg^{-1}. Before flood, available B

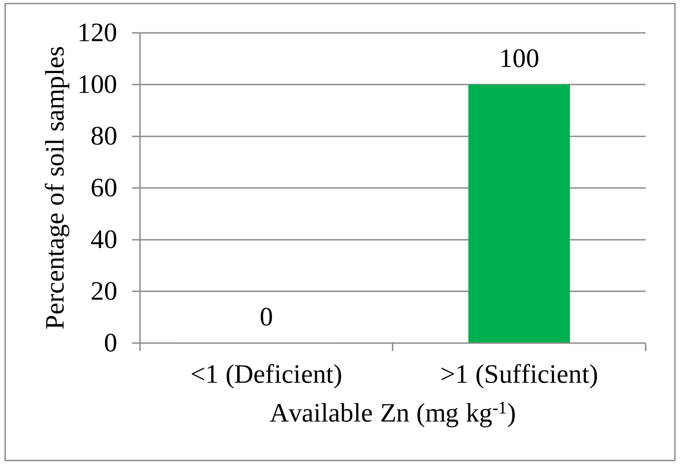

Fig. 5.19. Percentage distribution of available Zn (mg kg^{-1}) in AEU 6

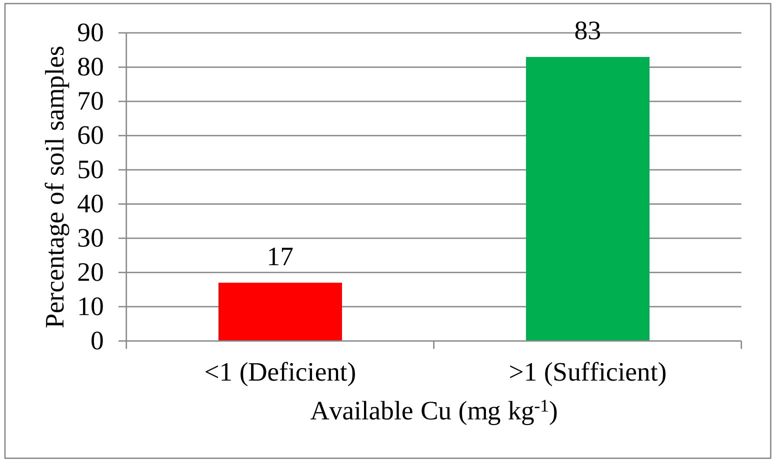

Fig. 5.20. Percentage distribution of available Cu (mg kg^{-1}) in AEU 6

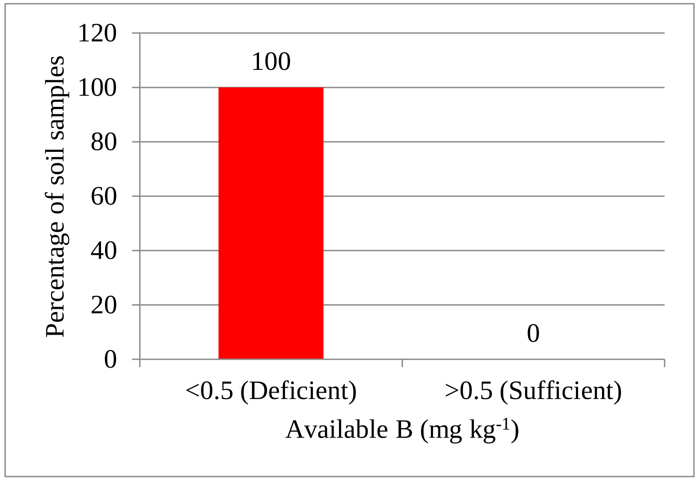

Fig. 5.21. Percentage distribution of available B (mg kg^{-1}) in AEU 6

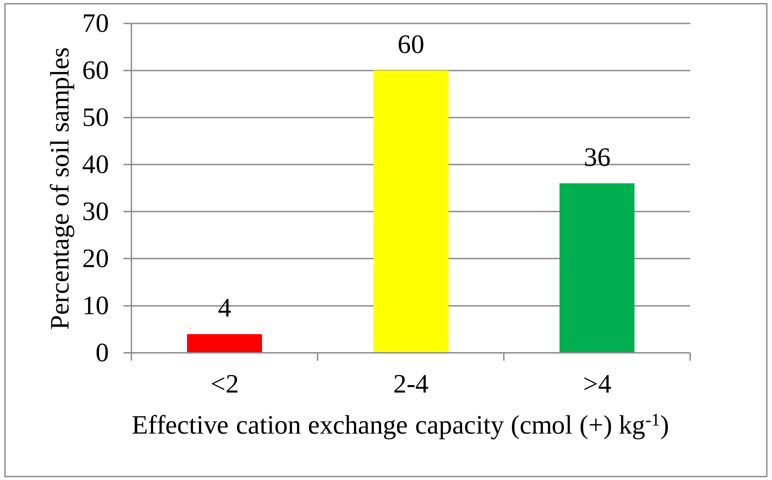

Fig. 5.22. Percentage distribution of effective cation exchange capacity (cmol (+) kg^{-1}) in AEU 6

found adequate in 58 per cent of soils (GoK, 2013). The acidic reaction in soil coupled with excessive leaching during flooding increased boron deficiency. This was supported by the findings of Rajasekharan *et al*. (2014) and Kavitha *et al.* (2019). According to them Kerala soils were highly deficient in available boron content due to acidic nature of soil and acid leaching environment of Kerala soils is not conducive for retention of boron.

5.1.2.16. Effective cation exchange capacity (ECEC)

The ECEC ranged from 0.62 cmol (+) kg^{-1} to 9 cmol (+) kg^{-1} with a mean value of 3.82 cmol (+) kg^{-1}. Sixty per cent of soil samples collected from AEU 6 has ECEC of 2 to 4 cmol (+) kg^{-1} and about 36 per cent had more than 4 cmol (+) kg^{-1} (Fig. 5.22). The variation in ECEC might be due to variation in amount of exchangeable ions such as Na, K, Ca and Mg and also might be due to excess aluminium and hydrogen ions in exchangeable sites. Similar findings were done by Amalu and Okon (2013). According to Kirk *et al*. (2003) and Favre *et al*. (2004), flooding for long-time increased ECEC due to strong reducing conditions. They attributed this increase was due to the reduction of structural Fe and the solubilization of Fe (hydr)oxide coatings from clay surface.

5.1.3. Biological attributes

5.1.3.1. Dehydrogenase activity

Dehydrogenase activity ranged from 65.54 µg TPF g^{-1} 24 hr^{-1} to 1909.59 µg TPF g^{-1} 24 hr^{-1} with a mean of 594.68 µg TPF g^{-1} 24 hr^{-1}, indicating a high dehydrogenase activity in *kole* lands (Fig. 5.23). Amritha and Durga Devi (2017) observed that soils collected from paddy fields of *kole* lands had high dehydrogenase activity. According to them dehydrogenase activity was high in soils with high organic matter content. This might be due to the supply of sufficient substrate to support microorganisms and their enzyme production (Yuan and Yue, 2012). McLatchey and Reddy (1998) observed high dehydrogenase activity under reduced system. George *et al.* (2017) also observed increased dehydrogenase activity by flooding.

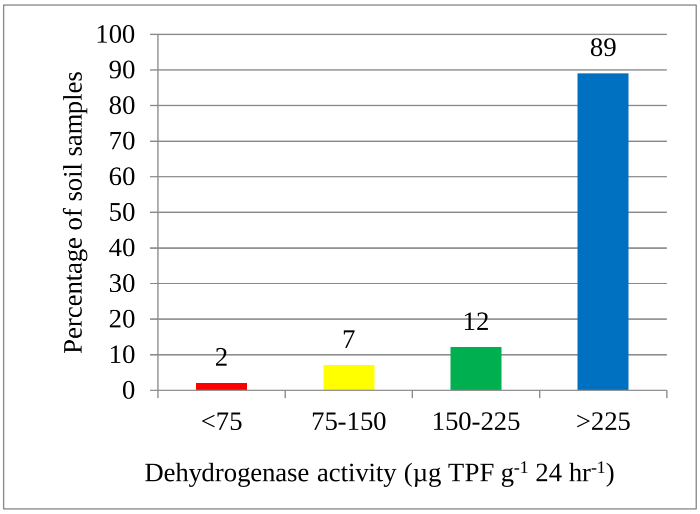

Fig. 5.23. Percentage distribution of dehydrogenase activity (µg TPF g^{-1} 24 hr^{-1}) in AEU 6

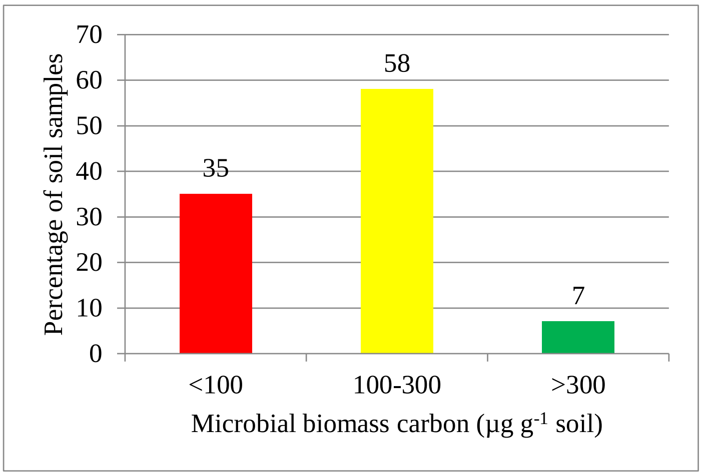

Fig. 5.24. Percentage distribution of microbial biomass carbon (µg g^{-1} soil) in AEU 6

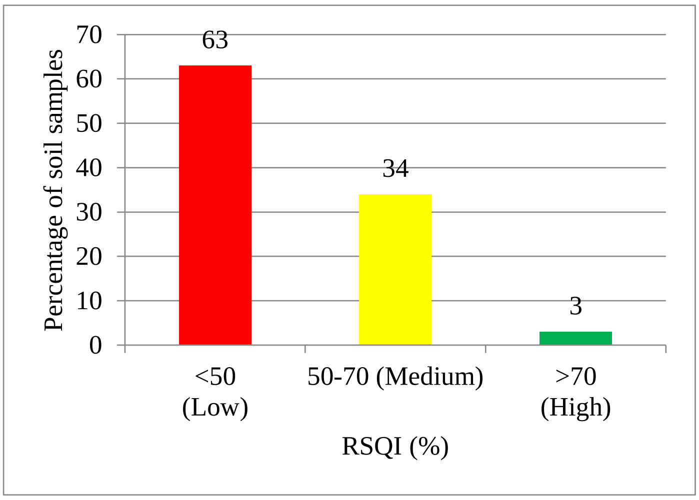

Fig. 5.25. Percentage distribution of relative soil quality index (%) in AEU 6

5.1.3.2. Microbial biomass carbon

Microbial biomass carbon content ranged from 6.47 to 383.26 µg g^{-1} soil with a mean value of 158.58 µg g^{-1} soil. About 58 per cent of soil samples collected from AEU 6 were medium in microbial biomass carbon and only 7 per cent with high microbial biomass carbon (Fig. 5.24). This might be due to sufficient organic matter content in soil which acts as a nutrient source for microorganisms. Amritha and Durga Devi (2017) observed high microbial biomass carbon content in soils collected from paddy fields of *kole* lands. However, 35 per cent of soil samples collected from AEU 6 was low in microbial biomass carbon. This variation in microbial biomass carbon might be due to low pH which affects microbial activity in soil (Vanhorn *et al*., 2013). According to George *et al.* (2017) anaerobic condition decreased microbial biomass carbon by decreasing microbial activity in soil.

5.1.2. RSQI

SQI developed in this study for AEU 6 varied from 0.28 to 0.78. Since there was no standard rating for SQI, RSQI was used to interpret the soil quality index of soil.

RSQI varied from 25.93 per cent to 72.22 per cent with a mean of 46.70 per cent. Sixty three per cent of soil collected from AEU 6 (*Kole* lands) were poor in soil quality, 34 per cent of soils with medium and only 3 per cent of soils with high soil quality (Fig. 5.25). The poor soil quality might be due to deficiency of boron coupled with toxicity of iron. Sandy texture of soil in coastal *kole* lands reduced the water and nutrient retention and would have contributed to poor SQI.

5.2. GENERATION OF MAPS USING GIS

Geo referenced thematic maps were developed using IDW (Inverse distance weighted) tool Arc GIS software. Major nutrients like available N, P, K and pH of soil were mapped along with relative soil quality index.

Spatial distribution of pH in AEU 6 (Fig. 5.26) revealed extreme acidity in Perumpadappu and Mullassery block panchayats and very strongly acidic soil in Irinjalakkuda, Anthikkad, Mullassery, Perumpadappu and Ponnani block panchayats.

Spatial distribution of available N in AEU 6 (Fig. 5.27) showed that all the block panchayats except Perumpadappu and Cherpu block panchayats were high in available N.

Spatial distribution of available P in AEU 6 was illustrated in Fig. 5.28. Available P low in Irinjalakkuda block panchayat and high in Mullassery block panchayat, while all other block panchayats were medium in available P status.

Spatial distribution of available K (Fig. 5.29) high in Perumpadappu block panchayat and low in Irinjalakkuda block panchayat, whereas all other block panchayats were medium in available K status.

Spatial distribution of relative soil quality index in AEU 6 was illustrated in Fig. 5.30. Mullassery and Anthikkad block panchayats were observed medium in relative soil quality index, while all other block panchayats were low in relative soil quality index.

5.3. NUTRIENT INDEX

Nutrient index of nitrogen varied from 2.2 to 3, with high values in Mullassery, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani block panchayats whereas with medium values in Cherpu block panchayat. Most of the samples collected from Mullassery, Anthikkad, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani block panchayat were high in available nitrogen, while in Cherpu block panchayat, most of the soil samples collected had low and medium status in available nitrogen compared to others (Fig. 5.31).

Nutrient index of phosphorus in *kole* lands varied from 1.53 to 2.6. It was low in both Irinjalakkuda block panchayat and Cherpu block panchayat, medium in Anthikkad, Puzhakkal, Perumpadappu and Ponnani block panchayats and high in Mullassery block panchayat. The low nutrient index of P in Irinjalakkuda block panchayat and Cherpu block panchayat might be due to the high deficiency of P,

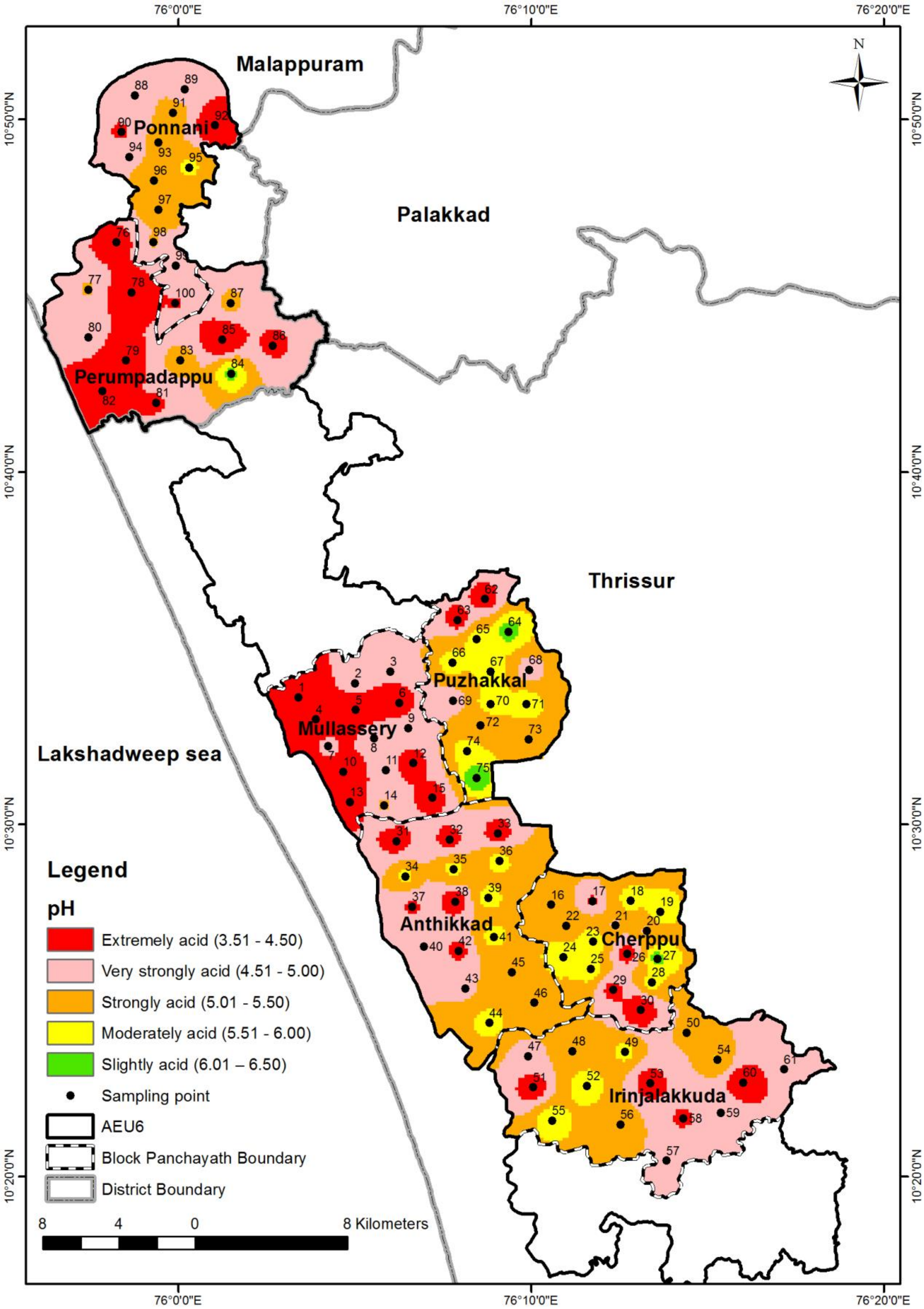

Fig. 5.26. Spatial distribution of pH in AEU 6

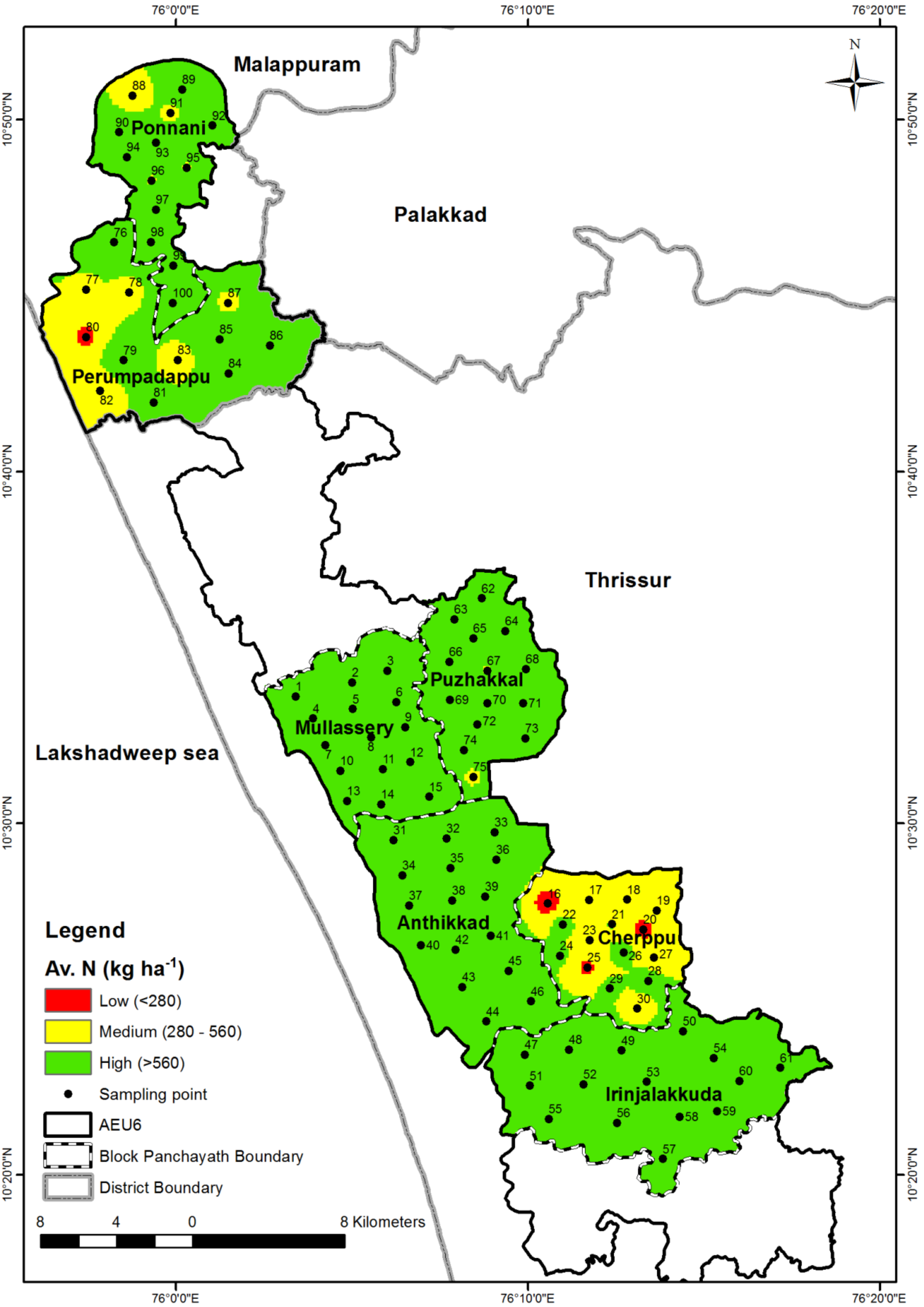

Fig. 5.27. Spatial distribution of available N in AEU 6

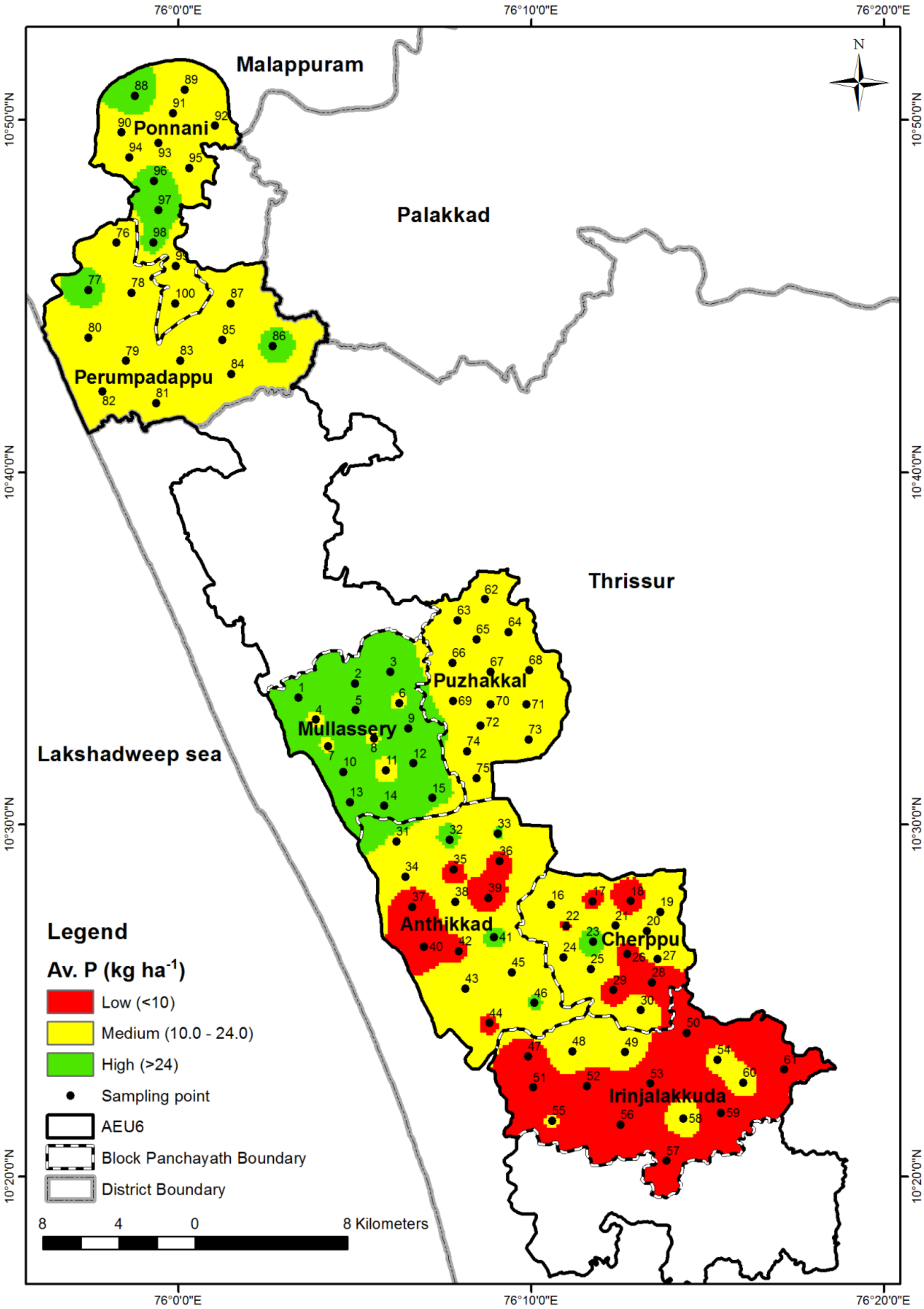

Fig. 5.28. Spatial distribution of available P in AEU 6

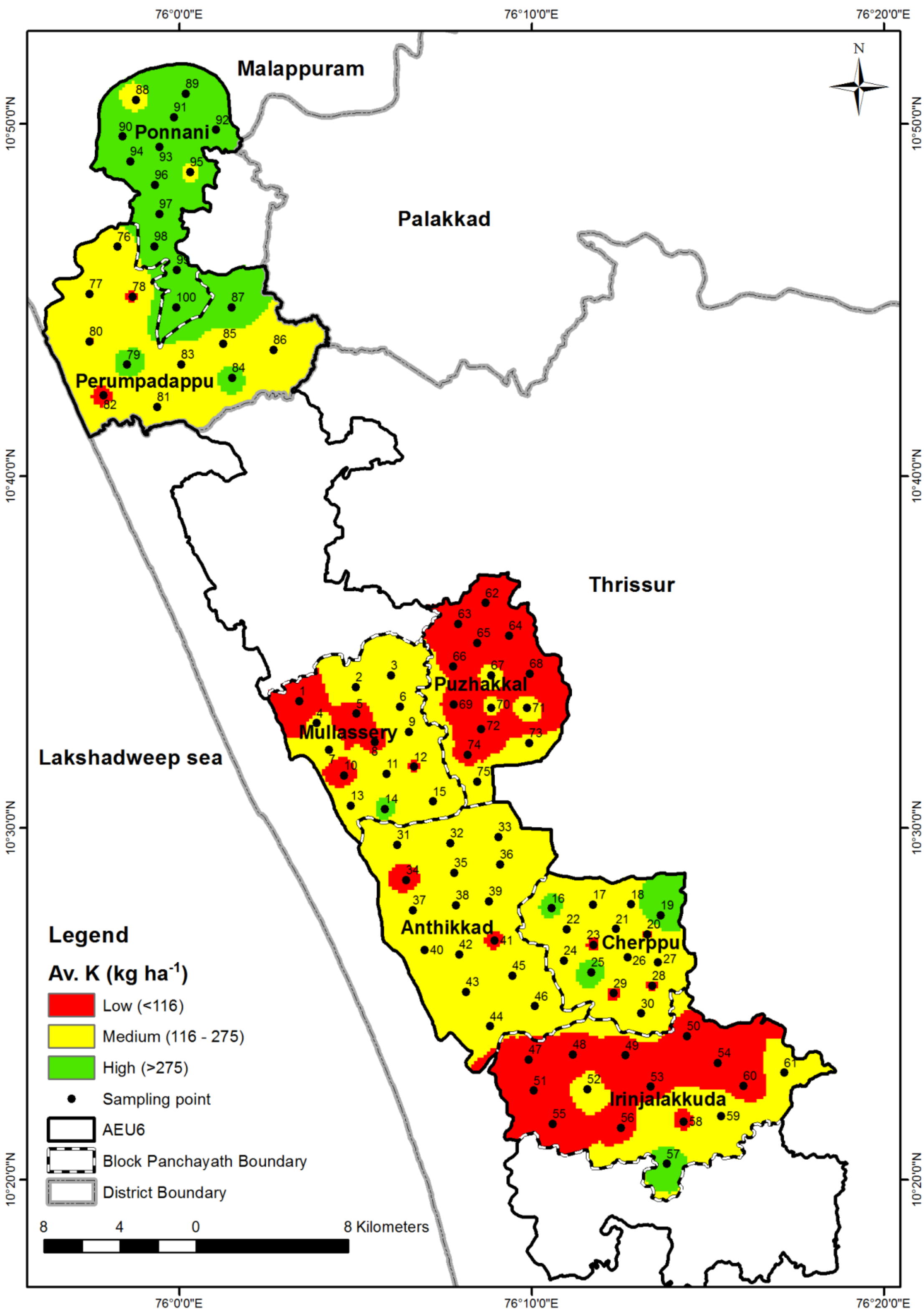

Fig. 5.29. Spatial distribution of available K in AEU 6

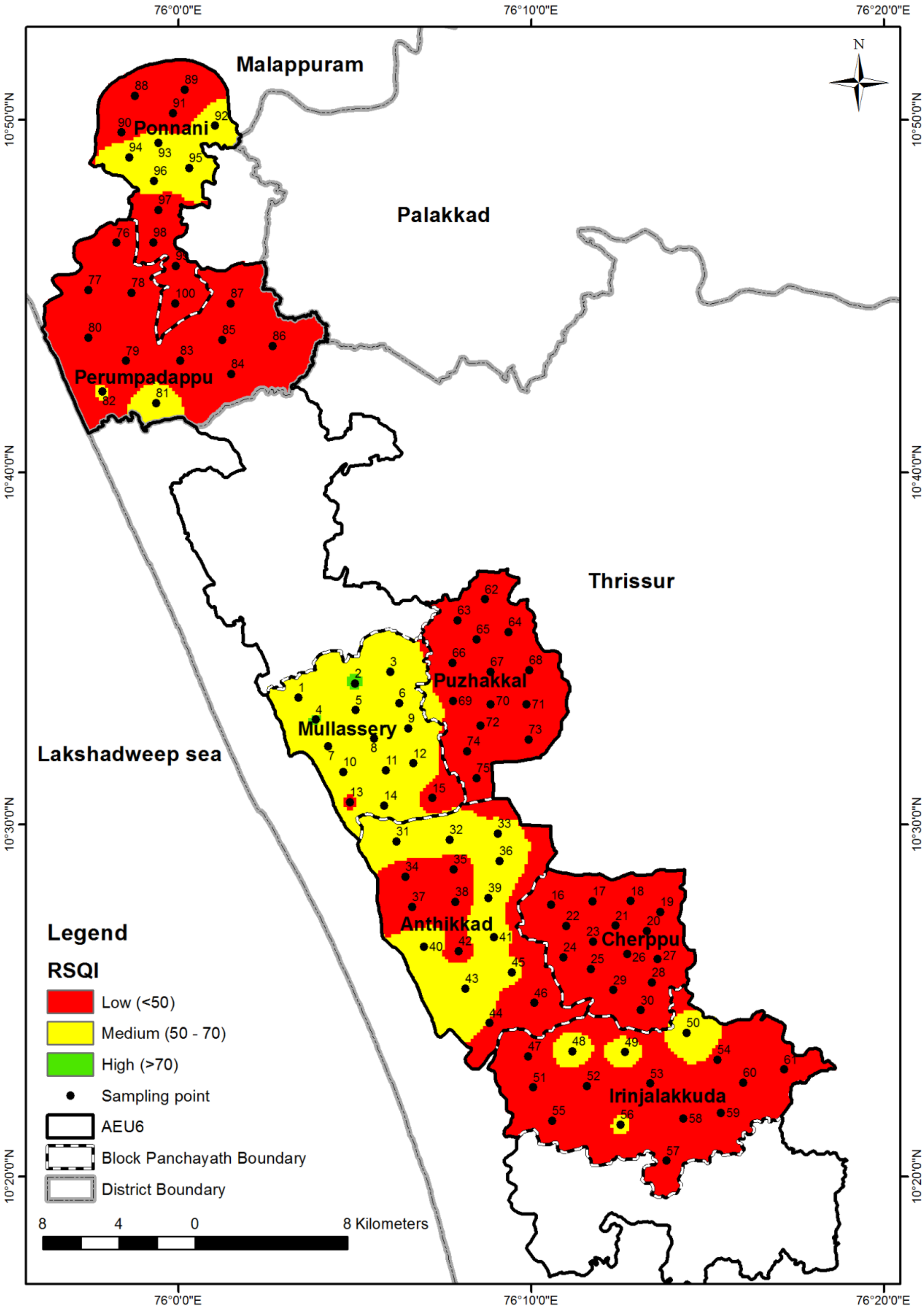

Fig. 5.30. Spatial distribution of RSQI in AEU 6

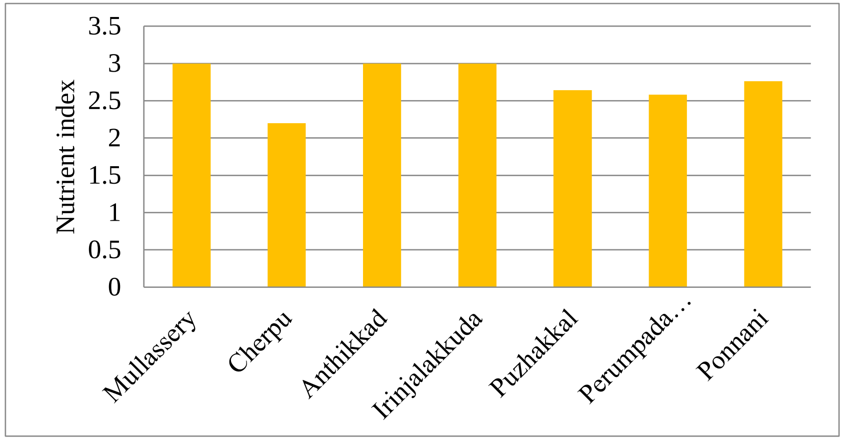

Fig. 5.31. Nutrient index of N in block panchayats of AEU 6

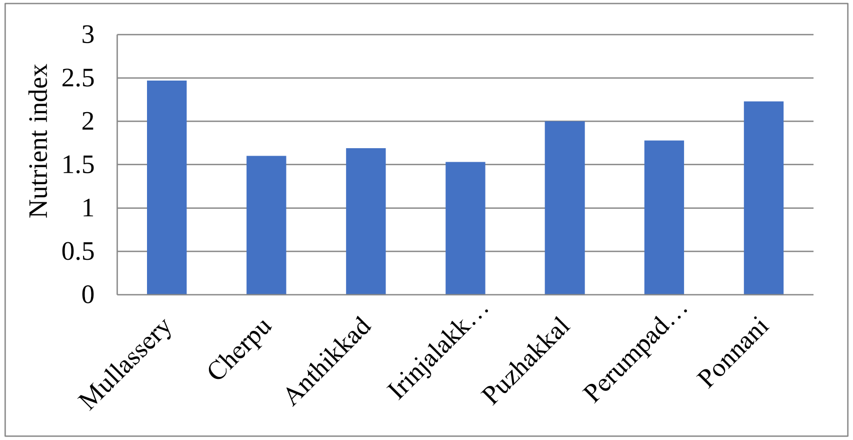

Fig. 5.32. Nutrient index of P in block panchayats of AEU 6

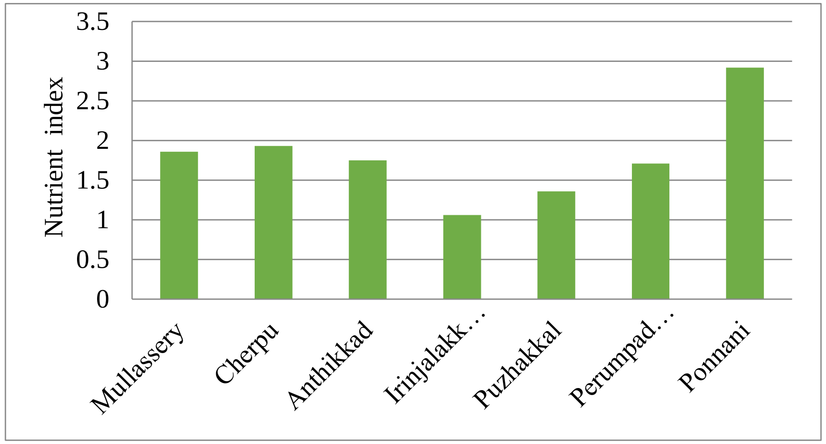

Fig. 5.33. Nutrient index of K in block panchayats of AEU 6

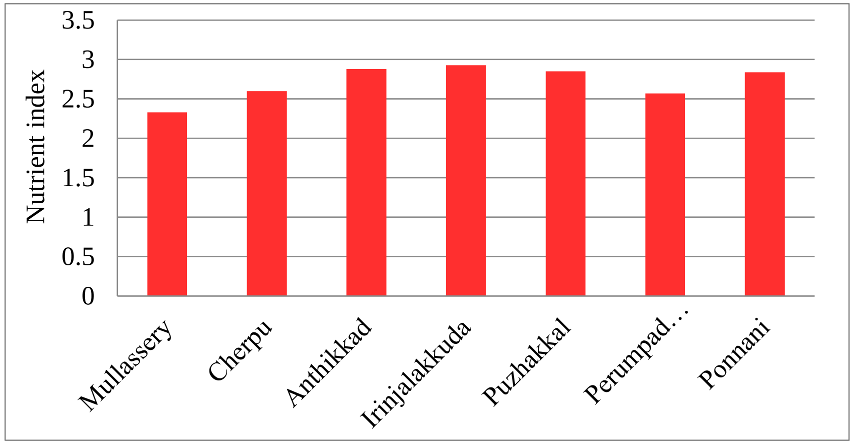

Fig. 5.34. Nutrient index of organic carbon in block panchayats of AEU 6

whereas in Mullassery block panchayat, the high nutrient index was associated with its medium and high content (Fig. 5.32).

Nutrient index of potassium varied from 1.33 to 2.69, with high values in Ponnani block panchayat and medium in Mullassery, Cherpu, Anthikkad and Perumpadappu block panchayats and low in Irinjalakkuada and Puzhakkal block panchayats (Fig. 5.33). The variation in nutrient index of K was due to the change in available K content in soil. The higher nutrient index of K in Ponnani block panchayat was associated with absence of deficiency of this nutrient.

Nutrient index of organic carbon varied from 1.53 to 2.13 (Fig. 5.34), and it was high in all block panchayats except in Mullassery block panchayat where it was medium. In all the block panchayat except Mullassery, most of the samples collected were higher in organic carbon content.

5.4. CORRELATION BETWEEN PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS

Significant positive correlations were observed between organic carbon and soil moisture content, organic carbon and available nitrogen. Correlation between soil moisture and organic carbon had also been reported by Behera and Shukla (2014). Correlation study revealed the existence of positive correlation between organic carbon and available nitrogen. These were in agreement with findings of Doran (1996), Pradeep *et al*. (2006) and Hojati and Nourbakhsh (2006).

A negative correlation existed between bulk density and porosity and organic carbon and bulk density. Celik (2005) also reported a decrease in bulk density with increased soil porosity. Reintam *et al*. (2005) and Karami *et al.* (2012) and also reported same trend between bulk density and porosity. Chaudhari *et al*. (2013) observed negative correlation between organic carbon and bulk density of soil.

5.5. GENERAL RECOMMENDATIONS FOR NUTRIENT MANAGEMENT

Site specific and integrated nutrient management can be recommended in each site based on soil test values. A general recommendation of nutrients and soil characteristics for each block panchayats is listed below (Table 5.1).

Table 5.1. Soil characteristics and general recommendation of nutrients in block panchayats in AEU 6

Block panchayats	Nutrient status of soil	Recommendations
Mullassery	• pH - extremely acidic • OC – Medium • P - High • K - Medium	• Application of lime (850 kg ha^{-1}) • Application of organic matter • N - 91 % of general recommendation • P - 25 % of general recommendation • K - 94 % of general recommendation • Mg application after every cropping season (100 kg $MgSO_4$ ha^{-1}) • B - 25 kg Borax ha^{-1} or 0.5 % solution of Borax
Cherpu	• pH - Strongly acidic • OC – Medium • P - Medium • K - Medium • Ca - Deficient	• Application of lime (350 kg ha^{-1}) • Application of organic matter • N - 91 % of general recommendation • P - 83 % of general recommendation • K - 71 % of general recommendation • Mg application after every cropping season (100 kg $MgSO_4$ ha^{-1}) • B - 25 kg Borax ha^{-1} or 0.5 % solution of Borax

Anthikkad	• pH - Very strongly acidic • OC - Medium • P - Medium • K- Medium	• Application of lime (600 kg ha^{-1}) • Application of organic matter • N - 84 % of general recommendation • P - 83 % of general recommendation • K - 83 % of general recommendation • Mg application after every cropping season (100 kg $MgSO_4$ ha^{-1}) • B - 25 kg Borax ha^{-1} or 0.5 % solution of Borax
Irinjalakkuda	• pH - Strongly acidic • OC - Medium • P - Low • K-Low	• Application of lime (350 kg ha^{-1}) • Application of organic matter • N - 84 % of general recommendation • P - 106 % of general recommendation • K - 116 % of general recommendation • Mg application after every cropping season (100 kg $MgSO_4$ ha^{-1}) • B - 25 kg Borax ha^{-1} or 0.5 % solution of Borax
Puzhakkal	• pH - Strongly acidic • OC - Medium • P - Medium	• Application of lime (350 kg ha^{-1}) • Application of organic matter • N - 84 % of general recommendation

	• K - Low	• P - 83 % of general recommendation • K - 106 % of general recommendation • Mg application after every cropping season (100 kg $MgSO_4$ ha^{-1}) • B - 25 kg Borax ha^{-1} or 0.5 % solution of Borax
Perumpadappu	• pH - Very strongly acidic • OC - Medium • P - Medium • K - Medium	• Application of lime (600 kg ha^{-1}) • Application of organic matter • N - 84 % of general recommendation • P - 71 % of general recommendation • K - 94 % of general recommendation • Mg application after every cropping season (100 kg $MgSO_4$ ha^{-1}) • B - 25 kg Borax ha^{-1} or 0.5 % solution of Borax
Ponnani	• pH - Strongly acidic • OC – Medium • P - Medium • K - Medium	• Application of lime (350 kg ha^{-1}) • Application of organic matter • N - 84 % of general recommendation • P - 83 % of general recommendation • K - 94 % of general recommendation

		• Mg application after every cropping season (100 kg $MgSO_4$ ha^{-1}) • B - 25 kg Borax ha^{-1} or 0.5 % solution of Borax

Summary

6. SUMMARY

A study on "Assessment of soil quality in the post flood scenario of AEU 6 in Thrissur and Malappuram districts of Kerala and mapping using GIS techniques" was carried out during 2018-2020 with an objective to assess the soil quality of post flood soils of AEU 6 in Thrissur and Malappuram districts and to develop maps on soil characters and quality using GIS techniques and to workout soil quality index.

A survey was carried out to identify the flood affected locations in *kole* lands. Hundred georeferenced composite soil samples were collected from seven block panchayats *viz*., Mullassery, Anthikkad, Cherpu, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani of Thrissur and Malappuram districts. The soil samples collected from post flood soils of *kole* lands were analysed for different physical, chemical and biological quality indicators and findings of investigations are summarised here.

The bulk density of soil varied from 0.53 to 1.34 Mg m^{-3} and particle density from 2.05 to 2.67 Mg m^{-3}. Porosity of soils of *kole* lands were very high and it varied from 44.34 to 78.21 per cent. Maximum water holding capacity of soil extended from 18.11 to 73.49 per cent, while soil moisture content ranged from 12.00 to 41.60 per cent. Soil moisture content, water holding capacity and mean weight diameter was high in AEU 6. Bulk density, particle density, porosity, maximum water holding capacity and aggregate stability of the soil samples did not differ significantly between the block panchayats whereas it was reverse in the case of soil moisture.

All the soil samples collected from AEU 6 showed acidic soil reaction. Addition of lime can be recommended to ameliorate soil acidity. Electrical conductivity in AEU 6 was below the toxicity level. The organic carbon had been shifted towards medium to high from low to medium after the flood. The exchangeable acidity varied from 0.05 to 2.2 cmol (+) kg^{-1}. Available nitrogen content was high in most of the soil samples whereas available phosphorus medium in 55 per cent of soil and high in 21 per cent of soils. The high content of available phosphorus before flood had changed to medium to high after flood. Available potassium was medium to high in 65 per cent of soil samples. Among the secondary nutrients, available calcium was sufficient in 64 per cent of soils. Deficiency of available magnesium was severe in *kole* lands. Available sulphur was sufficient in 89 per cent of soil. Among micro nutrients available Fe, Mn and Zn was high in AEU 6. Available Zn was adequate in 89 per cent of soil before flood, while it increased to 100 per cent of samples after flood. Available copper was sufficient in 83 per cent of soil, whereas available boron was deficient in all the soil samples. Effective cation exchange capacity of soil in AEU 6 varied from 0.62 to 9 cmol (+) kg^{-1}. Soil pH, electrical conductivity, available P, S, Fe, Zn and Cu were found significantly different among block panchayats in AEU 6, whereas organic carbon content, available N, K, Ca, Mg, Mn, B and effective cation exchange capacity were found on par in all the block panchayats in AEU 6.

Among the biological attributes, *kole* lands showed high dehydrogenase activity while microbial biomass carbon was medium in 58 per cent of soil samples. Microbial biomass carbon in AEU 6 was significantly different among the block panchayats.

Available Ca, S, N, porosity, exchangeable acidity, available Fe, Zn, particle density and available B formed the minimum data set for soil quality index. Soil quality index varied from 0.28 to 0.78. The highest mean soil quality index was recorded in Mullassery block panchayat, and the lowest in Cherpu block panchayat. Relative soil quality index varied from 25.93 to 72.22 per cent. The highest RSQI was recorded in Elamutha of Mullassery block panchayat and the lowest in Ponnani *kole* padavu 2 of Ponnani block panchayat. In AEU 6, 63 per cent of soils were poor in soil quality, 34 per cent medium in soil quality and 3 per cent with high soil quality.

Nutrient index of nitrogen was high in all block panchayats except Cherpu. Nutrient index of phosphorus was high in Mullassery block panchayat, whereas nutrient index of potassium was found high in Ponnani block panchayat. Nutrient index of organic carbon was high in all block panchayats except in Mullassery block panchayat where it was found medium.

Significant positive correlations were observed between electrical conductivity and available K, organic carbon and available nitrogen. Negative correlation existed between bulk density and porosity, organic carbon and bulk density.

The post flood study in *kole* lands revealed that drastic changes in soil environment had occurred with more than 50 per cent of soils showing low quality. The poor soil quality in AEU 6 might be due to toxicity of available Fe, deficiency of available boron and shift of soil physical properties from the optimum values. Hence, proper adoption of site specific soil management practices are essential to curb the soil fertility decline of *kole* lands.

References

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Appendices

Appendix I : Results of soil analysis

a. **Bulk density (Mg m^{-3}), particle density (Mg m^{-3}) and porosity (%) of soil samples in different sites of *kole* lands**

Sl No.	Block panchayats	Name of *kole* padavu	Bulk density	Particle density	Porosity
1	Mullassery	Ponnamutha	0.81	2.10	61.53
2		Elamutha	0.77	2.66	71.00
3		Mathukkara thekk	0.80	2.45	67.29
4		Pavudai	0.80	2.63	69.44
5		Parappadam kizhakkethala	0.72	2.34	69.15
6		Parappadam west	0.88	2.53	65.28
7		Penakam	0.82	2.48	66.96
8		Elavathur	0.73	2.31	68.44
9		Cherotha akkarapadam	0.76	2.08	63.41
10		Peruvalloor padav	0.82	2.66	70.32
11		Kaniyamthuruth	0.89	2.41	57.07
12		Annakkara chirakkal	1.16	2.49	53.35
13		Annakkara vadakk	1.14	2.34	51.09
14		Thanneerkayal	1.03	2.45	57.89
15		Pulipandi	0.88	2.47	64.16
16	Cherpu	Manakkal padavu	0.75	2.26	66.85
17		Madhammathopp	0.83	2.39	65.26
18		Nerkathir	0.72	2.56	72.06
19		Kanimangalam *kole* padav	0.89	2.22	59.65
20		Karimbatta	0.97	2.54	61.55
21		Kizhakkan *kole* padavu	1.07	2.50	57.17
22		Cheeyaram samajam	0.99	2.28	56.42

23		Avinissery samajam	0.64	2.25	71.55
24		Kodannur *kole* farming society	1.02	2.65	64.45
25		Pallippuram *kole* padav	1.01	2.11	52.30
26		Pandaran *kole*	1.02	2.38	57.02
27		Chovvoorthazham alukka padav	1.01	2.66	61.96
28		Jubilee thevar padav	0.88	2.16	59.40
29		Perumkulam east	0.84	2.24	62.49
30		Perumkulam west	1.06	2.60	59.00
31	Anthikkad	Chaladi pazhan *kole* 1	1.00	2.21	54.86
32		Themalippuram	0.87	2.35	62.78
33		Rajamukk	1.06	2.34	54.47
34		Arumuri	1.3	2.34	44.34
35		Manaloorthazham	1.02	2.52	59.38
36		Kodayatti	1.13	2.64	57.33
37		Ayyappan *kole*	0.97	2.11	54.18
38		Pazhuvil bund *kole*	1.04	2.50	58.12
39		Chaladi pazhan *kole* 2	0.75	2.57	63.43
40		Chennakari puncha	0.97	2.37	55.64
41		Jubilee thevar padav	1.07	2.34	56.89
42		Pallippuram	0.99	2.53	57.50
43		Pullu	0.94	2.38	62.74
44		Vilakkumadam padav	1.00	2.54	58.05
45		Variyam *kole* padav	1.08	2.51	57.40
46		Chettupuzha east	0.9	2.34	63.94
47	Irinjalakkuda	Painkili kayal	0.78	2.41	66.46
48		Chemmanda kayal	0.79	2.57	67.23
49		Vellani *kole*	0.81	2.24	68.44
50		Thekkumoola	1.03	2.65	54.11

51		Karppullithara kakkad	0.78	2.54	70.63
52		Muriyaad	1.05	2.59	58.85
53		Kalladi thazham	1.07	2.61	58.71
54		Chithravallipadam	1.00	2.39	61.72
55		Kochipadam	1.06	2.61	55.53
56		Kadumkadu	0.81	2.54	70.23
57		Mothalakkulam	0.78	2.67	69.46
58		Koda *kole*	0.72	2.49	75.74
59		Konthikulam	1.06	2.66	57.30
60		Parappookkara	1.06	2.64	61.49
61		Nedumbal	0.99	2.65	62.58
62	Puzhakkal	Pullazhi *kole* 1	0.78	2.63	70.63
63		Pullazhi *kole* 2	0.77	2.15	70.77
64		Pannikkara kin *kole*	0.68	2.29	68.58
65		Ombathumuri 1	0.69	2.19	69.87
66		Ombathumuri 2	0.68	2.10	68.88
67		Kadavil *kole*	0.73	2.05	65.43
68		Pandaran *kole* 1	0.73	2.24	64.18
69		Pandaran *kole* 2	0.76	2.37	66.19
70		Sangham south *kole*	0.92	2.17	61.01
71		Sangham north *kole*	0.94	2.43	56.61
72		Chirukandathu *kole* 1	1.04	2.51	57.13
73		Chirukandathu *kole* 2	1.08	2.25	56.87
74		Karikkin *kole*	0.72	2.51	67.89
75		Vadakke ponnur thazham	0.73	2.31	64.20
76	Perumpadappu	Maradi *kole* padavu	1.11	2.58	51.78
77		Nadupotta *kole*	1.19	2.58	51.62
78		Maradi *kole* padav, maranchery	1.20	2.57	53.54
79		Kundamkuzhi 1	1.34	2.30	50.25

80		Kundamkuzhi 2	1.06	2.46	54.05
81		Mullamadu	1.01	2.37	58.76
82		Arimbinkundu	0.73	2.39	69.25
83		Irumbayil *kole*	0.65	2.37	72.69
84		Aana *kole* 1	0.91	2.59	61.49
85		Aana *kole* 2	0.92	2.34	67.15
86		Kolothupadavu 1	0.83	2.30	66.42
87		Kolothupadavu 2	1.09	2.57	52.50
88	Ponnani	Ponnani *kole* padavu 1	1.12	2.49	59.86
89		Ponnani *kole* padavu 2	1.22	2.56	50.92
90		Ponnani *kole* padavu 3	0.92	2.46	64.19
91		Kanniyamkayal 1	0.75	2.65	67.74
92		Puzhangad *kole* 1	0.67	2.13	74.66
93		Kanniyamkayal 2	0.90	2.45	56.73
94		Anthalachira 1	0.93	2.44	62.23
95		Anthalachira 2	0.61	2.44	74.98
96		Puzhangad *kole* 2	0.53	2.15	78.21
97		Panthavoor 1	0.90	2.22	58.00
98		Panthavoor 2	1.13	2.48	49.33
99		Moochikkal kadavu 1	1.15	2.38	55.21
100		Moochikkal kadavu 2	0.94	2.38	60.39

b. Maximum water holding capacity (WHC) (%), soil moisture (%), mean weight diameter (MWD) (mm) of soil samples in different sites of *kole* lands

Sl No.	Block panchayats	Name of *kole* padavu	WHC	Soil moisture	MWD
1	Mullassery	Ponnamutha	55.39	31.70	4.04
2		Elamutha	62.95	38.80	2.43
3		Mathukkara thekk	62.73	36.50	1.82
4		Pavudai	58.49	38.80	2.17
5		Parappadam kizhakkethala	49.65	36.50	2.72
6		Parappadam west	58.01	36.50	1.93
7		Penakam	56.67	37.50	4.38
8		Elavathur	48.83	29.80	3.09
9		Cherotha akkarapadam	43.89	27.50	3.15
10		Peruvalloor padav	38.16	35.50	5.16
11		Kaniyamthuruth	55.21	21.90	5.87
12		Annakkara chirakkal	34.95	36.50	3.32
13		Annakkara vadakk	41.23	34.20	3.35
14		Thanneerkayal	37.85	23.20	3.41
15		Pulipandi	28.44	31.10	2.18
16	Cherpu	Manakkal padavu	59.40	18.31	2.57
17		Madhammathopp	51.32	16.20	2.92
18		Nerkathir	61.67	19.00	3.63
19		Kanimangalam *kole* padav	55.21	17.26	2.55
20		Karimbatta	52.94	15.78	3.36
21		Kizhakkan *kole* padavu	70.06	12.00	2.81
22		Cheeyaram samajam	71.29	12.65	3.15
23		Avinissery samajam	70.34	18.21	2.29

24		Kodannur *kole* farming society	49.66	16.85	2.17
25		Pallippuram *kole* padav	69.34	18.45	2.2
26		Pandaran *kole*	71.28	14.20	2.31
27		Chovvoorthazham alukka padav	71.07	12.15	2.02
28		Jubilee thevar padav	67.63	20.97	1.8
29		Perumkulam east	48.76	18.20	1.91
30		Perumkulam west	60.64	16.52	3.3
31	Anthikkad	Chaladi pazhan *kole* 1	68.51	40.30	1.85
32		Themalippuram	66.12	41.30	1.95
33		Rajamukk	48.93	38.00	2.17
34		Arumuri	55.94	35.00	2.62
35		Manaloorthazham	55.63	41.00	2.78
36		Kodayatti	69.09	33.00	2.55
37		Ayyappan *kole*	48.93	35.00	3.98
38		Pazhuvil bund *kole*	53.58	35.21	3.23
39		Chaladi pazhan *kole* 2	31.09	25.91	2.7
40		Chennakari puncha	61.77	36.50	2.33
41		Jubilee thevar padav	68.13	40.20	2.27
42		Pallippuram	69.50	35.30	2.00
43		Pullu	63.68	38.00	2.55
44		Vilakkumadam padav	71.05	33.00	2.96
45		Variyam *kole* padav	67.13	32.00	2.80
46		Chettupuzha east	36.80	32.11	2.26
47	Irinjalakkuda	Painkili kayal	73.49	34.60	3.72
48		Chemmanda kayal	67.15	33.70	2.06
49		Vellani *kole*	61.63	40.60	3.59
50		Thekkumoola	71.36	30.50	3.98
51		Karppullithara kakkad	69.61	37.00	2.96

52		Muriyaad	42.30	39.13	2.00
53		Kalladi thazham	55.21	27.96	3.54
54		Chithravallipadam	40.80	27.88	1.95
55		Kochipadam	43.89	35.53	3.83
56		Kadumkadu	38.16	40.20	3.26
57		Mothalakkulam	55.21	37.00	2.03
58		Koda *kole*	71.21	29.90	4.01
59		Konthikulam	45.15	36.20	3.08
60		Parappookkara	35.05	32.47	2.14
61		Nedumbal	33.96	36.31	2.47
62	Puzhakkal	Pullazhi *kole* 1	56.52	24.45	2.24
63		Pullazhi *kole* 2	57.82	23.25	2.24
64		Pannikkara kin *kole*	70.04	25.48	0.7
65		Ombathumuri 1	73.45	26.80	3.83
66		Ombathumuri 2	72.15	27.90	3.61
67		Kadavil *kole*	52.67	24.40	3.04
68		Pandaran *kole* 1	70.02	21.47	3.48
69		Pandaran *kole* 2	66.76	21.92	3.26
70		Sangham south *kole*	64.73	22.66	3.12
71		Sangham north *kole*	60.06	22.48	2.68
72		Chirukandathu *kole* 1	61.29	35.00	2.62
73		Chirukandathu *kole* 2	69.27	36.00	2.68
74		Karikkin *kole*	54.65	22.13	2.77
75		Vadakke ponnur thazham	49.17	20.70	3.15
76	Perumpadappu	Maradi *kole* padavu	39.60	37.60	3.89
77		Nadupotta *kole*	28.11	19.10	3.76
78		Maradi *kole* padav,maranchery	34.91	23.40	4.38
79		Kundamkuzhi 1	34.97	24.10	2.68
80		Kundamkuzhi 2	49.66	23.60	3.68

81		Mullamadu	39.98	30.30	3.21
82		Arimbinkundu	36.82	30.20	2.01
83		Irumbayil *kole*	34.41	26.70	4.39
84		Aana *kole* 1	35.90	35.30	3.71
85		Aana *kole* 2	49.66	31.80	4.38
86		Kolothupadavu 1	34.98	30.20	4.62
87		Kolothupadavu 2	46.77	19.50	3.54
88	Ponnani	Ponnani *kole* padavu 1	70.99	40.60	3.02
89		Ponnani *kole* padavu 2	39.98	34.21	2.68
90		Ponnani *kole* padavu 3	78.62	41.50	3.68
91		Kanniyamkayal 1	41.98	31.50	3.16
92		Puzhangad *kole* 1	59.00	34.61	5.51
93		Kanniyamkayal 2	55.52	41.60	6.95
94		Anthalachira 1	71.36	40.52	3.38
95		Anthalachira 2	41.98	27.40	2.62
96		Puzhangad *kole* 2	41.94	27.70	2.44
97		Panthavoor 1	59.00	38.80	2.94
98		Panthavoor 2	35.17	29.80	3.68
99		Moochikkal kadavu 1	38.94	36.80	3.14
100		Moochikkal kadavu 2	32.92	26.50	2.22

c. **pH, electrical conductivity (EC) (dS m^{-1}), organic carbon (OC) (%) and exchangeable acidity (EA) (cmol (+) kg^{-1}) of soil samples in different sites of *kole* lands**

Sl No.	Block panchayats	Name of *kole* padavu	pH	EC	OC	EA
1	Mullassery	Ponnamutha	4.40	0.10	1.24	1.18
2		Elamutha	4.65	0.11	0.84	0.24
3		Mathukkara thekk	4.63	0.14	0.57	0.25
4		Pavudai	4.25	0.27	0.79	1.02
5		Parappadam kizhakkethala	4.20	0.17	0.95	1.27
6		Parappadam west	4.02	0.17	1.31	1.19
7		Penakam	4.55	0.14	0.39	0.75
8		Elavathur	4.67	0.13	1.12	0.98
9		Cherotha akkarapadam	4.83	0.11	0.6	0.39
10		Peruvalloor padav	4.43	0.12	0.63	0.34
11		Kaniyamthuruth	4.58	0.09	0.42	0.52
12		Annakkara chirakkal	4.22	0.15	0.12	0.51
13		Annakkara vadakk	4.08	0.17	0.73	1.62
14		Thanneerkayal	5.06	0.25	0.82	0.20
15		Pulipandi	4.11	0.26	0.92	1.15
16	Cherpu	Manakkal padavu	5.14	0.06	1.09	0.44
17		Madhammathopp	4.4	0.08	0.86	1.06
18		Nerkathir	5.79	0.04	0.87	0.81
19		Kanimangalam *kole* padav	5.84	0.05	1.02	0.72
20		Karimbatta	4.96	0.06	1.5	0.17
21		Kizhakkan *kole* padavu	4.95	0.07	0.77	1.53
22		Cheeyaram samajam	5.13	0.07	1.39	1.51
23		Avinissery samajam	6.05	0.04	0.90	1.47

24		Kodannur *kole* farming society	6.02	0.04	0.67	0.67
25		Pallippuram *kole* padav	5.98	0.05	0.45	0.54
26		Pandaran *kole*	3.95	0.03	1.61	1.37
27		Chovvoorthazham alukka padav	6.23	0.06	0.58	0.23
28		Jubilee thevar padav	5.71	0.04	1.65	0.21
29		Perumkulam east	4.2	0.05	0.79	1.53
30		Perumkulam west	3.61	0.08	0.37	0.61
31	Anthikkad	Chaladi pazhan *kole* 1	4.21	0.08	1.77	0.60
32		Themalippuram	4.19	0.05	0.94	0.86
33		Rajamukk	4.04	0.09	0.97	1.74
34		Arumuri	5.67	0.07	0.81	1.73
35		Manaloorthazham	5.75	0.11	1.17	1.24
36		Kodayatti	5.79	0.05	1.13	1.16
37		Ayyappan *kole*	4.40	0.04	1.39	0.56
38		Pazhuvil bund *kole*	3.97	0.07	0.97	2.07
39		Chaladi pazhan *kole* 2	5.78	0.07	1.87	0.94
40		Chennakari puncha	4.93	0.01	1.11	0.47
41		Jubilee thevar padav	5.72	0.02	1.52	0.60
42		Pallippuram	4.27	0.06	1.3	0.60
43		Pullu	4.92	0.07	1.19	0.45
44		Vilakkumadam padav	5.80	0.05	1.13	0.27
45		Variyam *kole* padav	5.05	0.14	1.22	1.77
46		Chettupuzha east	5.11	0.17	0.42	1.39
47	Irinjalakkuda	Painkili kayal	4.78	0.06	1.32	1.00
48		Chemmanda kayal	5.24	0.05	1.30	0.06
49		Vellani *kole*	5.69	0.02	2.20	1.19
50		Thekkumoola	5.13	0.01	1.06	0.05
51		Karppullithara kakkad	3.94	0.06	1.22	1.01
52		Muriyaad	5.98	0.01	1.49	1.34

53		Kalladi thazham	4.02	0.07	0.88	0.62
54		Chithravallipadam	5.56	0.02	0.51	0.05
55		Kochipadam	5.91	0.01	1.03	1.42
56		Kadumkadu	5.49	0.01	1.36	0.52
57		Mothalakkulam	4.93	0.1	1.78	0.55
58		Koda *kole*	4.4	0.01	0.86	0.47
59		Konthikulam	4.91	0.05	1.86	0.77
60		Parappookkara	3.94	0.03	0.75	1.13
61		Nedumbal	4.58	0.01	1.09	0.64
62	Puzhakkal	Pullazhi *kole* 1	4.1	0.06	0.9	1.51
63		Pullazhi *kole* 2	4.12	0.06	0.93	1.64
64		Pannikkara kin *kole*	6.35	0.08	1.65	1.44
65		Ombathumuri 1	5.78	0.06	0.89	1.51
66		Ombathumuri 2	5.81	0.07	0.86	0.05
67		Kadavil *kole*	5.83	0.07	1.24	1.01
68		Pandaran *kole* 1	4.59	0.07	1.62	1.15
69		Pandaran *kole* 2	4.62	0.08	0.99	1.15
70		Sangham south *kole*	5.79	0.08	0.74	1.08
71		Sangham north *kole*	5.81	0.08	0.78	1.14
72		Chirukandathu *kole* 1	4.98	0.08	0.89	1.17
73		Chirukandathu *kole* 2	5.01	0.06	0.92	1.11
74		Karikkin *kole*	5.82	0.05	0.72	1.4
75		Vadakke ponnur thazham	6.35	0.05	0.76	1.27
76	Perumpadappu	Maradi *kole* padavu	4.04	0.08	1.17	1.83
77		Nadupotta *kole*	4.62	0.05	0.69	0.70
78		Maradi *kole* padav, maranchery	4.47	0.18	0.93	0.92
79		Kundamkuzhi 1	4.25	0.08	0.84	1.01
80		Kundamkuzhi 2	5.39	0.11	0.61	0.05
81		Mullamadu	6.13	0.08	1.29	0.60

82		Arimbinkundu	3.51	0.10	0.81	1.12
83		Irumbayil *kole*	4.40	0.15	3.47	0.80
84		Aana *kole* 1	5.15	0.09	1.19	0.56
85		Aana *kole* 2	4.60	0.04	1.44	1.64
86		Kolothupadavu 1	5.05	0.10	0.28	0.56
87		Kolothupadavu 2	3.85	0.06	0.44	1.05
88	Ponnani	Ponnani *kole* padavu 1	4.13	0.23	1.06	2.18
89		Ponnani *kole* padavu 2	4.56	0.36	1.31	1.80
90		Ponnani *kole* padavu 3	4.39	0.38	1.01	0.35
91		Kanniyamkayal 1	5.48	0.34	2.57	1.42
92		Puzhangad *kole* 1	3.69	.36	1.44	1.79
93		Kanniyamkayal 2	5.16	0.38	0.75	1.28
94		Anthalachira 1	4.86	0.29	1.63	1.75
95		Anthalachira 2	5.67	0.12	1.11	1.11
96		Puzhangad *kole* 2	5.41	0.14	0.50	1.06
97		Panthavoor 1	5.40	0.14	2.97	2.20
98		Panthavoor 2	5.04	0.10	1.51	2.15
99		Moochikkal kadavu 1	4.55	0.31	1.41	1.05
100		Moochikkal kadavu 2	4.49	0.14	2.89	1.35

d. Available nitrogen, phosphorus and potassium (kg ha^{-1}) of soil samples in different sites of *kole* lands

Sl No.	Block panchayats	Name of *kole* padavu	Avail. N	Avail. P	Avail. K
1	Mullassery	Ponnamutha	789.74	32.71	63.95
2		Elamutha	655.9	52.49	166.54
3		Mathukkara thekk	730.91	27.14	146.39
4		Pavudai	901.86	20.75	122.61
5		Parappadam kizhakkethala	770.42	25.01	82.90
6		Parappadam west	849.44	17.48	185.20
7		Penakam	782.75	18.83	121.86
8		Elavathur	625.41	19.29	86.15
9		Cherotha akkarapadam	553.67	88.44	146.76
10		Peruvalloor padav	797.37	101.39	76.40
11		Kaniyamthuruth	674.58	9.28	229.45
12		Annakkara chirakkal	651.89	30.21	104.06
13		Annakkara vadakk	610.04	24.48	158.3
14		Thanneerkayal	931.00	40.94	338.33
15		Pulipandi	655.42	24.25	185.31
16	Cherpu	Manakkal padavu	92.13	17.67	318.53
17		Madhammathopp	434.09	7.71	236.50
18		Nerkathir	480.06	2.46	271.52
19		Kanimangalam *kole* padav	439.65	20.95	460.89
20		Karimbatta	148.95	20.29	96
21		Kizhakkan *kole* padavu	570.17	9.69	272.34
22		Cheeyaram samajam	660.59	8.44	191.22
23		Avinissery samajam	552.11	43.00	72.99
24		Kodannur *kole* farming	603.46	14.72	144.20

		society			
25		Pallippuram *kole* padav	199.96	22.51	466.35
26		Pandaran *kole*	701.75	3.11	213.33
27		Chovvoorthazham alukka padav	371.26	10.34	214.09
28		Jubilee thevar padav	745.99	2.17	98.31
29		Perumkulam east	613.41	4.11	82.93
30		Perumkulam west	360.65	15.6	277.86
31	Anthikkad	Chaladi pazhan *kole* 1	1113.62	23.21	116.31
32		Themalippuram	790.68	27.86	278.57
33		Rajamukk	930.68	25.25	263.74
34		Arumuri	656.15	10.08	55.14
35		Manaloorthazham	951.61	6.97	146.76
36		Kodayatti	861.23	6.00	262.45
37		Ayyappan *kole*	907.03	5.58	220.55
38		Pazhuvil bund *kole*	813.2	11.51	164.23
39		Chaladi pazhan *kole* 2	616.77	3.51	136.31
40		Chennakari puncha	612.38	5.68	165.80
41		Jubilee thevar padav	1027.85	29.65	95.52
42		Pallippuram	620.41	7.34	145.41
43		Pullu	890.22	17.59	148.13
44		Vilakkumadam padav	879.95	8.73	122.03
45		Variyam *kole* padav	700.99	20.24	242.12
46		Chettupuzha east	692.08	25.59	140.97
47	Irinjalakkuda	Painkili kayal	863.12	4.59	74.03
48		Chemmanda kayal	832.48	17.89	62.81
49		Vellani *kole*	971.42	14.14	30.42
50		Thekkumoola	776.10	4.77	50.08
51		Karppullithara kakkad	856.18	4.73	77.13
52		Muriyaad	824.38	5.39	155.27
53		Kalladi thazham	661.65	4.14	110.27

54		Chithravallipadam	695.71	11.06	60.25
55		Kochipadam	972.91	10.30	63.31
56		Kadumkadu	901.99	2.23	92.02
57		Mothalakkulam	836.27	3.98	405.96
58		Koda *kole*	644.2	14.2	99.44
59		Konthikulam	707.81	5.27	192.73
60		Parappookkara	910.24	12.22	91.74
61		Nedumbal	925.73	3.31	128.80
62	Puzhakkal	Pullazhi *kole* 1	697.32	18.54	84.20
63		Pullazhi *kole* 2	637.45	19.28	81.58
64		Pannikkara kin *kole*	942.63	14.34	98.29
65		Ombathumuri 1	651.19	13.95	111.85
66		Ombathumuri 2	643.73	14.85	114.33
67		Kadavil *kole*	547.56	13.04	122.22
68		Pandaran *kole* 1	766.75	12.82	107.25
69		Pandaran *kole* 2	755.09	13.57	108.44
70		Sangham south *kole*	810.93	12.24	119.47
71		Sangham north *kole*	825.30	12.44	119.06
72		Chirukandathu *kole* 1	810.54	22.43	96.49
73		Chirukandathu *kole* 2	901.60	16.73	116.38
74		Karikkin *kole*	757.13	12.71	105.29
75		Vadakke ponnur thazham	506.16	19.29	120.89
76	Perumpadappu	Maradi *kole* padavu	1085.54	14.52	190.24
77		Nadupotta *kole*	217.08	15.03	112.75
78		Maradi *kole* padav, maranchery	638.66	18.39	210.23
79		Kundamkuzhi 1	297.49	14.74	89.48
80		Kundamkuzhi 2	328.38	14.53	209.57
81		Mullamadu	924.52	14.54	298.53
82		Arimbinkundu	1006.88	12.81	206.74
83		Irumbayil *kole*	614.32	28.08	114.93

84		Aana *kole* 1	484.7	15.32	379.85
85		Aana *kole* 2	349.47	40.55	143.31
86		Kolothupadavu 1	1065.83	27.16	346.31
87		Kolothupadavu 2	768.36	27.52	318.47
88	Ponnani	Ponnani *kole* padavu 1	467.26	31.50	264.55
89		Ponnani *kole* padavu 2	364.92	12.56	96.13
90		Ponnani *kole* padavu 3	896.00	15.43	328.86
91		Kanniyamkayal 1	743.49	14.06	580.45
92		Puzhangad *kole* 1	750.50	14.59	599.03
93		Kanniyamkayal 2	512.75	15.29	484.37
94		Anthalachira 1	690.50	17.47	684.03
95		Anthalachira 2	644.38	14.02	646.51
96		Puzhangad *kole* 2	1033.04	13.91	381.19
97		Panthavoor 1	552.90	19.21	225.13
98		Panthavoor 2	537.85	36.26	303.38
99		Moochikkal kadavu 1	893.16	14.58	313.92
100		Moochikkal kadavu 2	948.21	14.59	541.34

e. **Available calcium (mg kg^{-1}), magnesium (mg kg^{-1}) and sulphur (mg kg^{-1}) of soil samples in different sites of *kole* lands**

Sl No.	Block panchayats	Name of *kole* padavu	Avail. Ca	Avail. Mg	Avail. S
1	Mullassery	Ponnamutha	327.31	128.11	13.37
2		Elamutha	575.98	215.93	11.77
3		Mathukkara thekk	366.93	154.72	10.41
4		Pavudai	307.68	92.32	14.32
5		Parappadam kizhakkethala	311.65	80.55	16.95
6		Parappadam west	274.09	74.49	11.18
7		Penakam	301.92	106.48	6.04
8		Elavathur	223.79	68.73	5.86
9		Cherotha akkarapadam	288.62	100.34	7.88
10		Peruvalloor padav	213.95	73.26	6.35
11		Kaniyamthuruth	221.83	60.37	4.91
12		Annakkara chirakkal	240.71	98.66	9.58
13		Annakkara vadakk	240.65	80.40	6.24
14		Thanneerkayal	313.28	189.00	5.65
15		Pulipandi	255.81	224.60	7.16
16	Cherpu	Manakkal padavu	351.32	60.47	4.46
17		Madhammathopp	95.28	25.18	4.59
18		Nerkathir	254	46.36	4.84
19		Kanimangalam *kole* padav	209.93	51.61	4.48
20		Karimbatta	403.42	78.25	4.93
21		Kizhakkan *kole* padavu	248.01	58.86	4.89
22		Cheeyaram samajam	232.74	50.83	4.97
23		Avinissery samajam	255.16	64.25	6.39

24		Kodannur *kole* farming society	5.29	3.61	6.76
25		Pallippuram *kole* padav	275.6	77.5	4.95
26		Pandaran *kole*	378.37	103.2	11.34
27		Chovvoorthazham alukka padav	291.3	100.17	21.67
28		Jubilee thevar padav	291.02	75.86	8.37
29		Perumkulam east	73.29	18.95	12.31
30		Perumkulam west	243.07	60.92	5.35
31	Anthikkad	Chaladi pazhan *kole* 1	513.32	104.44	22.26
32		Themalippuram	649.74	235.18	29.67
33		Rajamukk	528.47	179.27	9.07
34		Arumuri	437.08	111.31	10.05
35		Manaloorthazham	170.52	45.60	8.69
36		Kodayatti	534.78	110.37	16.93
37		Ayyappan *kole*	258.85	68.69	10.25
38		Pazhuvil bund *kole*	730.62	236.35	10.85
39		Chaladi pazhan *kole* 2	347.57	159.31	11.44
40		Chennakari puncha	563.23	145.75	11.57
41		Jubilee thevar padav	598.33	140.55	11.52
42		Pallippuram	304.48	127.13	11.54
43		Pullu	863.71	210.32	11.13
44		Vilakkumadam padav	325.07	91.49	9.27
45		Variyam *kole* padav	732.21	128.01	10.83
46		Chettupuzha east	53.02	11.12	19.5
47	Irinjalakkuda	Painkili kayal	308.33	71.48	12.41
48		Chemmanda kayal	935.9	140.5	9.09
49		Vellani *kole*	571.21	334.70	10.08
50		Thekkumoola	768.35	333.96	10.73
51		Karppullithara kakkad	325.4	73.97	16.13
52		Muriyaad	323.67	77.38	7.63

53		Kalladi thazham	319.81	46.43	5.52
54		Chithravallipadam	390.86	53.66	5.51
55		Kochipadam	367.32	77.64	6.34
56		Kadumkadu	354.18	75.67	6.67
57		Mothalakkulam	345.48	63.41	7.37
58		Koda *kole*	253.99	45.36	6.28
59		Konthikulam	227.59	46.79	19.68
60		Parappookkara	370.22	104.63	6.51
61		Nedumbal	419.94	106.93	6.20
62	Puzhakkal	Pullazhi *kole* 1	352.07	43.28	8.87
63		Pullazhi *kole* 2	339.43	41.83	8.78
64		Pannikkara kin *kole*	290.19	30.6	9.22
65		Ombathumuri 1	281.97	30.19	9.40
66		Ombathumuri 2	290.43	38.97	9.54
67		Kadavil *kole*	403.44	43.25	13.24
68		Pandaran *kole* 1	368.02	42.09	12.41
69		Pandaran *kole* 2	377.18	34.96	21.06
70		Sangham south *kole*	374.31	34.84	21.58
71		Sangham north *kole*	375.4	31.54	5.27
72		Chirukandathu *kole* 1	479.23	49.38	6.77
73		Chirukandathu *kole* 2	467.19	43.91	6.46
74		Karikkin *kole*	415.44	43.34	5.05
75		Vadakke ponnur thazham	395.94	40.54	4.81
76	Perumpadappu	Maradi *kole* padavu	518.27	59.62	6.56
77		Nadupotta *kole*	276.14	50.31	8.82
78		Maradi *kole* padav, maranchery	278.52	46.15	4.97
79		Kundamkuzhi 1	427.87	65.61	9.17
80		Kundamkuzhi 2	441.49	76.44	5.35
81		Mullamadu	1112.23	104.69	7.36
82		Arimbinkundu	464.46	68.56	7.77

83		Irumbayil *kole*	178.28	103.79	10.45
84		Aana *kole* 1	390.42	71.95	11.06
85		Aana *kole* 2	226.32	95.09	10.93
86		Kolothupadavu 1	267.89	104.74	17.00
87		Kolothupadavu 2	263.89	103.63	6.93
88	Ponnani	Ponnani *kole* padavu 1	427.29	63.11	5.63
89		Ponnani *kole* padavu 2	213.15	27.7	4.65
90		Ponnani *kole* padavu 3	638.07	222.13	13.94
91		Kanniyamkayal 1	382.9	141.19	19.85
92		Puzhangad *kole* 1	561.37	197.95	27.19
93		Kanniyamkayal 2	1108.03	142.41	18.73
94		Anthalachira 1	1600.92	274.46	19.80
95		Anthalachira 2	1087.33	166.44	27.65
96		Puzhangad *kole* 2	359.5	177.56	53.16
97		Panthavoor 1	519.08	121.35	9.05
98		Panthavoor 2	528.84	105.53	7.26
99		Moochikkal kadavu 1	278.88	120.49	7.80
100		Moochikkal kadavu 2	270.71	105.67	8.20

f. **Available iron, manganese and zinc (mg kg^{-1}) of soil samples in different sites of *kole* lands**

Sl No.	Block panchayats	Name of *kole* padavu	Avail. Fe	Avail. Mn	Avail. Zn
1	Mullassery	Ponnamutha	37.35	15.61	2.31
2		Elamutha	49.75	7.37	2.09
3		Mathukkara thekk	33.35	7.95	1.95
4		Pavudai	105.47	17.65	3.14
5		Parappadam kizhakkethala	143.78	18.99	2.77
6		Parappadam west	103.75	14.60	1.37
7		Penakam	112.66	13.10	1.95
8		Elavathur	187.46	19.25	2.83
9		Cherotha akkarapadam	79.83	9.67	1.20
10		Peruvalloor padav	99.21	6.68	1.58
11		Kaniyamthuruth	61.79	4.47	1.60
12		Annakkara chirakkal	99.26	23.7	1.97
13		Annakkara vadakk	153.95	6.82	0.62
14		Thanneerkayal	181.77	7.71	1.50
15		Pulipandi	113.19	7.55	0.74
16	Cherpu	Manakkal padavu	100.67	7.60	2.15
17		Madhammathopp	127.20	35.07	2.43
18		Nerkathir	59.91	10.11	0.75
19		Kanimangalam *kole* padav	41.70	4.28	1.03
20		Karimbatta	15.06	4.42	1.12
21		Kizhakkan *kole* padavu	793.85	51.40	2.08
22		Cheeyaram samajam	1077.05	50.50	2.93
23		Avinissery samajam	148.67	7.13	2.95

24		Kodannur *kole* farming society	109.89	8.32	2.37
25		Pallippuram *kole* padav	211.53	10.06	1.69
26		Pandaran *kole*	99.66	7.65	1.38
27		Chovvoorthazham alukka padav	49.97	17.08	1.14
28		Jubilee thevar padav	66.83	10.5	1.09
29		Perumkulam east	145.36	7.18	1.52
30		Perumkulam west	96.32	17.77	1.39
31	Anthikkad	Chaladi pazhan *kole* 1	34.97	4.12	0.59
32		Themalippuram	686.2	23.97	3.82
33		Rajamukk	293.71	16.63	2.82
34		Arumuri	73.06	25.46	1.57
35		Manaloorthazham	149.81	73.76	2.79
36		Kodayatti	144.72	8.09	4.06
37		Ayyappan *kole*	417.85	19.57	2.88
38		Pazhuvil bund *kole*	21.83	7.61	0.56
39		Chaladi pazhan *kole* 2	285.55	21.74	6.83
40		Chennakari puncha	136.24	11.48	2.16
41		Jubilee thevar padav	359.03	10.75	2.31
42		Pallippuram	91.72	5.41	2.78
43		Pullu	33.68	5.89	3.13
44		Vilakkumadam padav	237.31	18.85	2.96
45		Variyam *kole* padav	217.94	34.07	2.90
46		Chettupuzha east	78.47	7.79	0.91
47	Irinjalakkuda	Painkili kayal	1639.14	48.61	5.70
48		Chemmanda kayal	48.75	5.10	2.13
49		Vellani *kole*	94.6	51.41	4.24
50		Thekkumoola	82.79	23.65	2.43
51		Karppullithara kakkad	1179.37	57.32	9.37
52		Muriyaad	2896.56	32.81	4.55

53		Kalladi thazham	170.87	4.98	2.14
54		Chithravallipadam	557.94	16.35	2.52
55		Kochipadam	2930.72	33.46	2.26
56		Kadumkadu	228.6	8.66	2.34
57		Mothalakkulam	100.62	27.95	3.38
58		Koda *kole*	151.36	8.80	1.08
59		Konthikulam	797.81	90.72	3.84
60		Parappookkara	125.94	10.06	2.98
61		Nedumbal	87.58	19.83	1.54
62	Puzhakkal	Pullazhi *kole* 1	2195.02	28.47	9.24
63		Pullazhi *kole* 2	2419.67	16.2	7.39
64		Pannikkara kin *kole*	279.65	13.19	1.99
65		Ombathumuri 1	1575.41	33.47	2.88
66		Ombathumuri 2	1826.63	35.19	2.95
67		Kadavil *kole*	1453.7	9.66	1.24
68		Pandaran *kole* 1	101.75	11.59	1.78
69		Pandaran *kole* 2	113.1	11.83	2.05
70		Sangham south *kole*	3178.96	36.78	9.57
71		Sangham north *kole*	3312.83	37.30	9.93
72		Chirukandathu *kole* 1	179.23	14.72	3.00
73		Chirukandathu *kole* 2	650.31	31.88	7.69
74		Karikkin *kole*	969.97	14.68	2.40
75		Vadakke ponnur thazham	524.81	25.35	6.83
76	Perumpadappu	Maradi *kole* padavu	2012.82	13.43	2.80
77		Nadupotta *kole*	98.76	3.20	2.31
78		Maradi *kole* padav, maranchery	115.29	10.03	0.47
79		Kundamkuzhi 1	3239.39	7.30	1.95
80		Kundamkuzhi 2	3361.26	9.01	2.76
81		Mullamadu	152.93	57.42	3.57

82		Arimbinkundu	110.17	6.51	1.57
83		Irumbayil *kole*	111.23	4.79	2.21
84		Aana *kole* 1	203.4	43.04	1.93
85		Aana *kole* 2	590.03	5.91	3.59
86		Kolothupadavu 1	680.07	9.62	1.23
87		Kolothupadavu 2	630.06	12.14	1.01
88	Ponnani	Ponnani *kole* padavu 1	1608.88	5.13	1.46
89		Ponnani *kole* padavu 2	1596.36	2.47	1.96
90		Ponnani *kole* padavu 3	1914.63	9.83	4.74
91		Kanniyamkayal 1	3851.06	11.23	2.25
92		Puzhangad *kole* 1	233.68	28.79	2.15
93		Kanniyamkayal 2	267.15	12.25	1.66
94		Anthalachira 1	132.28	27.58	1.65
95		Anthalachira 2	367.64	15.41	1.7
96		Puzhangad *kole* 2	195.8	15.9	1.43
97		Panthavoor 1	573.28	33.54	1.56
98		Panthavoor 2	1044.67	40.95	1.66
99		Moochikkal kadavu 1	629.75	35.82	1.34
100		Moochikkal kadavu 2	510.24	20.03	1.28

g. Available copper (mg kg^{-1}), boron (mg kg^{-1}), effective cation exchange capacity (ECEC) (cmol (+) kg^{-1}) of soil samples in different sites of *kole* lands

Sl No.	Block panchayats	Name of *kole* padavu	Avail. Cu	Avail. B	ECEC
1	Mullassery	Ponnamutha	3.60	0.09	4.23
2		Elamutha	3.94	0.01	2.82
3		Mathukkara thekk	2.93	0.10	3.09
4		Pavudai	4.93	0.15	3.99
5		Parappadam kizhakkethala	5.10	0.11	4.18
6		Parappadam west	6.50	0.05	4.00
7		Penakam	4.06	0.12	3.76
8		Elavathur	4.44	0.08	4.26
9		Cherotha akkarapadam	5.70	0.13	3.13
10		Peruvalloor padav	3.98	0.11	3.00
11		Kaniyamthuruth	3.01	0.09	3.73
12		Annakkara chirakkal	3.18	0.04	3.47
13		Annakkara vadakk	1.98	0.10	5.12
14		Thanneerkayal	2.12	0.08	7.03
15		Pulipandi	1.87	0.05	7.03
16	Cherpu	Manakkal padavu	3.67	0.06	2.49
17		Madhammathopp	2.23	0.03	3.67
18		Nerkathir	0.90	0.02	3.37
19		Kanimangalam *kole* padav	0.58	0.06	3.45
20		Karimbatta	1.25	0.05	3.43
21		Kizhakkan *kole* padavu	0.86	0.25	4.46
22		Cheeyaram samajam	0.63	0.03	4.51
23		Avinissery samajam	3.85	0.11	4.36
24		Kodannur *kole* farming	3.25	0.09	3.43

		society			
25		Pallippuram *kole* padav	1.79	0.07	3.33
26		Pandaran *kole*	1.59	0.06	4.51
27		Chovvoorthazham alukka padav	2.39	0.06	3.05
28		Jubilee thevar padav	1.52	0.07	3.08
29		Perumkulam east	2.15	0.02	4.44
30		Perumkulam west	4.29	0.15	3.18
31	Anthikkad	Chaladi pazhan *kole* 1	1.29	0.10	3.27
32		Themalippuram	4.19	0.02	3.58
33		Rajamukk	5.10	0.11	4.53
34		Arumuri	3.40	0.08	4.83
35		Manaloorthazham	1.66	0.08	4.12
36		Kodayatti	4.24	0.16	3.58
37		Ayyappan *kole*	3.45	0.10	3.32
38		Pazhuvil bund *kole*	1.57	0.06	6.28
39		Chaladi pazhan *kole* 2	4.77	0.29	4.02
40		Chennakari puncha	4.39	0.08	1.88
41		Jubilee thevar padav	4.13	0.03	3.53
42		Pallippuram	3.6	0.08	3.56
43		Pullu	4.1	0.06	2.16
44		Vilakkumadam padav	6.66	0.05	2.16
45		Variyam *kole* padav	2.15	0.12	5.63
46		Chettupuzha east	5.09	0.08	1.55
47	Irinjalakkuda	Painkili kayal	2.45	0.09	3.88
48		Chemmanda kayal	2.76	0.04	0.62
49		Vellani *kole*	4.9	0.07	2.1
50		Thekkumoola	3.64	0.06	2.28
51		Karppullithara kakkad	4.17	0.08	3.65
52		Muriyaad	1.43	0.07	1.65
53		Kalladi thazham	2.72	0.04	4.09

54		Chithravallipadam	1.08	0.27	2.74
55		Kochipadam	0.45	0.05	3.28
56		Kadumkadu	3.90	0.10	3.47
57		Mothalakkulam	4.52	0.06	3.01
58		Koda *kole*	4.08	0.09	2.47
59		Konthikulam	2.01	0.27	3.47
60		Parappookkara	5.04	0.04	3.85
61		Nedumbal	3.94	0.07	3.30
62	Puzhakkal	Pullazhi *kole* 1	1.56	0.05	4.07
63		Pullazhi *kole* 2	0.64	0.04	4.19
64		Pannikkara kin *kole*	2.54	0.03	4.16
65		Ombathumuri 1	0.56	0.06	3.69
66		Ombathumuri 2	0.46	0.06	2.25
67		Kadavil *kole*	0.75	0.10	3.66
68		Pandaran *kole* 1	1.44	0.18	4.42
69		Pandaran *kole* 2	2.73	0.13	4.42
70		Sangham south *kole*	0.28	0.04	3.94
71		Sangham north *kole*	0.37	0.04	4.01
72		Chirukandathu *kole* 1	4.78	0.07	3.88
73		Chirukandathu *kole* 2	5.00	0.07	3.85
74		Karikkin *kole*	1.80	0.08	4.17
75		Vadakke ponnur thazham	3.78	0.02	3.87
76	Perumpadappu	Maradi *kole* padavu	1.76	0.05	4.23
77		Nadupotta *kole*	1.16	0.08	2.98
78		Maradi *kole* padav, maranchery	4.32	0.08	3.33
79		Kundamkuzhi 1	0.83	0.07	4.74
80		Kundamkuzhi 2	0.65	0.12	2.86
81		Mullamadu	5.91	0.13	3.84
82		Arimbinkundu	1.52	0.14	3.95

83		Irumbayil *kole*	2.05	0.06	3.56
84		Aana *kole* 1	3.40	0.12	3.26
85		Aana *kole* 2	1.25	0.05	5.74
86		Kolothupadavu 1	14.77	0.06	4.90
87		Kolothupadavu 2	9.20	0.19	4.93
88	Ponnani	Ponnani *kole* padavu 1	2.69	0.07	3.24
89		Ponnani *kole* padavu 2	0.50	0.10	3.26
90		Ponnani *kole* padavu 3	2.54	0.06	5.33
91		Kanniyamkayal 1	0.44	0.12	9.00
92		Puzhangad *kole* 1	0.84	0.08	2.95
93		Kanniyamkayal 2	0.26	0.09	5.13
94		Anthalachira 1	3.91	0.07	5.95
95		Anthalachira 2	1.03	0.08	5.86
96		Puzhangad *kole* 2	1.9	0.07	5.04
97		Panthavoor 1	4.79	0.11	2.68
98		Panthavoor 2	4.19	0.07	3.98
99		Moochikkal kadavu 1	4.75	0.11	3.84
100		Moochikkal kadavu 2	2.77	0.06	3.89

h. **Dehydrogenase activity (µg TPF g^{-1} 24 hr^{-1}) and microbial biomass carbon (µg g^{-1} soil) of soil samples in different sites of *kole* lands**

Sl No.	Block panchayats	Name of *kole* padavu	Dehydrogenase activity	Microbial biomass carbon
1	Mullassery	Ponnamutha	624.14	295.76
2		Elamutha	660.94	262.83
3		Mathukkara thekk	500.64	162.90
4		Pavudai	214.05	383.26
5		Parappadam kizhakkethala	199.35	205.79
6		Parappadam west	65.54	158.01
7		Penakam	167.99	294.20
8		Elavathur	172.82	396.83
9		Cherotha akkarapadam	272.10	392.89
10		Peruvalloor padav	259.05	227.73
11		Kaniyamthuruth	1040.51	244.14
12		Annakkara chirakkal	255.92	339.35
13		Annakkara vadakk	472.08	283.44
14		Thanneerkayal	169.29	347.94
15		Pulipandi	749.49	212.62
16	Cherpu	Manakkal padavu	636.81	143.97
17		Madhammathopp	250.53	80.09
18		Nerkathir	217.20	165.28
19		Kanimangalam *kole* padav	867.66	82.19
20		Karimbatta	488.70	68.74
21		Kizhakkan *kole* padavu	950.26	91.39
22		Cheeyaram samajam	1081.73	143.96
23		Avinissery samajam	586.07	71.57

24		Kodannur *kole* farming society	655.20	12.62
25		Pallippuram *kole* padav	362.29	21.74
26		Pandaran *kole*	379.14	124.61
27		Chovvoorthazham alukka padav	79.26	161.22
28		Jubilee thevar padav	87.73	148.29
29		Perumkulam east	574.72	124.07
30		Perumkulam west	560.96	199.30
31	Anthikkad	Chaladi pazhan *kole* 1	272.21	219.22
32		Themalippuram	529.18	80.51
33		Rajamukk	209.70	69.87
34		Arumuri	794.46	168.82
35		Manaloorthazham	734.98	132.02
36		Kodayatti	603.72	57.96
37		Ayyappan *kole*	1315.96	136.78
38		Pazhuvil bund *kole*	1256.25	143.09
39		Chaladi pazhan *kole* 2	1056.88	167.13
40		Chennakari puncha	387.92	252.59
41		Jubilee thevar padav	244.78	200.72
42		Pallippuram	639.53	144.27
43		Pullu	1256.28	123.16
44		Vilakkumadam padav	1206.85	153.53
45		Variyam *kole* padav	1195.79	269.44
46		Chettupuzha east	262.53	31.89
47	Irinjalakkuda	Painkili kayal	106.47	84.29
48		Chemmanda kayal	104.58	241.98
49		Vellani *kole*	791.43	168.18
50		Thekkumoola	673.76	186.27
51		Karppullithara kakkad	1230.49	83.35
52		Muriyaad	1378.25	99.80

53		Kalladi thazham	573.39	6.47
54		Chithravallipadam	450.78	171.11
55		Kochipadam	1202.19	105.94
56		Kadumkadu	802.60	224.72
57		Mothalakkulam	1909.59	149.51
58		Koda *kole*	1310.07	46.22
59		Konthikulam	1490.31	81.02
60		Parappookkara	1041.23	169.40
61		Nedumbal	1320.5	207.06
62	Puzhakkal	Pullazhi *kole* 1	346.56	113.62
63		Pullazhi *kole* 2	348.47	71.41
64		Pannikkara kin *kole*	1147.82	75.12
65		Ombathumuri 1	1059.66	123.39
66		Ombathumuri 2	1128.84	76.31
67		Kadavil *kole*	895.93	289.06
68		Pandaran *kole* 1	341.48	263.28
69		Pandaran *kole* 2	315.49	89.06
70		Sangham south *kole*	667.89	94.39
71		Sangham north *kole*	671.1	62.19
72		Chirukandathu *kole* 1	323.00	82.13
73		Chirukandathu *kole* 2	274.91	184.29
74		Karikkin *kole*	921.97	118.05
75		Vadakke ponnur thazham	518.98	123.14
76	Perumpadappu	Maradi *kole* padavu	66.69	136.68
77		Nadupotta *kole*	206.53	251.77
78		Maradi *kole* padav, maranchery	293.26	259.07
79		Kundamkuzhi 1	406.35	224.54
80		Kundamkuzhi 2	197.80	225.73
81		Mullamadu	845.85	77.82

82		Arimbinkundu	1358.93	93.77
83		Irumbayil *kole*	256.73	25.33
84		Aana *kole* 1	480.11	374.98
85		Aana *kole* 2	190.64	36.85
86		Kolothupadavu 1	113.78	32.97
87		Kolothupadavu 2	98.77	173.78
88	Ponnani	Ponnani *kole* padavu 1	150.42	296.96
89		Ponnani *kole* padavu 2	147.06	281.29
90		Ponnani *kole* padavu 3	343.68	117.16
91		Kanniyamkayal 1	784.80	69.66
92		Puzhangad *kole* 1	728.70	341.35
93		Kanniyamkayal 2	590.50	127.06
94		Anthalachira 1	486.09	62.42
95		Anthalachira 2	224.32	188.76
96		Puzhangad *kole* 2	353.30	61.39
97		Panthavoor 1	295.76	20.73
98		Panthavoor 2	449.95	282.09
99		Moochikkal kadavu 1	743.84	15.51
100		Moochikkal kadavu 2	737.43	92.55

Appendix II: Fertility rating of soils

a. Organic carbon and major nutrients

Category	Organic Carbon (%)	Available nutrients (kg ha^{-1})		
		N	P	K
Low	<0.75	<280	<10	<116
Medium	0.75-1.50	280-560	10-24	116-275
High	>1.50	>560	>24	>275

(KAU POP, 2016)

b. Secondary nutrients

Nutrient	Category	
	Deficiency	Sufficiency
Available Ca (mg kg^{-1})	<300	>300
Available Mg (mg kg^{-1})	<120	>120
Available S (mg kg^{-1})	<5.00	>5.00

(KAU POP, 2016)

c. Micronutrients

Nutrient	Category	
	Deficiency	Sufficiency
Available Fe (mg kg^{-1})	<5.00	>5.00
Available Mn (mg kg^{-1})	<1.00	>1.00
Available Zn (mg kg^{-1})	<1.00	>1.00
Available Cu (mg kg^{-1})	<1.00	>1.00
Available B (mg kg^{-1})	<0.50	>0.50

(KAU POP, 2016)

ASSESSMENT OF SOIL QUALITY IN THE POST FLOOD SCENARIO OF AEU 6 IN THRISSUR AND MALAPPURAM DISTRICTS OF KERALA AND MAPPING USING GIS TECHNIQUES

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Kerala State experienced a devastating flood in 2018, causing significant damage to agricultural sector and human life. Major crop systems in the State have been negatively impacted, with more than 80 per cent of paddy fields including in *kole* lands. *Kole* land (AEU 6) is a low lying area situated 0.5m to 1m below mean sea level, which spread over an area of 13,632 ha in coastal parts of Thrissur and Malappuram districts of Kerala. Considering the damage caused by the flooding to the *kole* lands, the present study was carried out in the flood affected areas of *kole* lands in order to put forward post flood management strategies.

A survey was carried out to identify the flood affected locations in *kole* lands. Hundred georeferenced composite soil samples were collected from seven block panchayats *viz*., Mullassery, Anthikkad, Cherpu, Irinjalakkuda, Puzhakkal, Perumpadappu and Ponnani of Thrissur and Malappuram districts and analysed for different physical, chemical and biological soil quality indicators.

The results showed that the soils of *kole* lands were low in bulk density and high in porosity while particle density varied from 2.05 to 2.67 Mg m^{-3}. Maximum water holding capacity and soil moisture content of the soil samples ranged from 18.11 to 73.49 per cent and from 12.00 to 41.60 per cent respectively. High mean weight diameter of soil was also noticed in the study. The soils were acidic in reaction and the exchangeable acidity varied from 0.05 to 2.2 cmol (+) kg^{-1}. Electrical conductivity was below toxic level. The organic carbon was shifted towards medium to high level from low to medium after the flood. Available nitrogen content was high with a mean of 704.59 kg ha^{-1}. Availability of phosphorus and potassium were in the medium status within 55 and 44 per cent of samples respectively. Among the secondary nutrients, available calcium was sufficient in 64 per cent of soil sample while available magnesium was deficient in 72 per cent of soil samples and available sulphur was sufficient in 89 per cent of soil samples. The micro nutrients like available Fe, Mn and Zn were high in AEU 6. Available copper was sufficient in 83 per cent of soil samples, whereas available boron was deficient in all the soil samples. Effective cation exchange capacity of soil in AEU 6 varied from 0.62 to 9.00 cmol (+)

kg^{-1}. Among the biological attributes, *kole* lands showed high dehydrogenase activity while microbial biomass carbon was found medium in 58 per cent of soil samples.

Available Ca, S, N, porosity, exchangeable acidity, available Fe, Zn, particle density and available B formed the minimum data set for soil quality index. The highest mean soil quality index was recorded in Mullassery block panchayat and the lowest mean was in Cherpu block panchayat. Relative soil quality index varied from 25.93 to 72.22 per cent with 63 per cent of soils showing poor soil quality and 3 per cent showing high soil quality.

Nutrient index was high for nitrogen and medium for phosphorus, potassium and organic carbon in *kole* lands. Significant positive correlations were observed between organic carbon and available nitrogen, organic carbon and soil moisture content. Negative correlation existed between bulk density and porosity, organic carbon and bulk density.

The post flood study in *kole* lands revealed that drastic changes in soil environment had occurred with more than 50 per cent of soil samples falling in low soil quality range. Hence, proper adoptions of site specific soil management practices are essential to improve the soil fertility in *kole* lands.