SOIL AND VEGETATION CHARACTERISTICS IN THE POST FLOOD SCENARIO IN SELECTED TREE BASED LAND USE SYSTEMS IN THRISSUR, KERALA

by

ARSHAD A (2018-17-009)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"SOIL AND VEGETATION CHARACTERISTICS IN THE POST FLOOD SCENARIO IN SELECTED TREE BASED LAND USE SYSTEMS IN THRISSUR, KERALA"**is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"SOIL AND VEGETATION CHARACTERISTICS IN THE POST FLOOD SCENARIO IN SELECTED TREE BASED LAND USE SYSTEMS IN THRISSUR, KERALA"** is a record of research work done independently by Mr. Arshad A (2018-17-009) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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ARSHAD A

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

Kerala is a land of rains and rivers. The State has mainly two rainy seasons *viz*. the Southwest monsoon that arrives towards the end of May or early June, which is known as *edavapathi* and Northeast season which hits the State during mid-October which is known as *thulam*. The swirling, jostling, billowing monsoon rains were a part of the State every year, however, the Southwest season of 2018 had a different impact as the monsoon resulted in a disastrous flood. In a span of 30 days, 339 human lives were lost, thousands of houses damaged, over a million and half people were moved to relief camps, large stretches of major roads got washed away and many bridges got damaged. Uninterrupted rains lashed most areas in the State from 8th to 18th of August 2018 which resulted in wide spread destruction in all the major sectors of the state. The floods of 2018 Southwest season can be comprehended as an example of global climate change impact with very heavy rainfall in a short span of time as indicated and predicted by the Fifth Assessment Report published by the Intergovernmental Panel for Climate Change in 2014.

Extreme precipitation events, landslides, and floods are the most common natural disasters that affect human society and economy (Coumou and Rahmstorf, 2012; Crozier, 2010; Hirabayashi *et al*., 2008; Roxy *et al*., 2017). Frequent extreme precipitation events cause flooding (Fowler *et al*., 2010), which have become common in India (Mohapatra and Singh, 2003). The frequency of great floods and extreme precipitation events has substantially increased under the warming climate, which is consistent with the observations as well as climate model projections (Ali et al., 2014). The Kerala flood of 2018 has already attracted attention from the media, scientific community, and policymakers, which is probably the worst flood in a century. As per the preliminary estimates, the Kerala flood caused the death of more than 440 people and economic damage exceeding $3 billion. Despite the state-wide extreme rainfall in Kerala in August 2018, potential causes (heavy rain and reservoir operations) of floods have been greatly debated.

Soil waterlogging regulates the direction and rates of chemical, geochemical, and biological reactions in the soil. Indirectly these reactions can influence changes in soil physical properties during soil waterlogging. The extent of the changes is greatly affected by many factors, such as water-logging period, soil form, soil texture and soil organic matter (Cosentino *et al*., 2006; Li and Shao, 2006; Bandyopadhyay *et al*., 2010). According to Zhang *et al.* (2013), the temporal changes in soil physical properties in paddy soils depend not only on intrinsic soil properties but also on external hydrological conditions. Flooding can cause soil nutrient content to both rise and decrease. High magnitude floods in tropical regions have resulted in extreme impacts triggered by intense rainstorms, hurricanes, snow melt and dam failures (Jeb and Aggarwal, 2008). Flooding leads to food crop shortages due to the loss of entire harvest and the degradation of soil quality. When a soil is inundated (anaerobic conditions), microorganisms use the soil O_2 available to survive. Free O_2 normally lost in the soil within a few days of flooding. The longer the soil is flooded, the soil O_2 levels become more reduced. Oxygen deficiency is likely the most important environmental factor that triggers growth inhibition and injury in flooded plants (Visser and Voesenek, 2004).

Flooding had a different impact on soil and vegetation characteristics of specific land use systems. Also, flooding temporal variation had different impact intensity on different land use systems. Most of the impacts of flood on soil can be masked by the vegetation cover over time after flood. That is flooding can be from minutes to months from place to place, soil characteristic change would be different in these different durations.

Kerala had a flood in August, 2018 with a different duration or temporal variation from three to seven days due to heavy and unexpected rain on that month. Almost all districts of Kerala had affected by the flood. Kerala had a major part in the western ghat region having higher biodiversity which is also subjected to flood. Thrissur district also had flooded for three to five days durations. In these contexts, the present study was conducted in the Thrissur district of Kerala having diversity in land use systems which is affected by flood, having duration of three to five days in Varandarappilly panchayat. The farmers had approached the university frequently about the productivity decline in the soil after flood. The present study was conducted in five major land use systems in Varandarappilly panchayath to assess the changes in soil properties of flooded soil and the vegetation data as a supplementary data for it.

Hence, the present investigation entitled “**Soil and vegetation characterization in the post flood scenario in selected tree based land use systems in Thrissur, Kerala** " was carried out with the following objectives, keeping the above aspects in view.

- To assess the changes in physical, chemical and biological properties of the soil in the flood affected and adjacent non floodedareas under tree based land use systems in Kurumali river basin.
- To monitor the changes of seed bank and vegetation status in these lands.

REVIEW OF LITERATURE

Rainfall occurs when the moisture content of the soil rises above the surface of the earth and cools to form the resulting clouds._Heavy deforestation and floods have been among the most costly natural disasters in India and other parts of the world. Flooding is the most common of all environmental hazards and it regularly claims over 20,000 lives per year and adversely affects around 75 million people world-wide (Smith, 1996). Across the globe, floods have posed tremendous danger to people's lives and properties. Floods cause about one third of all deaths, one third of all injuries and one third of all damage from natural disasters

Kerala has an average rainfall of 3000 mm per year. Kerala has natural heritage settings and is India's third most populous state; the population is 3.48 cr. The total area is 38,863 sq. km. As Kerala owns 47% of the land dedicated to the Western Ghats in the biodiversity sector, there is a need to protect this category. In August 2018, the highest destruction has occurred all along the Periyar, Chalakkudy and Pamba rivers, all with numerous dams.

2.1 MAJOR VEGETATION IN KERALA

Due to its varied topographical features, high rainfall and geological conditions, Kerala has a luxuriant forest cover of 11,125.59 km^2, which is roughly 29% of Kerala’s land area. The most outstanding feature of the State is the formation of tropical rainforests along the windward side of the Southern Western Ghats, which is lying parallel to the west coast (Sasidharan, 2006). Major parts of Kerala’s forest cover are confined to the Western Ghats. The Western Ghats have recently been added to the UNESCO’s World Heritage Sites and is one of the eight "hottest hotspots" of biological diversity in the world (Myers *et al.,* 2000). The forests of Kerala harbour almost 25% of India’s plant species which includes many endemic, rare and endangered plants. The forest types of Kerala include evergreen forests (wet evergreen and semi-evergreen climax forests, west coast tropical evergreen forests, southern hill top tropical evergreen forests and semi-evergreen forests), deciduous forests (secondary dry deciduous forests, southern dry deciduous forests, secondary moist deciduous forests and dry deciduous forests), shola forests, grasslands, mangroves and the subtypes such as dry teak forests, lateritic semi-evergreen forest, littoral forests, myristica swamps, nilgiri subtropical hill forests, south Indian subtropical hill savannah, southern moist mixed deciduous forests, southern secondary moist mixed deciduous forests and very moist teak forests. These diverse forest types harbour rich and diverse vegetation. The major tree species found in the evergreen forests of Kerala are *Actinodaphne hookeri, Aglaia barberi, Antiaris toxicaria, Aporosa lindleyana, Artocarpus heterophyllus, Artocarpus hirsutus, Bischofia javanica, Bombax ceiba, Canarium strictum, Cinnamomum zeylanicum, Cynometra travancorica, Dipterocarpus indicus, Elaeocarpus tuberculatus, Ficus nervosa, Flacourtia montana, Holigarna grahamii, Holoptelea integrifolia, Hopea parviflora, Hydnocarpus macrocarpus, Litsea bourdillonii, Mallotus tetracoccus, Mangifera indica, Mimusops elengi, Myristica beddomei, Olea dioica, Oroxylum indicum, Otonephelium stipulaceum, Persea macrantha, Pterospermum reticulatum, Syzygium gardneri, Terminalia bellirica, Terminalia travancorensis, Toona ciliata* and *Vateria indica.* The tropical moist deciduous forests harbour trees like *Dillenia pentagyna, Strychnos nuxvomica, Tabernamontana haeyneana, Tectona grandis, Terminalia bellirica, Terminalia paniculata* and *Xylia xylocarpa.* Some of the common trees found in the shola forests of Kerala (Sasidharan, 2006) are *Actinodaphne bourdillonii, Cinnamomum sulphuratum, Elaeocarpus munronii, Elaeocarpus recurvatus, Euonymus indicus, Mahoniale schenaultii, Michelia champaca, Pittosporum neelgherrense, Myrsine wightiana, Rhododendron arboretum Symplocos cochinchinensis* and *Syzygium densiflorum.*

To conserve the vast biodiversity, many protected zones have been created in Kerala. The State has two biosphere reserves: the Nilgiri Biosphere Reserve (includes parts of Wayanad, Malappuram and Palakkad Districts) and the Agasthyamalai Biosphere Reserve (covers parts of Thiruvananthapuram, Kollam and Pathanamthitta Districts). In addition, Kerala has five National Parks: Aanamudi Shola National Park, Eravikulam National Park, Silent Valley National

Park, Mathikettan Shola National Park and Pampadum Shola National Park. There are thirteen Wildlife Sanctuaries in Kerala aimed to protect the wildlife of the regions: Aaralam Wildlife Sanctuary, Chimmini Wildlife Sanctuary, Chinnar Wildlife Sanctuary, Idukki Wildlife Sanctuary, Mangalvanam Bird Sanctuary, Neyyar Wildlife Sanctuary, Parambikulam Wildlife Sanctuary, Peechi-Vaazhaani Wildlife Sanctuary, Peppara Wildlife Sanctuary, Periyar Wildlife Sanctuary (Tiger Reserve), Shendurney Wildlife Sanctuary, Thattekkaad Bird Sanctuary and Wayanad Wildlife Sanctuary. Apart from the officially declared conservation zones, Kerala has roughly 2000 small and large sacred groves covering approximately 500 hectares (Khan *et al*., 2008). Although they are the part of religious and cultural practices, they form finest models of traditional conservation systems that are practiced for centuries in Kerala (Gadgil and Chandran 1992; Chandrashekara and Sankar 1998*). Adenanthera pavonina, Aglaia elaeagnoidea, Antiaris toxicaria, Artocarpus hirsutus, Caryota urens, Celtis timorensis, Cinnamomum malabathrum, Ficus mysorensis, Ficus tsjahela, Ficus virens, Flocourtia montana, Garcinia gummi-gutta, Hopea parviflora, Hopea ponga*, *Ixora brachiata*, and *Macaranga peltata* are some of the tree species found in the sacred groves of Kerala (Chandrashekara and Sankar, 1998).

2.2 CLIMATE OF KERALA

The climate of Kerala is tropical, maritime and monsoonal. The state receives a mean annual rainfall of 2693 mm spread over 120-140 rainy days annually. Kerala gets most of its rainfall during the two monsoon seasons: the south-west monsoon season starting from early June and extending up to September and the north-east monsoon season, occurring in the period of October-December. The south-west monsoon provides most of the rainfall and contributes nearly 60% of the annual precipitation. North-east monsoon is characterized by much less rainfall. Off seasonal rainfall is occasionally received. The winter months (December – February) are characterized by minimum clouding and rainfall. The mean annual temperature varies from 25.4ºC to 31ºC in the midlands of Kerala while it drops to 15ºC in the hills. The temperature rises to about 40ºC during the summer months of March, April and May. The mean relative humidity varies between 85% and 95% during June and lowers to 70% in summer months (Sasidharan 2006; Simon and Mohankumar 2004).

2.3 KERALA FLOODS: CAUSES AND CONSTRAINTS

Kerala is a densely populated area and as a result, Kerala's proper rivers have been further contaminated from industrial and household pollution and from pesticides and fertilizers in agriculture, which are the major ecological issues. Rainfall is dominated by Southwest and northeast monsoon in Kerala (Mishra *et al.*, 2018). In August 2018, Kerala experienced unusually heavy rainfall, resulting in flooding in 13 districts had a daily rainfall of 398 mm, 305 mm, 255 mm, 254 mm, 211 mm and 214 mm was recorded in Nilambur of Malappuram Dist., in Mananthavadi of Wayanad District, Peerumade, Munnar KSEB and Myladumpara in Idukki District and in Palakkad District respectively. Water was distributed between the sub-regions of Periyar and Pamba in Kerala which means that the whole of Kerala was flooded. Kerala province has 47% of the land dedicated to Western as a natural environment rich in natural resources. The Western Ghats is considered one of the eight tropical hotspots of biodiversity. Due to climate change and human disturbance in these areas, biodiversity is beginning to be affected. The Western Ghats have the largest population in the Wayanad tracts. Under the protection of biodiversity conservation, WGEEP prepared a flood report for Kerala and the government took some action in terms of the report (Kerala disaster in part: man-made: Madhav Gadgil, lead expert for the Western Ghats report, 2018).

Kerala has almost 50% of the world's natural resources which means the area has conservation importance but the picture is different due to high demographic pressure of the state. In the real sense, all Western Ghats should be called a Natural Critical Area. To control the region's environment and to ensure its unsustainable development, the Western Ghats Ecology Team is on hand. This authority was appointed by the Department of Environmental Affairs and Forestry, GoI under the Environmental Protection Act, 1986. This authority is affiliated with the Marine Ecological Council, Pollution Control Boards and Government Planning Departments. In this region, 11 evergreen species were distributed in 3 regions, 4000 flowering plants and 645 evergreen trees. Along with this, 500 species of birds and 120 species of mammals are found here. Rainfall is very high compared to the surrounding regions, this situation being affected by the flood disaster in 2018.

Floods affected hundreds of towns, damaging infrastructure. This situation has been regularly monitored by the Central Government and the National Disaster Management Committee which also oversees rescue and relief operations (Nandargi and Aman, 2018). Kerala has 57 major dams, out of which 4 dams are being used by the Tamil Nadu Government. The floods attracted the attention of the media, the scientific community, and policy makers, who were not seen as a precautionary measure by mainly policy makers and planners.

Another potential source of land-use change in the state was previously limited construction and nowadays this adaptation is increasing even in ecosystems, and is the direct cause of major flooding in cities. When the study looks at the details, flooding occurred for a number of reasons such as small deposits in the soil. During the first phase of the monsoons, all the water will be drawn from the ground and will also create groundwater. When the water table approaches the surface, a number of flow mechanisms will be used including soil pipes (Madhusoodhanan, 2019). It is seen that the area contributing to the flow of pipes increases with the size and duration of the rainfall. If the management does not work, these types of disaster will be in the worst form and therefore lack of preparation / inactivity / delay in the DMAs can cause great misery and suffering for the people and the state economy (Narayan, 2018). Urban areas do not have enough drainage infrastructure, so this type of disaster is taking advantage. According to the Land Use and Land Cover (LULC) study, it is clear that the cities in the province have increased construction as compared with previous studies, most of them are disrupting ecological reform. Various illegal activities are set up in these parts of the Western Ghats such as mining operations, large buildings, thermal power stations, and highly polluting industries etc. (Sen, 2018).

According to the Indian Department of Environment, there is a decrease in water levels in rivers, canals and other things, due to prolonged erosion after flood

(Madhusoodhanan, 2019). Due to heavy rainfall, earthquakes have occurred and have caused significant property damage (Kuriakose, 2009). Flood pollution can be contaminated with dangerous substances, faeces, dead bodies and medical waste. As waste would become wet, there is an increased chance of decay within a short period of time. At that time, the pollution process will take place and this will affect the soil and water. Eventually these things progress to environmental pollution and health issues will shoot up over time.

The European Union defines a flood as "a temporary covering of groundwater that is not normally covered by water" and indicates that the flood is made up of temporary and semi-permanent areas. The temporary portion can last from minutes to months. Spatial extensions can range from a few square meters to ten thousand square kilometers (Hirschboeck, 1988).

2.4 EARLIER FLOODS IN KERALA

The year 1924 witnessed unprecedented and very heavy floods in almost all rivers of Kerala. Heavy losses to life, property and crops etc. had been reported. The rainstorm of 16-18, July 1924 was caused by the South-west monsoon that extended to the south of peninsula on 15th July and caused rainfall in Malabar. Under its influence, heavy rainfall occurred in almost entire Kerala. The area under the storm recorded 1-day maximum rainfall on 17th of July, 2- day maximum rainfall for 16-17, July 1924 and 3-day maximum rainfall for 16-18, July 1924. The fury of 1924 flood levels in most of the rivers was still fresh in the memory of people of Kerala. The year 1961 also witnessed heavy floods and rise in the water levels of reservoirs. Usually in the state, heavy precipitation is concentrated over a period of 7 to 10 days during the monsoon when the rivers rise above their established banks and inundate the low lying areas. But in 1961, floods were unusually heavy not only in duration, but also in the intensity of precipitation. During the year 1961, the monsoon started getting violent towards the last week of June and in the early days of August, the precipitation was concentrated on most parts of the southern region of Kerala. By the first week of July, the intensity gradually spread over other parts of the State and the entire State was reeling under severe flood by the second week of July. The worst affected area was Periyar sub-basin and it was also impacted other sub-basins. Many of the important infrastructures like highways etc were submerged. After a brief interval, by the middle of July, the monsoon became more violent, affecting the northern parts of the State. The average rainfall was 56% above normal.

2.5 IMPACT OF FLOOD ON SOIL

Soil is the edge of the earth's crust composed of crushed and decomposed rocks containing complex elements of minerals, water, air, and organic matter. Soil supports the growth of terrestrial plants and provides nutrients to plants. It has many important plant nutrients, the main elements are Nitrogen (N), Phosphorus (P) and Potassium (K). Besides, plants need certain nutrients such as Calcium (Ca), Magnesium (Mg) and Sulphur (S) in small amounts. Plants also require other nutrients such as Boron (B), Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn) etc. in very small quantities. There is, however, a small deposition of silt, when fields are irrigated by rivers. The silt contains fine particles of soil, mixed with an abundance of nutrients, produced in the upper layers. Microorganisms break down the organic matter and bring the nutrient into absorbable form by the plants. Humus is the only source and reservoir of nitrogen. Thus, the silt raises soil fertility and improves its fine texture and soil quality due to floods. In addition, flood water can dissolve dissolved salts in the soil and reduce soil salts. In contrast, floods have created a very destructive environment in soil quality due to the ingestion of sandy material. Sand materials break down soil texture and will reduce water holding capacity and nutrient retention capacity.

Ground water is so high in this situation that it does not allow for convenient agricultural practices (Sharma and Swarup, 1988). Water logging conditions change dramatically the soil properties, these soil changes adversely affect a plant's ability to live in these circumstances (Dat *et al.*, 2004).. The loss of soil productivity by processes of degradation, as excess water in the soil, has inspired many researchers from different countries around the world (Kozlowski, 1985; Dat *et al.*, 2004; Jackson and Colmer, 2005; Irfan *et al.*, 2010; Nickum *et al.*, 2010; Yong *et al.*, 2011; Ammara and Shumaila, 2012; Mahabaleshwara and

Nagabhushan, 2014; Raut *et al*., 2014; Valipour, 2014 and Morales-Olmedo *et al*., 2015;), to develop various quantifying studies to promote the selection of systematic soil management practices for specific land use and protection purposes (Rivera, 1999). In Australia, water logging losses were more severe than those in winter cereals due to soil salinity (Grieve *et al.,* 1986).

2.5.3 Impact of flood on soil physical properties

The occurrence of soil flooding may be attributed to delay in water infiltration following the formation of the impermeable soil crust in the relatively lower furrow and reduction in RAC (Rainfall Acceptable Capacity) due to the rising water table and heavy rainfall (Yong *et al.*, 2011). Many factors, such as the duration of water logging, soil type, soil texture, and soil organic matter greatly influence the magnitude of the changes (Cosentino *et al*., 2006; Li and Shao, 2006; Bandyopadhyay *et al*., 2010). Soil water logging influences soil physical properties such as; lead swelling of colloids, reduce aggregate stability, and reduces permeability of soil (Ponnamperuma, 1984; Reddy and De Laune, 2008). Increasing the bulk density and/or the presence of small pores intensifies the impact of water on this parameter. Modification of these factors also influences the pores' morphology, resulting in a decrease in macro pores and a rise in micropores (Letey, 1985).

Fahmi *et al.* (2014) showed that the soil water logging decreased aggregate stability, soil particle density and bulk density. The effect of flooding on soil bulk density, moisture content and total porosity shows a significant ($P < 0.05$) difference in bulk density, moisture content and total porosity among all the flood meadows and control, studied by Njoku and Okoro (2015). Control recorded the highest bulk density of 1.59g/cm^3. This observed bulk density in control was higher than the bulk density in cultivated flood meadow, a year fallowed flood meadow and more than a year fallowed flood meadow by 9, 17 and 22%, respectively (Njoku and Okoro, 2015). The order of increase in total porosity and moisture content were was more than in one year fallowed flood meadow which is > cultivated flood meadow which is > control. This lower bulk density and higher total porosity and moisture content in flood meadows compared to control may be as a result of materials such as debris, silt and microscopic organisms that were brought to the flood meadow by flood that help to improve properties of flood meadow soil. (Njoku and Okoro, 2015).

2.5.2 Impact of flood in soil chemical properties

Past research suggests that anaerobic soil conditions due to flooding will lead to a reduced availability of nutrients for riparian plants. In particular, N availability may decline due to either increase in denitrification and nitrate reduction (Baldwin and Mitchell, 2000; Vepraskas and Faulkner, 2001), or decrease in effective N concentration due to altered decomposition of residues (Baldwin and Mitchell, 2000; Baker *et al.*, 2001; Schuur and Matson, 2001; Neatrour *et al.*, 2004). Lockaby *et al.*, (1996) recorded a general loss of N in flood treatments; the greatest loss of N occurred in continuous flooding for 3 months, but all flood treatments resulted in a loss of N in relation to the control.

The plants that tolerate flooding have certain physical conditions that allow them to deal with the low oxygen content of the soil; while tolerant plants are less adaptable. With the loss of global oxygen, viruses lacking anaerobic respiration will switch to other electron acceptors for their metabolic needs. This results in the reduction of oxygen, nitrogen, manganese, iron or sulphur levels in the soil. The reduction reaction may be due to changes in phase or solubility. For example, reduced Fe and Mn are more soluble; these reduced ions move through the soil resulting in areas with reduced or complete Fe and Mn concentrations (Vepraskas and Faulkner, 2001). Fe and Mn are predominantly found in plants, and toxic concentrations are possible. The kinetics of the partial pressure of CO_2 in flooded soils plays a crucial role in bringing about changes in pH, redox potential, and solubility of Ca^{2+}, Mg^{2+}, Fe^{2+} and Mn^{2+} and also indirectly influences specific conductance and cation exchange reactions. The concentration of CO_2 in the soil-water system is equally important for its physiological influence, for high concentration of CO_2 at partial pressures exceeding 15% has been shown to impede water and nutrient uptake by the rice plant (Ponnamperuma, 1984).

Phosphorus (P) availability increases when the soil is flooded due to the increase of phosphate reaching the roots and the release of phosphate into the soil solution (Young and Ross, 2001). When the soil is placed under condensation conditions, the iron (Fe) oxide dissolves, and the associated P is released (both adsorbed and incorporated species). In contrast, when flooded soils are depleted, the availability of P decreases (Seng *et al.,* 1999; Scalenghe *et al.,* 2002; Huguenin-Elie *et al.,* 2003).

Other studies have shown that Fe phosphate compounds are the main source of P for rice plants (Shahandeh *et al.*, 1994). Floods increase the strength of Fe oxides due to the reduction of Ferric (Fe^{3+}) to ferrous (Fe^{2+}) ion. Scalenghe *et al.* (2002) observed that the amorphous oxides were especially involved in this process as there was selective oxidation of Fe from the oxalate species. As a result of the reduction of Fe, the P associated with these oxides is released into the ground solution. The amount of P extracted from the soil solution depends on the soil components involved in the reduction cycle (the amount of Fe oxides, their crystallinity, and the content of soil organic matter (SOM)), and the rate of soil saturation with P. OM favours a reduction because it is a significant electron donor (Scalenghe *et al*., 2002).

2.5.3 Impact of flood in soil biological properties

Numerous studies have shown that long inundations lead to anaerobic conditions, thereby reducing the decay and replacement of nutrient cycling (Baker *et al.,* 2001; Baldwin and Mitchell, 2000; Neatrour *et al.,* 2004; Schuur and Matson, 2001). Changes in the structure of the global microbial community are expected when anaerobic conditions occur in flooding (Elhottova *et al.,* 2002; Mentzer *et al.,* 2006). These changes can subsequently affect the lateral parts of the organism due to the critical roles played by bacteria andmould in nutrient recycling (Suzuki *et al.,* 2005).

Mentzer *et al*. (2006) found that excessive flooding had a greater impact than nutrient loading in that flooding altered both microbial population composition as well as functional components. In particular, flooding decreased mycorrhizal fungal markers, thus growing bacterial Gram-negative, anaerobic, and Gram-positive bacterial markers. Drenovsky *et al*. (2004) also observed a decrease in fungal biomarkers, but not in bacterial biomarkers with increased soil water. In addition, Bossio and Scow (1998) reported a decrease in fungal and aerobic indicators, and an increase in Gram-positive flooding bacterial indicators; however, improvements in microbial indicators with straw incorporation were also reported. In other studies, the reduced prevalence of fungi under flooded conditions (Bossio and Scow, 1998; Drenovsky *et al*., 2004; Mentzer *et al*., 2006) is consistent with the hypothesis that fungi are less abundant in inundated soils.

In the leaves and roots of plants subjected to flooding, production of alcohol dehydrogenase increased. These are due to the hypoxic condition and consequent production of alcohol created through the fermentation process (Benz *et al*., 2007). During flooding there is minimal oxygen capitation and consequently paralysis in the transport of electrons and oxidative phosphorylation in the mitochondria. In other words, ATP cannot generate in the tricarboxylic acid cycle, and this energy source can only be obtained via fermentation process. According to Moraes *et al.* (2001), this metabolic adaptation linked to the action of alcohol dehydrogenase is important to prevent accumulation of alcohol and other adverse effects on the tissue of plants.

Floods promote the separation between soil and oxygen, activating the biological and chemical processes that transform the aerobic system from aerobic oxidation to anaerobic reduction. That is, after flooding, oxygen is quickly consumed by microbial respiration and chemical oxidation. After using oxygen, nitrate, manganese and nitrite are used as electrodes, the fertile metal is reduced to a porous state, sulphate converts to hydrogen sulphite, and CO_2 converts to methane; therefore, this soil has great potential for cycling of nutrients.

2.6 IMPACT OF FLOOD ON SOIL SEED BANK

The term soil seed bank was used to identify the viable seed reserve present in a soil according to Roberts (1981). For Baker (1989), this reservoir refers to seeds that are not germinated but capable of replacing the annual adult plants that have or have not vanished by natural death and perennial plants susceptible to plant diseases, disturbance and animal consumption, including man.

All viable seeds present in the soil or mixed with soil debris form the seed bank of the soil (Simpson *et al.,* 1989). The soil seed bank is closely related to weed studies in the agro ecosystems. Its commitment enables population system models to be established over time, enabling weed control programs to be described (Martins and Silva, 1994). Owing to their ability to withstand many adverse climatic conditions, tolerating high and low temperatures, dry and humid climates, and oxygen supply variations, the weed species have persisted over time. The fundamental aspect of weed survival success is their capacity for persistence in some regions. This potential is the product of a large number of developed seeds, long-term viability, continuous germination, phenotypic and genetic plasticity (Freitas, 1990; Fernández-Quintanilla and Saavedra, 1989).

Another feature of seed dormancy is that it affects the seed bank reservoir. Seed populations of several vegetable species behave differently in terms of germination; the weeds produce polymorphic seeds, with a certain proportion dormant and a different proportion not (Freitas, 1990); Dormancy provides a significant mechanism for the survival of biodiversity at the seed bank, spreading germination throughout the year. It can guarantee the species survival in seed form, under adverse conditions, even when the plant population is totally eliminated (Carmona, 1992).

The range, duration and frequency of flooding all influence seed dispersal range and affect species composition and spatial distribution patterns of seed banks (Capon 2007; Hou *et al.,* 2008; Osunkoya *etal.,* 2014), and ultimately determine vegetation development (Battaglia and Collins 2006; Stroh *et al.,* 2013; Su *et al.,* 2012) Studies have recently been reported which show considerable variation in the number of seeds in the soil in relation to different flood regimes. Capon and Bock (2006) have shown that flood-prone areas tend to have more sprouting plants than less-affected areas. Earlier work by Casanova and Brock (2000) found that seed bank formation was related to depth, duration and frequency of floods.

In addition to flooding, topographic position and chemical and soil properties can also influence crop distribution. The results reported by Focht and

Pillar (2003) and Maia *et al.,* (2004) revealed that the soil seed bank is related to position in the release, humidity, potassium level, organic matter, saturation of cation base exchange, exchangeable bases and part of the clay in the soil.

In the Pantanal floodplain, spatial and temporal variability of flooding has been reported as an important factor determining the composition and abundance of herbaceous species (Rebellato and Cunha, 2005). For herbaceous species, the soil seed bank is vital for the maintenance of its diversity (Thompson and Grime, 1979), since their short life cycle gives rise to a constant renewal of the stock of seeds in the soil (Costa and Araújo, 2003). Capon and Brock (2006) also found a relation between seed banks and flooding, reporting that the abundance of seeds was related to flood frequency. Without the disturbance caused by flooding, soil seed banks in rarely-flooded areas may diminish in abundance (and subsequently in diversity) simply as a result of seed mortality.

2.7 IMPACT OF FLOOD ON VEGETATION

Spring floods have destroyed seeds of some species that germinate on thick alluvial deposits only after leaf litter and other organic debris. Some are able to grow on thinly spread bedrock overlying with alluvium. Due to flooding in late spring or early summer, seedlings are often removed or buried by sediments, indicating that good growth can coincide with periods of low flow (Sigafoos, 1964)._Hosner (1958) found that, within 32 days of complete submergence, first-year seedlings of six flood-plain species died and different species died at different rates. Hosner (1960) found in more extensive studies that seedlings survived for longer periods when only the roots were flooded because the crowns retained the capacity to exchange gas.

2.8 DIFFERENCE IN SOIL PROPERTIES UNDER DIFFERENT LAND USE SYSTEMS

Soil modification due to changes in land use types and patterns is a major threat to sustainable productivity of the soil (Ayoubi *et al.,* 2011) and is considered as one of the major factors that affect the distribution patterns of nutrients (Islam and Weil, 2000) in the soil. North eastern India is drastically affected by land use change (Grogan *et al.,* 2012; Tao *et al.,* 2018), particularly, shifting cultivation, closely linked to ecological, socio-economic, cultural and land tenure systems of tribal communities (Tripathi *et al.,* 2017) which profoundly affects the soil fertility and crop productivity (Wapongnungsang and Tripathi, 2018). Soil organic carbon (SOC) is an important component of the global carbon cycle indicating soil fertility and productivity (Van der Werf *et al.,* 2009) and studies have shown a significant variation in relation to land uses (Ali *et al.,* 2017; Iqbal *et al.,* 2014; Maurya *et al.,* 2014). The land use practices often influences the fluxes of soil carbon stocks and have been reported to vary with the change in land use systemss.

Soil productivity and sustainability depends on dynamic equilibrium among its physical, chemical and biological properties. These properties are continuously influenced by land uses with profound influence on soil properties and thus, help in restoration of soil quality (Deekor, 2012). Therefore, knowledge on the impacts of land use on soil property is indispensable for sustainable agricultural production (Fesha *et al.,* 2002). Several researchers have studied the effect of land use on soil properties that provides an opportunity to evaluate sustainability of land use systems.

Lal (1996) and Shepherd *et al.* (2000) examined that land use changes in tropical ecosystems could cause significant modifications in soil properties. Conversion of native forests and pristine soils to cultivation is usually accompanied by decline in SOC and deterioration of soil structure. Offiong *et al*., (2009) reported that the levels of SOC, total N and CEC were substantially higher in soils of the undisturbed secondary forest than in soils adjoining the road. Similarly, several studies reported on impacts of land use on soil properties under arable lands in India (Joshi, 2002; Suma *et al.,* 2011).

According to Wang and An (2001), climate and geological history are importance factors to affecting soil properties on regional and continental scales. However, land use may be the dominant factors of soil properties under small catchment scale. Land use and soil management practices influence the soil nutrients and related soil processes, such as erosion, oxidation, mineralization, and leaching, etc (Celik, 2005; Liu *et al.,* 2010). As a result, it can modify the processes of transport and redistribution of nutrients. In non-cultivated land, the type of vegetative cover is a factor influencing the soil organic carbon content (Liu *et al.,* 2010). Moreover, soils through land use change also produce considerable alterations (Fu *et al.*, 2000), and usually soil quality diminishes after the cultivation of previously untilled soils (Neris *et al.*, 2012). Thus, land use and type of vegetation must be taken into account when relating soil nutrients with environmental conditions (Liu *et al.*, 2010).

Dynamics of soil properties such as texture, pH, electrical conductivity, carbon (C), nitrogen (N), available phosphorus (P), available potassium (K), and micronutrients are studied in different land use scale and dimensions (Jafarian *et al*., 2014; Kharal *et al*., 2018; Kilic *et al*., 2012; Wei *et al*., 2007). Out of eight micronutrients (B, Zn, Fe, Cu, Cl, Mo, Ni, Mn), Boron (B) and Zinc (Zn) are the most limited in Nepalese soils, followed by Molybdenum (Mo) (Andersen, 2007). Nepal is a predominantly rice (*Oryza sativa* L.), maize (*Zea mays* L.), and wheat (*Triticum aestivum* L.) crop-based country where the deficiency of B and Zn greatly influence yield gain. Molybdenum is mostly deficient in the growing area of cole crops. It is important to know how these soil properties vary in different land use contexts so that best management practice options can be recommended to growers based on the limited nutrients.

Soil properties vary in different spatial areas due to the combined effect of biological, physical, and chemical processes over time (Santra *et al*., 2008), and can vary within farmland or at the landscape scale (Corwin *et al.,* 2003; McBratney and Pringle, 1997; Mouazen *et al*., 2003). Different land use and management practices greatly impact soil properties (Spurgeon *et al*., 2013), and knowledge of the variation in soil properties within farmland use is essential in determining production constraints related to soil nutrients. It is also important to suggest different remedial measures for optimum production and appropriate land use management practices (Panday *et al*., 2018). Sustainable land management practices are necessary to meet the changing human needs and to ensure long-term productivity of farmland (Hălbac-Cotoară-Zamfir *et al*., 2019).

2.9 GLOBAL SIGNIFICANCE OF FLOOD

The increase in global demand due to increasing population and food insecurity has prompted farmers to farm in semi-arid lands such as erosion-prone areas (Quansah, 1997; Sanchez *et al.*, 1997).

In August 2018, the state of Kerala experienced its worst flooding since 1924. The devastating food and associated landslides affected 5.4 million people and claimed over 400 lives. The post-disaster assessment commissioned by the Government of Kerala estimated the economic loss to be more than $3.8 million. These floods, as well as many like the ones listed earlier, occurred during the passage of a monsoon depression.

Flooding can cause crop shortages in flood plains and regions (Powell, 2009). It also contributes positively to soil properties by the provision of nutrients that may be lacking in the soil (Stephen, 1993; O'Connor *et al.*, 2004).

MATERIALS AND METHODS

The study on “Soil and vegetation characteristics in the post flood scenario in selected tree based land use systems in Thrissur, Kerala’’ was carried out at College of Forestry, Kerala Agricultural University, Thrissur during April 2019 to June 2020. The materials used and the methodology adopted for the study is described in this chapter.

3.1 STUDY AREA

The present study for the comparison of soil and vegetation of the selected flood affected and the adjacent non flooded tree based land use systems were conducted in ‘Kurumali river’ basin of Thrissur, Kerala. The study site consisted of five different land use systems under both flood affected and non flooded conditions,

The land use systems studied are:

1) Forest flood affected (FF)
2) Forest non flooded (FNF)
3) Rubber flood affected (RF)
4) Rubber non flooded (RNF)
5) Nutmeg flood affected (NF)
6) Nutmeg non flooded (NNF)
7) Coconut flood affected (CF)
8) Coconut non flooded (CNF)
9) Open flood affected (OF)
10) Open non flooded (ONF)

The Kurumali river, one of the two important tributaries of Karuvannur river, originates from the Pumalai hills in Chimmony wildlife sanctuary in the Western Ghats of Kerala and flows westwards through the Thrissur district to join with the Arabian Sea. The Karuvannur river lies in the latitude longitude range of 10°15’ N to 10° 40’N and 76°00’ E to 76° 35’ E. Total catchment area of the river is 1054 km^2 . The *Mupli* stream coming from Pundimudi region at an elevation of

+1116 m and joins the Chimmony River, forming the Kurumali River in Elikode near Karikulam. Further downstream, Kurumali River joins with Manali River at Palakkadavu and forms Karuvannur River. Karuvannur is the most important river basin of Thrissur district with utilizable water resources of 623 million cubic metres per annum of which the net utilizable surface and ground water resources are 519.8 million cubic metre and 103.2 million cubic metre, respectively. During the study period (2019-2020), the average annual rainfall in the low land of the Karuvannur basin was estimated to be 2858 mm, the midland receiving 3011mm and the highland 2851 mm. About 60 per cent of the annual precipitation is received during South West monsoon period, 30 per cent from North East monsoon and 10 per cent as the summer and pre monsoon period. The outlet selected for the watershed is at Kurumali in Varandarappilly Grama panchayath with a latitude and longitude of 10°24’4” N and 76°16’56” E, respectively.

3.1.1 Location

The study area is in Varandarappilly Grama panchayath of Thrissur district. The study was conducted in ten different places in the panchayath. A total of 10 plots (Table 1) were taken. Geographical co- ordinates of sampling sites recorded using a GPS are tabulated as below:

Table 1. Location of the sampling sites

Land use systems	**N latitude**	**E longitude**
Forest Flood Affected	10°32' 53.32"	76°16' 44.53"
Forest Non flooded	10°25' 32.10"	76°25' 0.48"
Rubber Flood Affected	10°25' 42.34"	76°22' 43.54"
Rubber Non flooded	10°25' 41.11"	76°22' 40.77"
Nutmeg Flood Affected	10°25' 46.97"	76°22' 02.21"
Nutmeg Non flooded	10°25' 52.56"	76°21' 58.33"
Coconut Flood Affected	10°25' 36.89"	76°21' 10.75"
Coconut Non flooded	10°25' 34.07"	76°20' 40.12"
Open Flood Affected	10°25' 40.31"	76°23' 05.89"
Open Non flooded	10°25' 43.16"	76°23' 03.59"

3.2. MATERIALS

Soil samples were collected from different depths (0-20 cm, 21-40 cm, 41-60 cm, 61-80 cm, 81-100 cm). Plots of size 20 m x 20 m from the flood affected and nearby non flooded affected areas for the vegetation analysis. Three representative samples were collected from flood affected and non flooded affected areas of all these five land use systems viz. Rubber plantations, Coconut plantations, Nutmeg plantations, Natural forest and Open land as control.

3.2.1 Collection of soil sample

Representative soil samples from five different depths ((0-20 cm, 21-40 cm, 41-60 cm, 61-80 cm, 81-100 cm) are collected from all the ten treatments (table 1). Firstly removed the surface litter by very light scraping. Clean plastic containers were used for collection and mixing of soil samples. Clean labelled cloth bags used were for keeping the soil sample up to analysis.

3.2.2 Processing of sample

Large crumbs or aggregates of soil were broken and kept it in a clean paper for air drying. After air drying, ground the soil sample was grinded and sieved it through 2mm sieve and kept in cloth bags for doing the analysis.

3.2.3. Estimation of soil physical properties

Soil porosity, Bulk density and Soil texture are estimated as soil physical properties of the representative sample collected.

3.2.3.1 Estimation of Soil Porosity

Pore space is the share of volume occupied by pores in a definite volume of soil. Porosity is the ratio of the volume of the pore space to the total volume of the soil. It is expressed as a fraction or more commonly as percent. Porosity is calculated using the formula (Black *et al.*, 1965):

Porosity = (1-Db/Dp)*100

Where, Db = Bulk density

Dp= Particle density

3.2.3.2 Soil Bulk density

The bulk density was calculated by taking out of core sampler (Gupta and Dakshinamurthy, 1980). The core is driven into undisturbed soil in the field and sample is collected into the core. The core is carefully taken out and the edges are trimmed to level the surface using a sharp stainless steel knife. Keep the core at 105 °C until it attains stable weight. Record the stable weight and from this calculate the weight of dry soil filled in the core. The volume of soil was calculated by measuring the volume of cylinder.

The Bulk density is calculated by the formula:

Bulk density (g cm^{-3}) = Mass of dry soil solid particle/ Volume of soil (with pore space)

3.2.3.3 Soil texture

Soil texture refers to the relative percentage of sand, silt, and clay within a soil layer. Soil texture was estimated by feel method proposed by Thien (1979).

3.2.4 Estimation of soil chemical properties

Soil pH, EC, Organic carbon, Available N, P, K, Ca, Mg, S and Fe, Mn, Cu, Zn, B were estimated as soil chemical properties using the representative soil samples collected.

3.2.4.1 Soil pH

For pH estimation 1:25 ratio of soil: water suspension was prepared. The pH was measured by using pH meter (Eutech, Singapore) as described by Jackson (1973).

3.2.4.2 Soil electrical conductivity

The electrical conductivity of soil samples collected from different depths were determined from the supernatant liquid of the water suspension (1:2.5) with the help of a conductivity meter. (Jackson, 1958).

3.2.4.3 Organic Carbon

Determination of organic carbon was done by wet digestion method (Walkley and Black, 1934).The soil samples collected from five depths (0-20cm, 21-40cm, 41-60cm, 61-80cm, 81-100cm) were air dried and passed through 0.2 mm sieve. The soil organic carbon was estimated using equation:

$$\text{Soil organic carbon (\%)} = \frac{(\text{blank value} - \text{titre value}) \times 10 \times 0.003 \times 100}{\text{weight of soil samble (g)} \times \text{blank value}}$$

3.2.4.4 Available Nitrogen

Available nitrogen at five different soil depths (0-20, 21-40, 41-60, 61- 80, 80-100 cm) were determined by alkaline permanganate method (Subbaih and Asija, 1956).

3.2.4.5 Available phosphorus

Available phosphorus in the soil samples were extracted using Bray N0.1 reagent (Bray and Kurtz, 1945) and estimated colorimetrically by reduced Molybdate-Ascorbic acid blue colour method (Watanabe and Olsen, 1965) using spectrophotometer (Thermo Scientific, USA).

3.2.4.6 Available potassium

Available potassium in the soil samples from different depths (0-20, 21-40, 41-60, 61-80, 81-100 cm) were extracted using neutral normal ammonium acetate and its content in the extract was determined by flame photometry (Jackson, 1958).

3.3.4.7. Available Calcium and Magnesium

Shake 5 g of soil with 25 ml of neutral normal ammonium acetate for 5 minutes and filtered immediately through a dry Whatman No.42 filter paper.From the soil extract Ca and Mg are estimated by Atomic Absorption Spectrophotometer (AAS).

Available Ca/Mg (mg/kg soil) =µg Ca/Mg/ml of the aliquot × 5

3.3.4.8 Available Sulphur

It was extracted by 0.15 per cent $CaCl_2$ solution as method given by Williams and Steinbergs (1959) and determined by turbidimetric method given by Chesnin and Yein (1951).

3.3.4.9 Estimation of Fe, Mn, Zn and Cu in acid soils (pH<6.5)

Available micronutrients in soil samples were extracted using 0.1M HCl (Slims and Johnson, 1991). Shake 2g of soil with 20ml of 0.1 M HCl for 5 min

.Filter through Whatman No. 42 filter paper. Collected the filtrate and estimated the contents of Fe, Mn, Zn and Cu using Atomic Absorption Spectrometer.

Amount of micronutrient (mg/kg soil) = Concentration from the instrument × 2

3.3.4.10 Available Boron

Available boron in soil samples were extracted with hot water (Gupta, 1967) and estimated colorimetrically by azomethine – H using spectrophotometer.

Amount of B in soil (mg /kg soil) = (Absorbance reading x 2)/Slope from curve

3.3.5 Estimation of soil biological properties

The soil biological properties such as the Total microbial count, Dehydrogenase activity and Microbial biomass carbon were estimated.

3.3.5.1 Total microbial count

Estimation of total microbial count was done by "Serial dilution plate technique (Johnson and Curl, 1971) using soil extract agar medium for bacteria, Martin's Rose bengal agar medium for fungi and Ken Knight's Agar medium for actinomycetes."

Weigh 10g soil sample and mix in 90 ml sterile blank. Mix thoroughly and shake for 15 min for complete dilution (10^{-1} dilution). Transfer one ml of the suspension to 9ml water blank (10^{-2} dilution), repeat it till 10^{-6} dilutions are obtained. Transfer one ml of appropriate dilutions to sterile Petri dishes. (Normally 10^{-3} or 10^{-6} can be used for bacteria 10^{-3} or 10^{-4} for fungi and 10^{-4} or 10^{-5} for actinomycetes may be used). Maintain 2or 3 replication for each dilution. Pour melted and cooled media (just before solidification) of about 20 ml and mix by moving clock wise and anti-clock wise direction for 3 to 4 times and allow it for solidification. Incubate the plate in an inverted position at 28^{o}C room temperature for 2 – 14 days. Observe the bacterial colonies after 2 days; fungi for 5 to7 days; actinomycetes after 7 – 14 days.

The total microbial count were recorded by counting the colonies per plate, calculating the population and expressed as colony forming units per gram of soil (cfu/g) (Martin, 1950).

3.3.5.2 Dehydrogenase activity

The dehydrogenase activity was estimated as per the procedure described by Casida *et al*. (1964). About one gram of air dried soil was weighed and taken in an air tight screw capped test tube of 15ml capacity, to which 0.2 ml of 3 % triphenyl tetrazolium chloride solution was added in each tube. Gently tapered the bottom of the tube to drive out all trapped oxygen, and thus a water seal was formed above the soil and ensured that no air bubbles was formed in tube. Tube was incubated at 28 ±0.5°C for 24h. After incubation 10 ml methanol was added and the contents were vigorously shaken for proper mixing. Samples were allowed to stand for 6 h. The clear, pink coloured supernatant was removed and the readings were taken with a spectrophotometer at a wavelength of 485nm. A series of standards were used for preparing the calibration curve. The results were expressed as Dehydogenase activity and expressed in terms of Triphenyl formazan hydrolysed per gram of soil per 24 h in micrograms.

3.3.5.3 Microbial biomass carbon

Microbial biomass carbon is estimated through Chloroform fumigation extraction method as per the procedure of Jenkinson and Powlson (1976). Weigh five sets of 10 g soil for each sample. In one set determine the moisture content of the soil gravimetrically. Of the remaining four sets of the soil, keep two sets in 50 ml beakers for fumigation and pack remaining two sets to keep in refrigerator for extraction on the next day. Place all the beakers containing soil and ethanol free chloroform in a vacuum desiccator. Put on the vacuum pump and keep it on until the chloroform boils for about five minutes. Close the outlet, switch off the pump and put the desiccators in dark for 24 hours.

Next day release the vacuum, take out beaker containing chloroform, and the inner paper lining and perform back suction for five to six minutes to ensure removal of any excess/adhered chloroform vapour. Transfer both the fumigated and non-fumigated soils in 250 ml conical flasks. Add 25 ml of 0.5M K_2SO_4 and shake for ½ hour. After shaking, filter the suspension through Whatman No.1 filter paper. Transfer 10 ml of the filtrate, add 2 ml $K_2Cr_2O_7$ (0.2N), 10 ml conc. H_2SO_4 and 5 ml orthophosphoric acid. Keep the flask on hot plate at 100^oC for

$^1/_2$hour under refluxing condition. Take out the flasks and add about 250 ml of distilled water immediately. Add ferroin indicator and titrate the contents against 0.005N ferrous ammonium sulphate to get a brick- red end point.

The microbial biomass carbon was calculated using the formula:

$$\text{MBC } (\mu\text{g g}^{-1}\text{ soil}) = \frac{EC_F - EC_{NF}}{K_{EC}}$$

Where, EC_F= Extractable carbon in fumigated sample

EC_{NF} = Extractable carbon in non-fumigated sample

K_{EC} = 0.25±0.05 and it represents the efficiency of extraction of MBC

3.3.7 Estimation of soil seed bank

Seed bank estimation was done using seedling emergence method (Roberts, 1981). Soil samples were collected from the surface of land. Coarse debris were removed from the sample collected, each soil sample were spread on a layer of sand (2cm thick) in a seed germination tray and germination trays were watered daily to keep the soil moist. The newly germinated seedlings were identified at the species level .Unidentified seedlings were transplanted to polybag for further growth until the species is to be positively identified .For seed bank assessment, observations were taken in the pre monsoon (April/May 2019) and post monsoon seasons (October /November 2019)

3.3.8 Vegetation Analysis

The quantitative analysis of the flora was done using Quadrat method. Ten quadrats each in each of the land use systems under flood affected and non floodedcondition were taken. Each of the quadrat had a size of 20 m x 20 m (400 m^2). All the trees of and above 10 cm girth at breast height (1.37 m) were identified and measured. The attributes taken for the measurement were girth at breast height (gbh) and total height of the tree. Plot sizes of 3m×3m were taken for shrub diversity and 1m×1 m plot size for herb diversity. Floristic diversity was done with the help of diversity indices like Simpson's Index and Shannon Weiner Index. The data were analyzed to find out Importance Value Index (IVI) using standard formula (Curtis and Mc Intosh, 1950).

The data of phytosociological analysis was processed as detailed below:

Density of a species (Ds) = $\frac{\text{Total number of individuals of a species}}{\text{Total area of Quadrats studied}}$

Frequency of a species (Fs) = $\frac{\text{Number of quadrats in which a species occurs}}{\text{Total number of quadrats studied}} \times 100$

Relative density of a species (RDs) = $\frac{\text{Density(Ds)ofaspecies}}{\text{Totaldensityofallspecies}} \times 100$

Relative frequency of a species (RFs) = $\frac{\text{Frequency(Fs)ofaspecies}}{\text{Sumoffrequenciesofallspecies}} \times 100$

Relative dominance of a species (RBAFs) = $\frac{\text{Totalbasalareaofaspecies}}{\text{Totalbasalareaofallspecies}} \times 100$

IVI of a species (IVIs) =$RDs + RFs + RBAFs$

3.3.8.1 Analysis of tree diversity

Shannon–Wiener diversity index (Shannon and Weiner, 1963) and Simpson index (Simpson, 1949) were calculated for understanding the tree diversity, Shrub diversity and Herb diversity.

a) Shannon-Wiener diversity index = $\sum[pi \times \ln(pi)]$

b) Simpson Diversity Index = $\frac{\sum_{\mathrm{i}} \mathrm{n}_i(\mathrm{n}_i-1)}{\mathrm{N}(\mathrm{n}-1)}$

Pi = proportion of total sample represented by species i

n_i- Number of individuals of the species i

N – Total number of individuals

Diversity indices were calculated with PAST software.

3.3.9 Statistical analysis

The statistical analyses were carried out by one way ANOVA in each depth of all treatments. Analyses helped to study the changes in parameters of both flood affected and non floodedtreatments in each depth of same land use systems as well as in different land use systems. The test was carried out in Agricolae under R environment.

RESULTS

The results of the study entitled“Soil and vegetation characteristics in the post flood scenario in selected tree based land use systems in Thrissur, Kerala’’are presented in the following sections. Impact of flood on soil and vegetation characteristics has been studied in five different land use systems in Thrissur, Kerala.

4.1 IMPACT OF FLOOD ON SOIL PROPERTIES

4.1.1 Impact of Flood on Physical Properties of Soil in different land use systems

4.1.1.1 Soil Porosity

Variation in the soil porosity of various land use systems under flood affected and non-flooded at different depths are shown in Table 2. The data observed here expressed a decreasing trend from top layer (0-20 cm) to bottom layer (80- 100 cm) under normal condition in all land use systems. At the depth of 0-20 cm, highest porosity was observed for open non flooded (57.15%) followed by coconut non flooded (53.84%) and forest non flooded (53.60%). The lowest value was recorded for open flood affected (40.11%) followed by coconut flood affected (45.81%) and nutmeg non flooded (47.87%). Fig.1 presented the porosity (%) of five different land use systems under flood affected and non flooded conditions at the depth of 0-20cm.

Table 2. Soil Porosity (%) of five different land use systems under flood affected and non flooded conditions

Sl. No.	Land use systems	Porosity (%)				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	48.23	51.39	50.61	50.08	47.93
2	Forest non flooded (FNF)	53.60	50.84	50.59	47.13	41.96
3	Rubber flood affected (RF)	53.15	54.82	55.93	21.63	45.06

Table 2 continued

Sl. No	Land use systems	Porosity (%)				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
4	Rubber non flooded (RNF)	52.63	48.13	43.44	36.62	34.92
5	Nutmeg flood affected (NF)	50.07	51.03	52.61	45.58	40.73
6	Nutmeg non flooded (NNF)	47.87	49.15	45.38	44.50	37.46
7	Coconut flood affected (CF)	45.81	42.38	42.99	34.92	35.16
8	Coconut non flooded (CNF)	53.84	43.50	37.61	23.77	20.47
9	Open flood affected (OF, Control-1)	40.11	7.33	67.90	47.64	9.49
10	Open non flooded (ONF, Control-2)	57.15	36.31	20.81	41.68	16.14

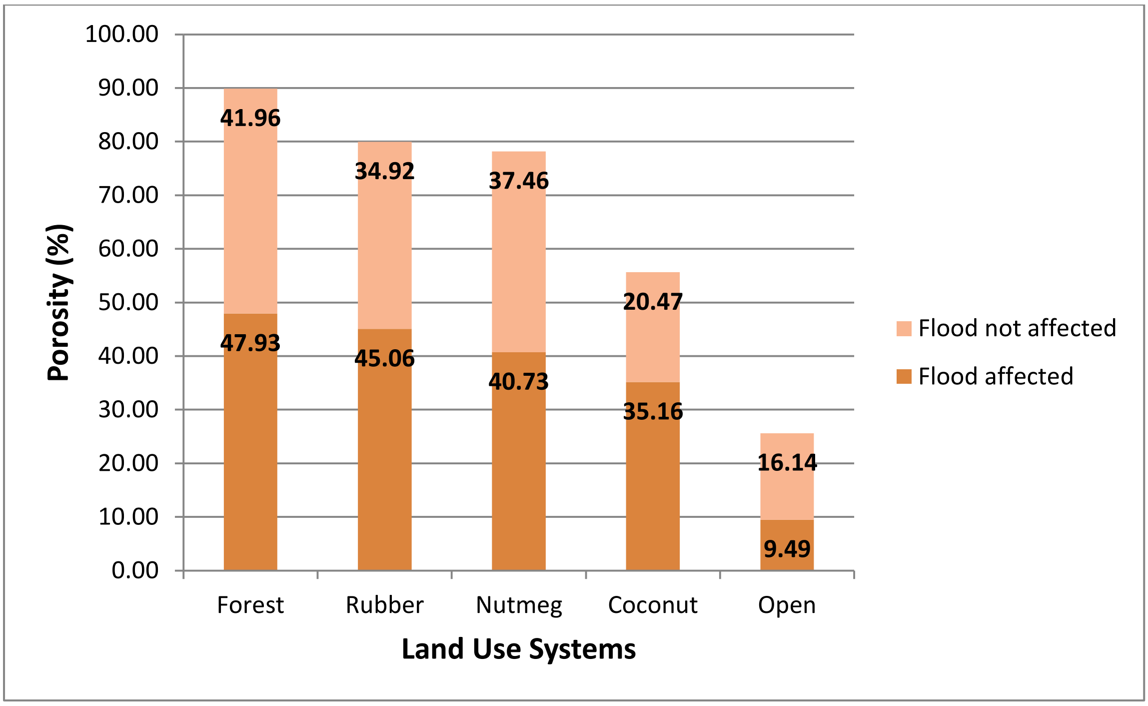

Figure 1. Soil porosity (%) of five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

4.1.1.2 Bulk Density

Variation in the Bulk Density of various land use systems under flood affected and non flooded at different depth are shown in Table 3. The data observed here expressed an increasing trend from top layer (0-20 cm) to bottom layer (81- 100 cm). In forest land use systems, bulk density is higher for forest non flooded (1.09 g cc^{-1}) than forest flood affected (1.07 g cc^{-1}) at the depth of 0-20 cm. Similarly, the same observation was recorded in rubber and nutmeg land use systems. But in other two land use systems (coconut and open) showed a higher value for flood affected conditions. Fig.2 presented the Bulk Density (g cc^{-1}) of five different land use systems under flood affected and non flooded conditions at the depth of 0-20cm.

Table 3. Bulk Density (g cc^{-1}) of five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Bulk Density (g cc^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	1.09	1.13	1.17	1.17	1.21
2	Forest non flooded (FNF)	1.07	1.06	1.14	1.22	1.27
3	Rubber flood affected (RF)	1.02	1.03	1.09	1.71	1.22
4	Rubber non flooded (RNF)	1.1	1.21	1.27	1.35	1.42
5	Nutmeg flood affected (NF)	1.07	1.06	1.13	1.2	1.32
6	Nutmeg non flooded (NNF)	1.13	1.17	1.28	1.33	1.38
7	Coconut flood affected (CF)	1.19	1.22	1.23	1.36	1.38
8	Coconut non flooded (CNF)	1.05	1.25	1.37	1.69	1.71
9	Open flood affected (OF, Control-1)	1.24	1.25	1.34	1.33	1.4
10	Open non flooded (ONF, Control-2)	1.21	1.32	1.37	1.37	1.45

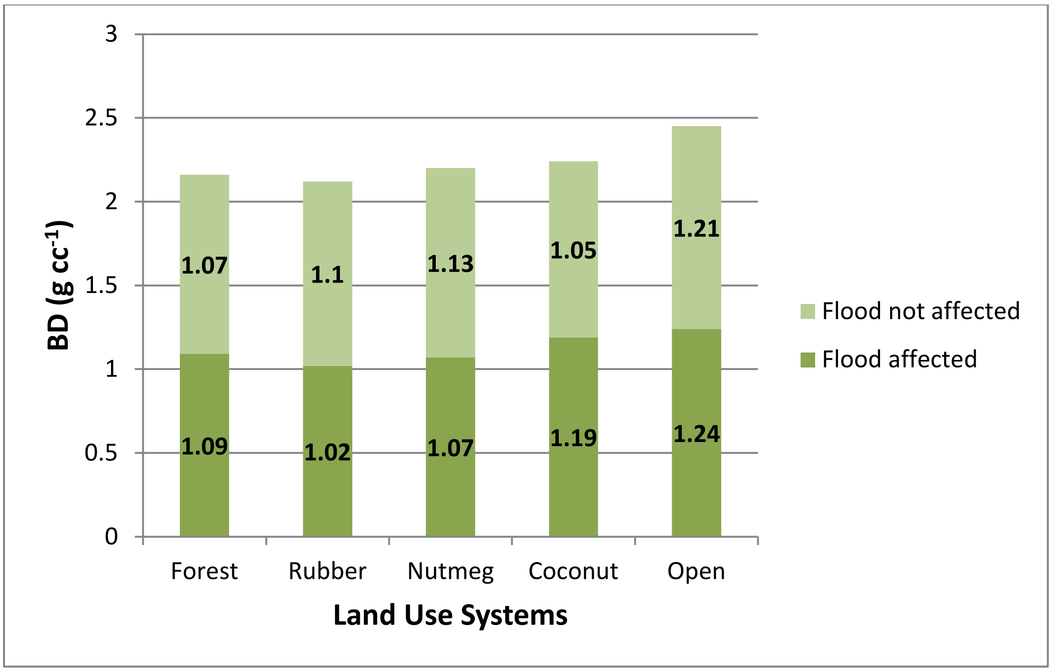

Figure 2. Bulk Density (g cc^{-1}) of five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20cm

4.1.1.3 Soil Texture

Table 4 showed the data on Soil texture of five different land use systems under flood affected and non flooded conditions. Most of the land use systems (forest non flooded, rubber flood affected, rubber non flooded, nutmeg flood affected, nutmeg non flooded and coconut flood affected) showed a sandy clay loam texture at the depthof 0-20 cm. Forest flood affected areas showed a clay loam texture, coconut non flooded locations showed a loamy sand texture, open flood affected showed a silt clay loam texture and open non flooded sites showed a loamy sand texture.

Table 4. Soil texture of five different land use systems under flood affected and non flooded conditions

Sl. No.	Land use systems	Soil Texture				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	CL	CL	SCL	SCL	SCL
2	Forest non flooded (FNF)	SCL	SCL	SCL	SCL	SCL
3	Rubber flood affected (RF)	SCL	SCL	SCL	SCL	CL
4	Rubber non flooded (RNF)	SCL	LS	LS	SiCL	SiCL
5	Nutmeg flood affected (NF)	SCL	SCL	SCL	SCL	SCL
6	Nutmeg non flooded (NNF)	SCL	SCL	SCL	SCL	SCL
7	Coconut flood affected (CF)	SCL	SCL	SCL	SCL	SCL
8	Coconut non flooded (CNF)	LS	LS	LS	LS	LS
9	Open flood affected (OF,Control-1)	SiCL	SiCL	SiCL	LS	LS
10	Open non flooded (ONF, Control-2)	LS	SiCL	SiCL	LS	SiCL

CL = Clay Loam, CL = Sandy Clay Loam, SiCL = Silt Clay Loam, LS = Loamy Sand

4.1.2 Impact of flood on chemical properties of soil in different land use systems

4.1.2.1 pH

Variation in the pH under different depths on five different land use systems under flood affected and non flooded have listed in Table 6. Rubber flood affected showed high acidic soil (4.30) followed by rubber non flooded (4.46). The lowest acidity nature is shown by nutmeg non flooded (5.95) followed by nutmeg flood affected (5.93). Table showed a significant difference between the same land use systems under flood affected and non flooded conditions except in nutmeg plantations at the depth of 0-20cm. Fig.3 presented the pH of five different land use systems under flood affected and non flooded conditions at the depth of 0-20 cm. At a depth of 21-40 cm only two land use systems (nutmeg plantation and Coconut plantation) showed significant difference under flood affected and non flooded situation, the other three are non-significant. In depth of

41-60 cm, all land use systems showed a significant difference under flood affected and non flooded condition. At a depth of 61- 80 cm, all land use systems showed a significant difference under flood affected and non flooded condition except coconut plantations. Coconut flood affected (5.19) is on par with coconut non flooded (5.23). At a depth of 61- 80 cm, all land use systems showed a significant difference under flood affected and non flooded condition except forest and open land use systems; here forest flood affected (5.02) is on par with forest non flooded (5.01). Also open flood affected (5.34) is par on with open non flooded (5.39).

Table 5.pH of five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**pH**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	5.71^{c}	5.30^{b}	5.10^{d}	5.10^{d}	5.02^{f}
2	Forest non flooded (FNF)	5.40^{d}	5.33^{b}	5.32^{bc}	5.22^{c}	5.01^{ef}
3	Rubber flood affected (RF)	4.30^{h}	4.81^{d}	4.79^{f}	4.84^{e}	5.08^{f}
4	Rubber non flooded (RNF)	4.46^{g}	4.71^{d}	4.55^{g}	4.66^{f}	4.72^{g}
5	Nutmeg flood affected (NF)	5.93^{b}	5.71^{a}	5.70^{a}	5.68^{a}	5.65^{a}
6	Nutmeg non flooded (NNF)	5.95^{b}	5.39^{b}	5.22^{cd}	5.21^{cd}	5.22^{d}
7	Coconut flood affected (CF)	4.94^{f}	4.79^{d}	4.96^{e}	5.19^{cd}	$5.18d^{e}$
8	Coconut non flooded (CNF)	6.28^{a}	5.15^{c}	5.18^{d}	5.23^{c}	5.45^{b}
9	Open flood affected (OF,Control-1)	5.26^{e}	5.29^{b}	4.86^{ef}	5.14^{cd}	5.34^{c}
10	Open non flooded (ONF, Control-2)	5.00^{f}	5.31^{b}	5.36^{b}	5.47^{b}	5.39^{bc}
	P value	<0.01	<0.01	<0.01	<0.01	<0.01
	C.D (0.05)	0.12	0.12	0.12	0.11	0.01
Same superscripts in columns do not differ significantly						

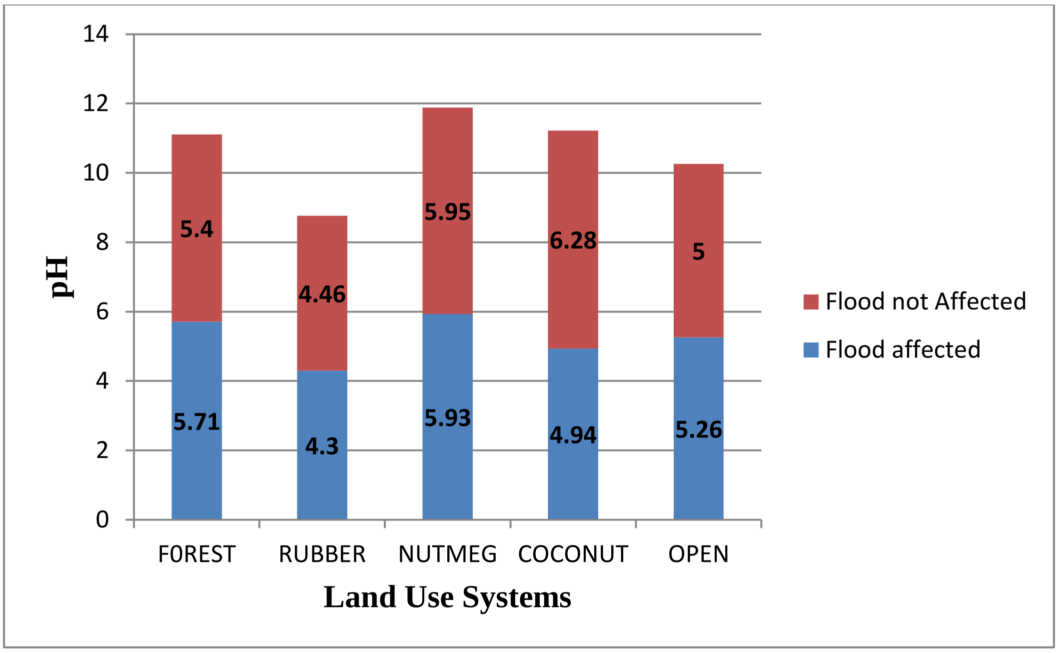

Figure 3.pH of five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

4.1.2.2 EC

Variation in the EC under different depths on five different land use systems under flood affected and non flooded have been listed in the Table 6. Table showed a significant difference between the all same land use systems under flood affected and non flooded conditions except in forest conditions and nutmeg plantations at the depth of 0-20cm. Nutmeg flood affected (0.36 dS m-1) is par on with nutmeg non flooded (0.41 dS m-1) The EC recorded highest value in rubber non flooded (1.33 dS m^{-1}) followed by coconut non flooded (1.00 dS m^{-1}). The lowest value was recorded in open flood affected (0.20 dS m^{-1}) followed by coconut flood affected (0.28 dS m^{-1}). Fig.4 showed the EC of five different land use systems under flood affected and non flooded conditions at the depth of 0-20 cm. At a depth of 21-40 and 41-60 cm the all land use systems showed significant difference under flood affected and non flooded conditions. In 61- 80 cm depth, only forest and open land use system showed non-significance. All other land use systems showed significance. Forest flood affected (0.09 dS m^{-1}) is on par with forest non flooded (0.08 dS m^{-1}). But at the bottom depth (81- 100 cm), significant difference is only between open land use systems. All others showed non-significance. Here nutmeg flood affected (0.17 dS m^{-1}) is on par with nutmeg non flooded (0.10 dS m^{-1}).

Table 6. EC (dS m^{-1}) five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**EC (dS m^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	0.40^{de}	0.18^{c}	0.09^{f}	0.09^{de}	0.09^{b}
2	Forest non flooded (FNF)	0.37^{de}	0.08^{g}	0.08^{g}	0.08^{ef}	0.06^{b}
3	Rubber flood affected (RF)	0.43^{d}	0.11^{f}	0.09^{f}	0.07^{f}	0.07^{b}
4	Rubber non flooded (RNF)	1.33^{a}	0.15^{de}	0.11^{de}	0.10^{c}	0.09^{b}
5	Nutmeg flood affected (NF)	0.36^{e}	0.23^{b}	0.20^{a}	0.17^{a}	0.17^{ab}
6	Nutmeg non flooded (NNF)	0.41^{de}	0.14^{e}	0.11^{d}	0.10^{c}	0.10^{b}
7	Coconut flood affected (CF)	0.20^{g}	0.11^{f}	0.12^{d}	0.08^{ef}	0.09^{b}
8	Coconut non flooded (CNF)	1.00^{b}	0.14^{e}	0.10^{e}	0.09^{d}	0.08^{b}
9	Open flood affected (OF, Control-1)	0.28^{f}	0.27^{a}	0.14^{b}	0.11^{c}	0.39^{a}
10	Open non flooded (ONF, Control-2)	0.65^{c}	0.18^{d}	0.12^{c}	0.12^{c}	0.13^{b}
	P value	<0.01	<0.01	<0.01	<0.01	0.36
	C.D (0.05)	0.05	0.01	0.01	0.01	0.27

Same superscripts in columns do not differ significantly

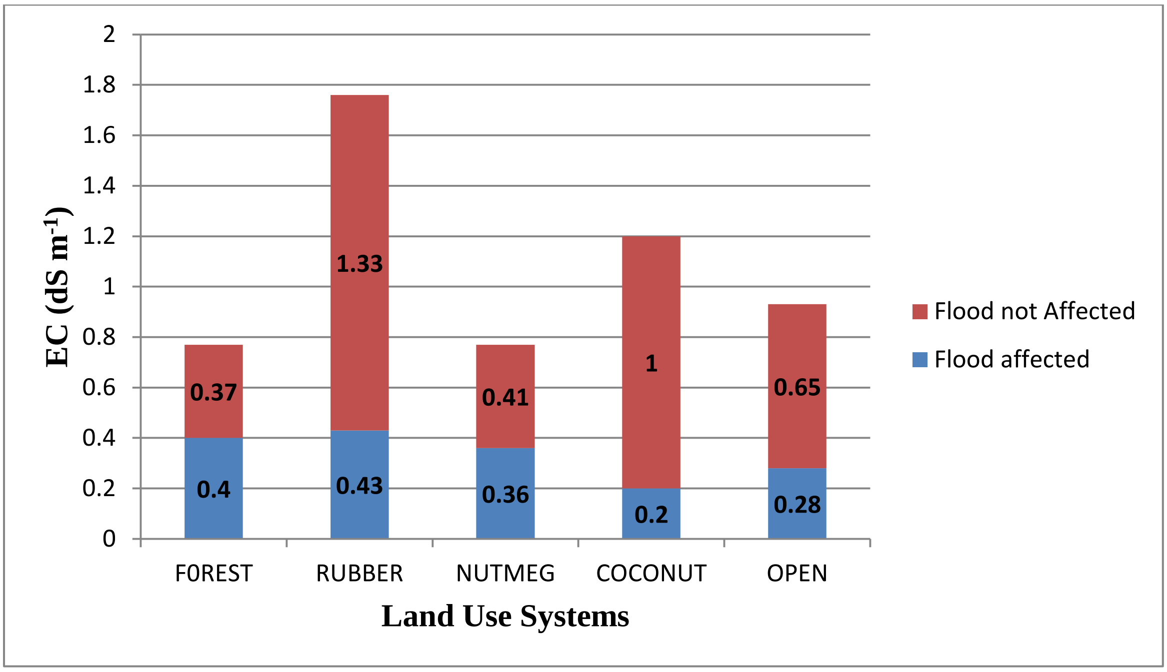

Figure 4. EC of five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

4.1.2.3 Organic Carbon

Variation in the organic carbon content under five different landuse systems, at different depths, under flood affected and non flooded conditions are given in the Table 7. There is significant difference between same land use systems under flood affected and non flooded conditions at a depth of 0-20 cm. That is forest flood affected (2.5%) showed significant difference with non flooded (2.3%) in the top soil at a depth 0-20cm. Other land use systems studied also showed significant difference in flood affected and non flooded conditions. At a depth of 0-20 cm, highest organic carbon is found under Rubber flood affected (2.74%) followed by forest flood affected (2.52 %). While comparing the flood affected and non flooded conditions, the organic carbon, in general, was more in flooded conditions as in forest, rubber and nutmeg plantations. But in two flood affected land use systems *viz.* coconut flood affected (0.970%) and open flood affected (1.42%), the organic carbon content was less as compared to their respective non flooded conditions.

At a depth of 21- 40 cm also, there is significant difference in soil organic carbon between same land use systems under flood affected and non flooded situations except in coconut plantation. That is there is no significant deference between coconut flood affected (0.96%) and coconut non flooded (0.92%) land use systems. At a depth of 41-60cm also, there is significant difference between same land use systems under flood affected and non flooded situations except for rubber plantation. That is there is no significant difference between rubber flood affected (0.76%) and rubber non flooded (0.65%) land use systems. Similar trend was observed at the depth of 61-80cm. At a depth of 81-100 cm showed significant difference between all land use systems in flood affected and non flooded situations.

Generally, a decreasing trend was observed from top layer to bottom layer. All top layers (0-20cm) of different land use systems shows the higher value except in open flood affected (1.4%) land use systems. All land use systems showed a significant difference from top layer (0-20cm) to bottom layer (81- 100 cm). Fig.5 showed the organic carbon (%) content in five different land use systems under flood affected and non flooded conditions at the depth of 0-20 cm.

Table 7. Organic Carbon content (%) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Organic carbon (%)**						
		Soil Depth (cm)						
		0-20	21-40	41-60	61-80	81-100	P value	C.D (0.05)
1	Forest flood affected (FF)	2.52^{b}_{A}	2.12^{a}_{B}	2.07^{b}_{B}	1.71^{b}_{C}	2.01^{a}_{B}	<0.01	0.06
2	Forest non flooded (FNF)	2.30^{c}_{A}	1.32^{f}_{B}	1.06^{c}_{C}	0.97^{c}_{C}	0.72^{d}_{D}	<0.01	0.08
3	Rubber flood affected (RF)	2.74^{a}_{A}	1.1^{c}_{B}	0.76^{e}_{C}	0.56^{d}_{D}	0.55^{e}_{D}	<0.01	0.09
4	Rubber non flooded (RNF)	1.97^{e}_{A}	0.59_{BC}	0.65^{e}_{B}	0.53^{d}_{CD}	0.45^{d}_{D}	<0.01	0.10
5	Nutmeg flood affected (NF)	2.01^{e}_{A}	1.09^{d}_{B}	0.73^{e}_{D}	0.82^{c}_{CD}	0.84^{d}_{C}	<0.01	0.07
6	Nutmeg non flooded (NNF)	1.56^{f}_{A}	0.79^{b}_{B}	0.47^{f}_{C}	0.43^{de}_{C}	0.29^{g}_{D}	<0.01	0.08
7	Coconut flood affected (CF)	0.97^{h}_{A}	0.96^{e}_{A}	0.93^{d}_{A}	0.82^{c}_{B}	0.74^{d}_{C}	<0.01	0.12
8	Coconut non flooded (CNF)	2.22^{cd}_{A}	0.92^{e}_{B}	0.67^{e}_{C}	0.58^{d}_{D}	0.37^{fg}_{E}	<0.01	0.11
9	Open flood affected (OF, Control-1)	1.42^{g}_{D}	1.44^{b}_{D}	2.18^{a}_{B}	2.46^{a}_{D}	1.77^{b}_{C}	<0.01	0.17
10	Open non flooded (ONF, Control-2)	2.16^{d}_{A}	0.73^{f}_{B}	0.50^{f}_{C}	0.33^{e}_{D}	0.31^{g}_{D}	<0.01	0.14
	P value	<0.01	<0.01	<0.01	<0.01	<0.01		
	C.D (0.05)	0.08	0.09	0.11	0.17	0.10		

Same superscripts (in columns) and same subscripts (in rows) do not differ significantly

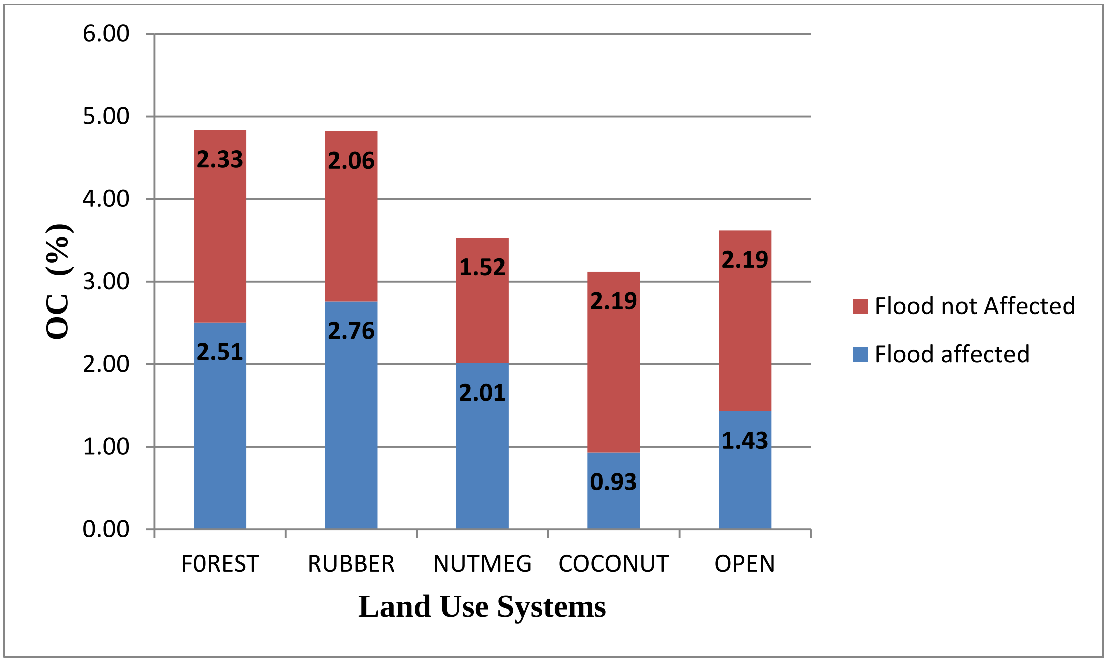

Figure 5. Organic carbon (%) content in five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

4.1.2.4 Available Nitrogen

Variation in the available nitrogen content under different depths on five different land use systems under flood affected and non flooded have listed in the Table 8In the top layer (0-20cm) of soil, available nitrogen content was significantly differed between the flood affected and non flooded situation under same land use systems except in coconut plantations. Also rubber plantation in non flooded situation showed higher nitrogen content (371.7 kg ha^{-1}) in the top layer followed by open land use systems (296.1 kg ha^{-1}) in non flooded condition. The lowest available nitrogen was recorded in forest non flooded (54 .6 kg ha^{-1}) followed by open flood affected (88.2 kg ha^{-1}) condition.

At 20- 40 cm depth all the land use systems showed significant difference under flood affected and non flooded conditions except in coconut plantations. Here coconut flood affected (184.6kg ha^{-1}) is on par with coconut non flooded (163.8 kg ha^{-1}). Also in 41-60 cm there is significant difference between same land use systems except in nutmeg plantation (nutmeg flood affectedshowed 88.2 kg ha^{-1} and nutmeg non flooded showed 96.6 kg ha^{-1}) and forest condition. Forest flood affected (71.5kg ha^{-1}) is on par with forest non flooded (46.5kg ha^{-1}). At 61-80 cm depth, three land use systems (forest, coconut and open) showed a significant difference under flood affected and non flooded situation. The other two land use systems (rubber and nutmeg) didn't showed anysignificant difference. At 81-100 cm depth, significant difference between same land use systems (rubber plantations, coconut plantations and open condition) under flood affected and non flooded conditions. The other two land use systems (forest and nutmeg plantation) are on par with each other.

The data in table, showed a significant difference across the depth in content of available nitrogen in all land use systems except in coconut flooded. Also top layer shows highest available nitrogen in all land use systems. Fig.6 showed the record of available nitrogen (kg ha^{-1}) content in five different land use systems under flood affected and non flooded conditions at a depth of 0-20 cm.

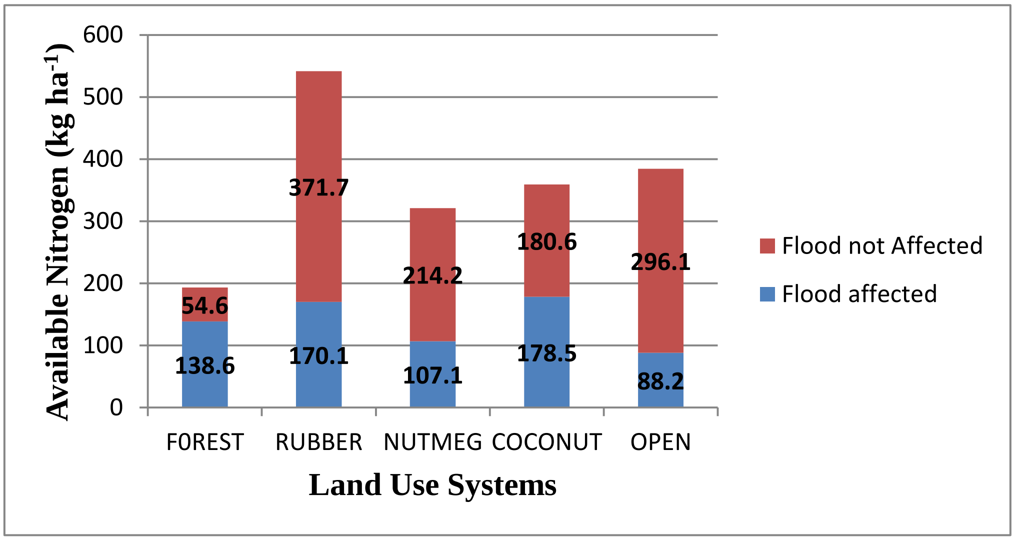

Figure 6. Available nitrogen content (kg ha^{-1}) in five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

Table 8. Available nitrogen content (kg ha^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Available Nitrogen (kg ha^{-1})**						
		Soil Depth (cm)						
		0-20	21-40	41-60	61-80	81-100	P value	C.D (0.05)
1	Forest flood affected (FF)	138.6^{e}_{A}	157.5^{ab}_{A}	71.4^{cd}_{BC}	86.1^{b}_{B}	48.3^{d}_{C}	<0.01	33.2
2	Forest non flooded (FNF)	54.6^{g}_{AB}	59.5^{c}_{A}	46.5^{d}_{ABC}	42.8^{c}_{BC}	38.3^{de}_{C}	0.03	13.4
3	Rubber flood affected (RF)	170.1^{d}_{A}	67.2^{c}_{C}	50.4^{d}_{C}	44.1^{b}_{C}	130.2^{a}_{B}	<0.01	26.5
4	Rubber non flooded (RNF)	371.7^{a}_{A}	140.7^{b}_{B}	95.1^{bc}_{C}	85.2^{b}_{CD}	50.4^{d}_{D}	<0.01	44.4
5	Nutmeg flood affected (NF)	107.1^{f}_{A}	83.9^{c}_{AB}	88.2^{bc}_{AB}	91.4^{b}_{AB}	82.3^{bc}_{B}	0.21	23.3
6	Nutmeg non flooded (NNF)	214.2^{c}_{A}	170.1^{ab}_{B}	96.6^{bc}_{C}	88.2^{b}_{C}	94.5^{b}_{C}	<0.01	35.6
7	Coconut flood affected (CF)	178.5^{d}_{A}	184.6^{a}_{A}	157.5^{a}_{A}	147.0^{a}_{A}	134.4^{a}_{A}	0.32	57.2
8	Coconut non flooded (CNF)	180.6^{d}_{A}	163.8^{ab}_{B}	107.9^{b}_{C}	96.4^{b}_{CD}	86.2^{bc}_{D}	<0.01	11.8
9	Open flood affected (OF, Control-1)	88.2^{f}_{A}	84.0^{c}_{A}	46.2^{d}_{B}	34.3^{c}_{BC}	31.5^{e}_{C}	<0.01	14.4
10	Open non flooded (ONF, Control-2)	296.1^{b}_{A}	155.4^{ab}_{B}	109.2^{b}_{C}	88.2^{b}_{D}	77.7^{c}_{D}	<0.01	17.8
	P value	<0.01	<0.01	<0.01	<0.01	<0.01		
	C.D (0.05)	22.25	38.7	26.5	35.9	16.2		

Same superscripts (in columns) and same subscripts (in rows) do not differ significantly

4.1.2.5 Available phosphorous

Variation in the available phosphorous content under different depths on five different land use systems under flood affected and non flooded have listed in the Table 9. There is a significant difference between land use systems under flood affected and non flooded condition. In the depth of 0-20 cm, available phosphorous shows significant difference among same land use systems under flood affected and non flooded conditions. Table 9 showed the highest available phosphorous in open non floodedcondition (204.5 kg ha^{-1}) followed by nutmeg flood affected (167.5 kg ha^{-1}) and rubber flood affected (164.09 kg ha-^{1}). The lowest available phosphorous was recorded in coconut flood affected (8.73 kg ha^{-1}) followed by forest non flooded (12.1 kg ha^{-1}) land use systems**.** Similarly, it shows significant difference at the depth of 21-40 cm in all land use systems except in coconut plantation. Here coconut flood affected (4.64 kg ha^{-1}) is on par with coconut non flooded (9.23 kg/ ha). At 41- 60cm depth, table 9 showed significant difference between all same land systems under flood affected and non flooded conditions except in coconut plantations. At 61- 80 cm depth, table 9 showed a significant difference between all same land use systems under flood affected and non flooded conditions except in coconut plantation. Coconut flood affected (6.8 kg ha^{-1}) is on par with coconut non flooded (4.75 kg ha^{-1}). In 81- 100 cm depth also data shows significant difference between all same land use systems under flood affected and non flooded situations except open land use systems, rubber plantation and coconut plantation. Coconut flood affected (5.36 kg ha^{-1}) is on par with coconut non flooded (2.35 kg ha^{-1}).

The data in table 9, showed a significant difference across the depth (from 0-20, 81- 100cm) in content of available phosphorous in each land use systems. Also top layer shows highest available phosphorus in all land use systems. Fig.7 showed the available phosphorous (kg ha^{-1}) in five different land use systems under flood affected and non flooded conditions at the depth of 0-20 cm.

Table 9. Available phosphorous content (kg ha^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Available Phosphorus (kg ha^{-1})**						
		Soil Depth (cm)						
		0-20	21-40	41-60	61-80	81-100	P value	C.D (0.05)
1	Forest flood affected (FF)	48.95^{f}_{A}	25.23^{d}_{B}	15.25^{cd}_{C}	21.74^{c}_{B}	12.58^{b}_{C}	<0.01	5.71
2	Forest non flooded(FNF)	12.10^{g}_{A}	5.12^{f}_{B}	2.11^{e}_{BC}	31.9^{gh}_{BC}	1.12^{e}_{C}	<0.01	3.16
3	Rubber flood affected (RF)	164.09^{b}_{A}	48.23^{c}_{B}	31.50^{ab}_{C}	29.57^{b}_{C}	14.87^{b}_{D}	<0.01	13.00
4	Rubber non flooded(RNF)	131.49^{c}_{A}	13.31^{e}_{B}	13.07^{d}_{B}	9.59^{de}_{B}	12.58^{b}_{B}	<0.01	4.37
5	Nutmeg flood affected (NF)	167.59^{b}_{A}	52.45^{c}_{B}	34.50^{a}_{CD}	35.47^{a}_{C}	27.88^{a}_{D}	<0.01	6.74
6	Nutmeg non flooded(NNF)	129.17^{c}_{A}	14.75^{e}_{B}	3.79^{e}_{C}	2.83^{h}_{C}	2.11^{de}_{C}	<0.01	3.64
7	Coconut flood affected (CF)	8.73^{g}_{A}	4.64^{f}_{B}	6.20^{e}_{B}	6.80^{efg}_{AB}	5.36^{cd}_{B}	0.016	2.17
8	Coconut non flooded(CNF)	65.93^{e}_{A}	9.23^{ef}_{B}	5.24^{e}_{C}	4.75^{fgh}_{C}	2.35^{de}_{D}	<0.01	1.49
9	Open flood affected (OF,Control-1)	93.03^{d}_{A}	97.49^{b}_{A}	18.97^{c}_{B}	8.25^{ef}_{C}	16.20^{b}_{B}	<0.01	5.41
10	Open non flooded(ONF, Control-2)	204.55^{a}_{A}	132.42^{a}_{B}	26.43^{b}_{C}	12.35^{d}_{D}	7.29^{b}_{D}	<0.01	9.18
	P value	<0.01	<0.01	<0.01	<0.01	<0.01		
	C.D (0.05)	9.25	5.91	5.62	3.77	3.65		

Same superscripts (in columns) and same subscripts (in rows) do not differ significantly

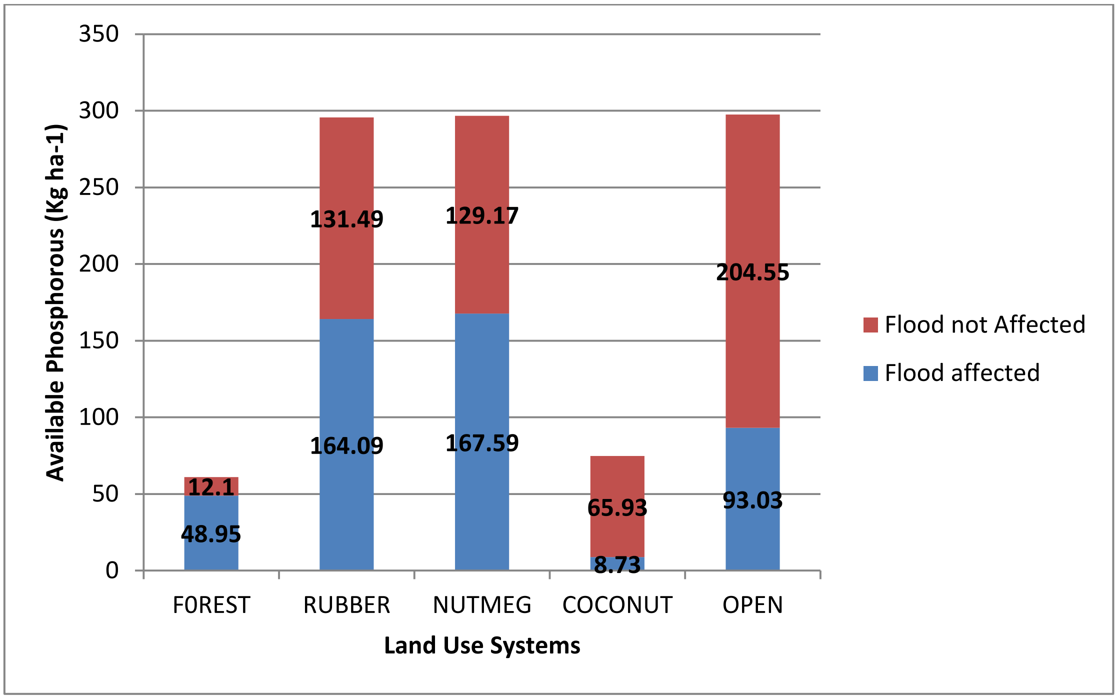

Figure 7. Available phosphorus content (kg ha^{-1}) in five different land use systems under flood affected and non flooded conditions at the soil depth of 0-20 cm

4.1.2.6 Available potassium

Variation in the available potassium content under different depths on five different land use systems under flood affected and non flooded have listed in the Table 10. The Table 10 shows a significant difference between the all same land use systems under flood affected and non flooded conditions at all depths (0-20 cm, 21-40 cm, 41-60 cm, 61-80 cm, 81-100 cm). The highest available potassium was recorded at a depth of 0-20 cm in nutmeg flood affected condition (892.2 kg ha^{-1}) followed by forest non flooded(566.2 kg ha^{-1}) and open non flooded(554.8 kg ha^{-1}). The lowest available potassium was recorded in coconut flood affected (111 kg ha^{-1}) followed by rubber non flooded (169.1 kg ha^{-1}).

The data in table 10, showed a significant difference across the depth in content of available potassium in all land use systems. Also top layer shows highest available potassium in all land use systems except in open flood affected (429 kg/

ha/). Open flood affected showed higher content in 21– 40 cm layer (469.6 kg/ha). Fig.8 recorded the available potassium (kg ha^{-1}) in five different land use systems under flood affected and non flooded conditions at the depth of 0-20 cm.

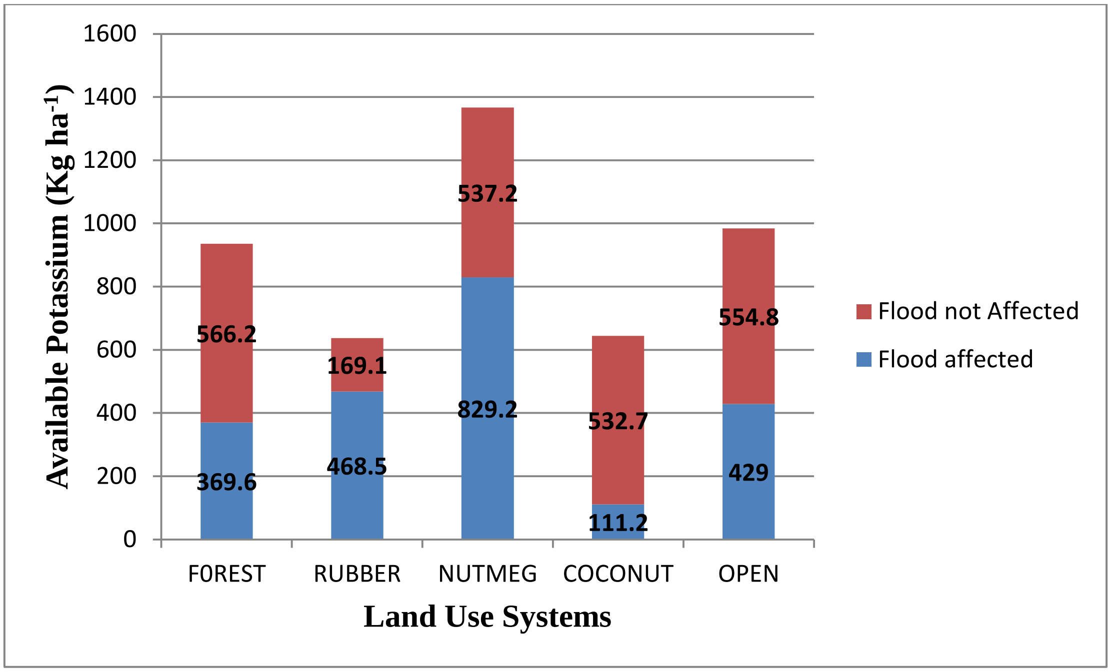

Figure 8. Available potassium content (kg ha^{-1}) in five different land use systems under flood affected and non flooded conditions at the soil depth of 0-20 cm

Table 10. Available potassium content (kg ha^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Available Potassium (kg ha^{-1})**						
		Soil Depth (cm)						
		0-20	21-40	41-60	61-80	81-100	P value	C.D (0.05)
1	Forest flood affected (FF)	369.6^{f}_{A}	196.0^{f}_{B}	107.9^{h}_{C}	93.0^{h}_{D}	82.1^{g}_{E}	<0.01	5.3
2	Forest non flooded (FNF)	566.2^{b}_{A}	301.6^{d}_{C}	364.7^{b}_{B}	313.6^{b}_{C}	260.2^{d}_{D}	<0.01	17.6
3	Rubber flood affected (RF)	468.5^{d}_{A}	204.2^{ef}_{D}	202.7^{e}_{D}	223.2^{e}_{C}	272.5^{cd}_{B}	<0.01	14.7
4	Rubber non flooded (RNF)	169.1^{g}_{A}	154.9^{g}_{B}	149.3^{f}_{BC}	143.7^{f}_{C}	142.6^{e}_{C}	<0.01	8.8
5	Nutmeg flood affected (NF)	829.2^{a}_{B}	725.4^{a}_{C}	725.4^{a}_{C}	848.2^{a}_{B}	907.6^{a}_{A}	<0.01	23.8
6	Nutmeg non flooded (NNF)	537.2^{c}_{A}	205.3^{ef}_{B}	132.5^{g}_{C}	117.2^{g}_{D}	110.1^{f}_{E}	<0.01	4.6
7	Coconut flood affected (CF)	111.2^{h}_{A}	65.7^{h}_{BC}	70.2^{i}_{B}	53.4^{i}_{D}	62.3^{h}_{C}	<0.01	5.2
8	Coconut non flooded (CNF)	532.7^{c}_{A}	215.8^{e}_{B}	155.7^{f}_{C}	124.7^{g}_{D}	97.4^{f}_{E}	<0.01	9.9
9	Open flood affected (OF, Control-1)	429.0^{e}_{B}	469.6^{b}_{A}	298.3^{c}_{C}	282.6^{c}_{C}	286.0^{c}_{C}	<0.01	23.4
10	Open non flooded (ONF, Control-2)	554.8^{b}_{A}	370.3^{c}_{B}	277.0^{d}_{D}	252.7^{d}_{D}	322.0^{b}_{C}	<0.01	26.5
	P value	<0.01	<0.01	<0.01	<0.01	<0.01		
	C.D (0.05)	12.5	15.9	14.7	17.1	14.9		

Same superscripts (in columns) and same subscripts (in rows) do not differ significantly

4.1.2.7 Calcium

Variation in the calcium content under different depths on five different land use systems under flood affected and non flooded have listed in the Table 11. Table 11 shows there is a significant difference in Nutmeg plantation and Coconut plantation under flood affected and non flooded condition at the depth of 0-20 cm. Here, Forest flood affected (1116.0 mg kg^{-1}) is on par with forest non flooded (814.5 mg kg^{-1}), and open flood affected (259.6 mg kg $^{-1}$) is on par with open non flooded (339.2 mg kg^{-1}). The maximum value for calcium was recorded for coconut non flooded (1997.7 mg kg^{-1}) followed by forest flood affected (1116.0 mg kg^{-1}). The minimum value was recorded for rubber non flooded (111.5 mg kg^{-1}) followed by coconut flood affected (157.1 mg kg^{-1}). Fig.9 recorded the calcium content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at the depth of 0-20 cm**.** In the depth of 21- 40cm, Table 11 showed a significant difference in all land use systems under flood affected and non flooded condition except for rubber plantation. Rubber flood affected (132.4 mg kg^{-1}) is on par with rubber non flooded (82.3 mg kg^{-1}). At the depth of 41-60 cm, 61- 80 cm and 81 - 100cm all land use systems showed significant difference under flood affected and non flooded condition.

Table 11. Calcium content (mg kg^{-1}) in five different land use systems under Flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Calcium (mg kg^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	1116.0^{b}	762.5^{a}	211.5^{f}	189.3^{f}	162.6^{f}
2	Forest non flooded (FNF)	814.5^{bc}	132.4^{ef}	102.0^{h}	77.6^{g}	50.6^{g}
3	Rubber flood affected (RF)	172.2^{d}	82.3^{fg}	125.7^{g}	227.3^{e}	400.3^{c}
4	Rubber non flooded(RNF)	111.5^{d}	39.9^{g}	50.2^{i}	80.6^{g}	81.9^{g}
5	Nutmeg flood affected (NF)	1795.5^{a}	710.7^{b}	743.0^{a}	755.0^{a}	687.2^{a}
6	Nutmeg non flooded(NNF)	876.2^{b}	259.4^{d}	278.5^{d}	251.0^{e}	241.1^{e}
7	Coconut flood affected (CF)	157.1^{d}	146.8^{e}	250.8^{e}	295.7^{d}	327.8^{d}

Same superscripts in columns do not differ significantly

Table 11. Continued

Sl. No.	Land use systems	Calcium (mg kg^{-1})				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
8	Coconut non flooded(CNF)	1997.7^{a}	235.3^{d}	313.5^{c}	335.6^{c}	416.4^{c}
9	Open flood affected (OF, Control-1)	280.0^{d}	259.6^{d}	105.8^{h}	162.6^{f}	395.6^{c}
10	Open non flooded (ONF, Control-2)	397.7^{cd}	339.2^{c}	420.5^{b}	456.6^{b}	469.1^{b}
	P value	<0.01	<0.01	<0.01	<0.01	<0.01
	C.D (0.05)	443.4	51.6	15.5	31.8	46.7

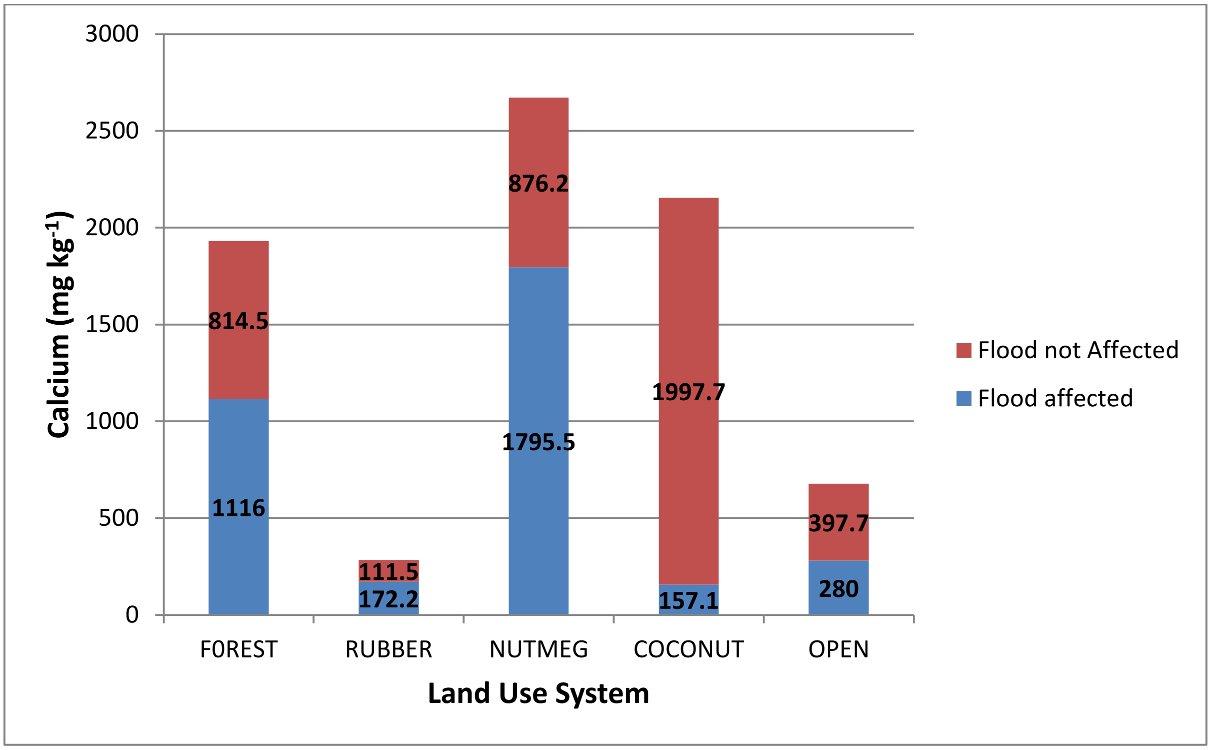

Figure 9. Calcium content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

4.1.2.8 Magnesium

Variation in the magnesium content under different depths in five different land use systems under flood affected and non flooded have listed in the table 12. Table 12 shows a significant difference in nutmeg plantation and coconut plantation under flood affected and non floodedcondition at the depth of 0-20 cm. Forest flood affected (218.7 mg kg^{-1}) is on par with forest non flooded (257.2 mg kg^{-1}). The highest value for magnesium was recorded for nutmeg flood affected (322.0 mg kg^{-1}) followed by forest non flooded (257.2 mg kg^{-1}). The lowest value was recorded for rubber non flooded (22.5 mg kg^{-1}) and rubber flood affected (43.9 mg kg^{-1}). Fig.10 showed the magnesium content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at the depth of 0-20 cm. In the depth of 21-40 cm, nutmeg plantation and coconut plantation showed a significant difference under flood affected and non flooded condition. Here, forest flood affected (135.4 mg kg^{-1}) is on par with forest non flooded (156.7 mg kg^{-1}), rubber flood affected (13.1 mg kg^{-1}) is on par with rubber non flooded (7.5 mg kg^{-1}) and open flood affected (60.6 mg kg $^{-1}$) is on par with open non flooded (35.6 mg kg^{-1}).

Table 12. Magnesium content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Magnesium (mg kg^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	218.7^{bc}	135.4^{b}	47.6^{d}	35.6^{f}	29.8^{f}
2	Forest non flooded (FNF)	257.2^{ab}	156.7^{ab}	155.6^{b}	128.8^{b}	120.7^{b}
3	Rubber flood affected (RF)	43.9^{e}	13.1^{ef}	19.7^{f}	39.4^{f}	66.9^{de}
4	Rubber non flooded (RNF)	22.5^{e}	7.5^{f}	9.9^{g}	18.0^{h}	20.0^{f}
5	Nutmeg flood affected (NF)	322.0^{a}	173.6^{a}	198.0^{a}	182.9^{a}	142.2^{a}
6	Nutmeg non flooded (NNF)	147.9^{d}	72.4^{c}	67.4^{c}	73.8^{c}	70.2^{d}
7	Coconut flood affected (CF)	47.4^{e}	17.5^{ef}	45.3^{d}	73.5^{c}	98.3^{c}
8	Coconut non flooded (CNF)	178.8^{cd}	53.6^{cd}	68.3^{c}	66.4^{d}	74.0^{d}
9	Open flood affected (OF, Control-1)	62.4^{e}	60.6^{cd}	18.6^{f}	24.3^{g}	64.1^{de}
10	Open non flooded (ONF, Control-2)	70.2^{e}	35.6^{de}	38.6^{e}	55.8^{e}	59.5^{e}
	P value	<0.01	<0.01	<0.01	<0.01	<0.01
	C.D (0.05)	69.7	26.2	4.9	5.6	10.0

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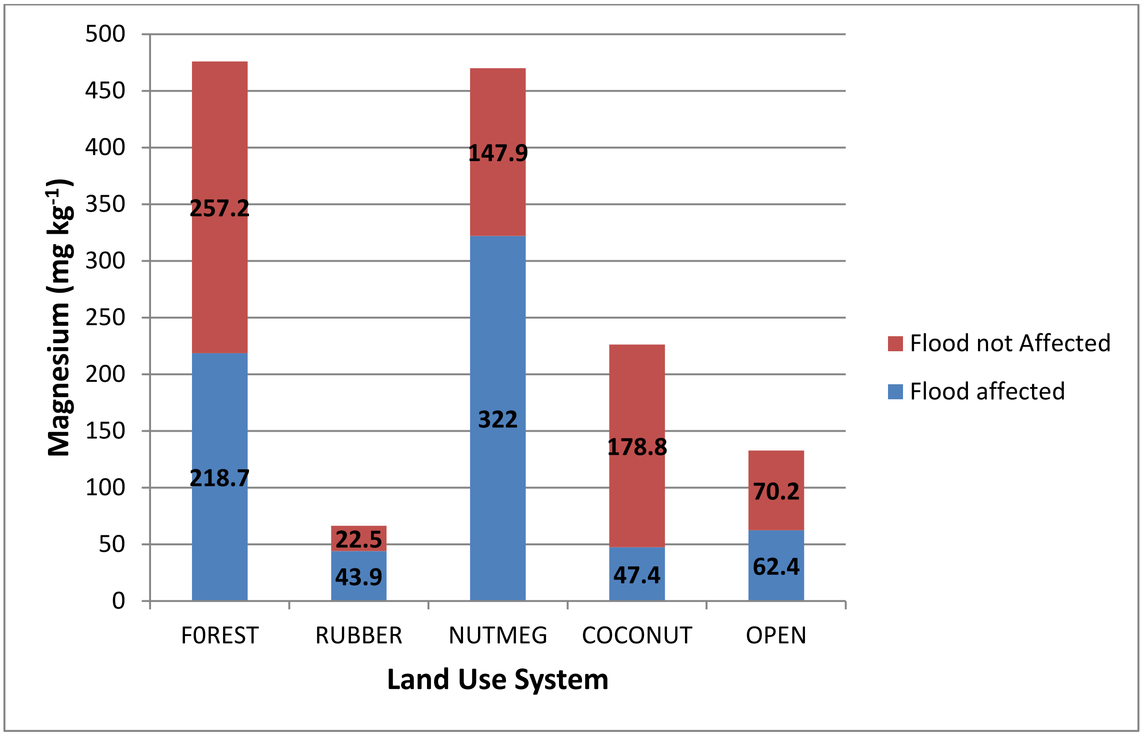

Figure 10. Magnesium content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

In the depth of 41- 60 cm and 61- 80 cm, all land use systems shows a significant difference under flood affected and non floodedcondition.In the depth of 81- 100 cm, all land use systems shows a significant difference under flood affected and non flooded condition except open land use systems. Open flood affected (64.1 mg kg $^{-1}$) is on par with open non-flooded (59.5 mg kg $^{-1}$).

4.1.2.9 Sulphur

Variation in the sulphur content under different depths on five different land use systems under flood affected and non flooded have listed in the Table 13. In the depth of 0-20 cm, only rubber plantation shows significant difference under flood affected and non flooded conditions. Here forest flood affected (4.08 mg kg^{-1}) is on par with forest non flooded (4.65mg kg^{-1}). Similarly, nutmeg flood affected (8.08 mg kg^{-1}) is on par with nutmeg non flooded (4.7 mg kg^{-1}) and coconut flood affected (4.27 mg kg^{-1}) is on par with coconut non flooded (5.41 mg kg^{-1}); also open flood affected (4.37 mg kg^{-1}) is on par with open non flooded (4.56 mg kg $^{-1}$). The maximum sulphur content was recorded in rubber non flooded (8.93mg kg^{-1}) followed by nutmeg flood affected (8.08 mg kg^{-1}) and minimum value was recorded in rubber flood affected (1.18mb kg^{-1}) followed by forest flood affected (4.08 mg kg^{-1}).

Table 13. Sulphur content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Sulphur (mg kg^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	4.08^{bc}	1.14^{e}	0.33^{e}	0.38^{c}	0.71^{d}
2	Forest non flooded (FNF)	4.65^{b}	4.56^{c}	4.98^{abc}	0.61^{c}	0.52^{de}
3	Rubber flood affected (RF)	1.18^{c}	0.33^{e}	0.38^{e}	0.28^{c}	0.33^{e}
4	Rubber non flooded (RNF)	8.93^{a}	8.79^{b}	0.99^{de}	0.57^{c}	0.47^{de}
5	Nutmeg flood affected (NF)	8.08^{ab}	3.27^{d}	3.04^{bc}	3.75^{b}	3.32^{c}
6	Nutmeg non flooded (NNF)	4.70^{b}	3.23^{d}	3.04^{bc}	3.51^{b}	3.23^{c}
7	Coconut flood affected (CF)	4.27^{bc}	3.46^{d}	2.75^{cd}	0.33^{c}	0.38^{de}
8	Coconut non flooded (CNF)	5.41^{b}	3.32^{d}	5.03^{a}	0.61^{c}	0.66^{de}
9	Open flood affected (OF, Control-1)	4.37^{bc}	10.02^{a}	2.75^{cd}	4.03^{b}	5.03^{a}
10	Open non flooded (ONF, Control-2)	4.56^{b}	2.94^{d}	4.46^{abc}	4.75^{a}	4.37^{b}
	P value	0.01	<0.01	<0.01	<0.01	<0.01
	C.D (0.05)	3.31	0.83	1.95	0.65	0.34

Same superscripts in columns do not differ significantly

Fig.11 recorded the Sulphur content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at a depth of 0-20 cm**.** In 21-40 cm depth, all land use systems showed significant difference under flood affected and non flooded condition except in nutmeg and coconut plantations.In 41- 60 cm depth, only forest and coconut plantation shows significant difference under flood affected and non flooded conditions. Here rubber flood affected (0.33 mg kg^{-1}) is on par with rubber non flooded (0.99 mg kg^{-1}) and open flood affected (2.75mg kg^{-1}) is on par with open non-flooded (4.46 mg kg^{-1}). In showed significant both depth 61- 80 cm and 81- 100 cm only open land use systems was difference under flood affected and non flooded conditions. But in 81- 100 cm depth, forest flood affected (0.71 mg kg^{-1}) is on par with forest non flooded (0.53 mg kg^{-1}) and rubber flood affected (0.33 mg kg^{-1}) is on par with rubber non flooded (0.47 mg kg^{-1}).

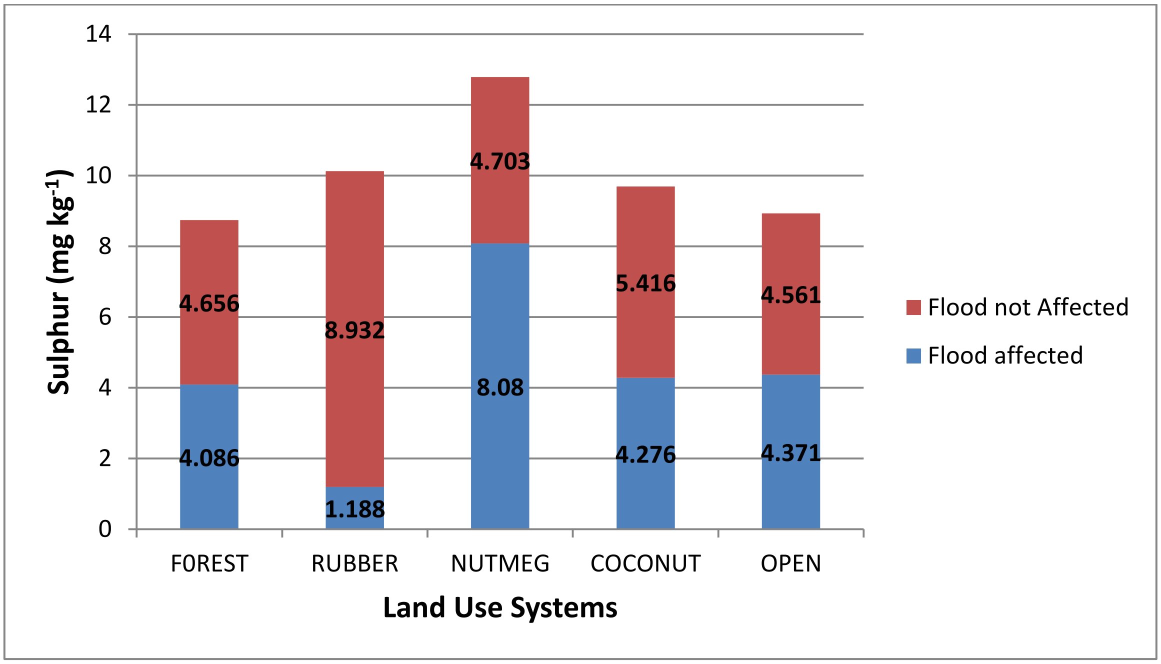

Figure 11. Sulphur content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

4.1.2.10 Iron

Variation in the iron content under different depths on five different land use systems under flood affected and non flooded have listed in the Table 14**.** Table 14 shows at the depth of 0-20 cm, only forest and open land use systems shows significant difference under flood affected and non flooded condition. Here, nutmeg flood affected (26.5 mg kg^{-1}) is par on with nutmeg non flooded (25.5 mg kg^{-1}) and coconut flood affected (25.1 mg kg^{-1}) is on par with coconut non flooded (26.8 mg kg^{-1}). The maximum iron was recorded in rubber non flooded (33.4 mg kg^{-1}) and followed by rubber flood affected (32.7 mg kg^{-1}). The minimum iron was recorded in Forest non flooded (17.2 mg kg^{-1}) and followed forest flood affected (21.7 mg kg^{-1}). Fig.12 presented the iron content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at the depth of 0-20 cm**.** At the depth of 21-40 cm, 41- 60 cm and 61 - 80 cm all land use systems showed non-significant under flood affected and non flooded condition. At the depth of 61 - 80 cm, forest flood affected (15.5 mg kg^{-1}) is on par with forest non flooded (20.6 mg kg^{-1}). Rubber flood affected (22.4 mg kg^{-1}) is par on with rubber non flooded (13.4 mg kg^{-1}) nutmeg flood affected (28.7 mg kg^{-1}) is par on with nutmeg non flooded (21.4 mg kg^{-1}) and open flood affected (14.8 mg kg $^{-1}$) is on par with open non flooded (17.6 mg kg^{-1}). At the depth of 81 – 100 cm, only coconut plantation had significant difference under flood affected and non flooded condition. Here, forest flood affected (30.3 mg kg^{-1}) is on par with forest non flooded (18.6 mg kg^{-1}). Rubber flood affected (21.7 mg kg^{-1}) is par on with rubber non flooded (14.9 mg kg^{-1}) and open flood affected (18.5 mg kg $^{-1}$) is on par with open non flooded (14.6 mg kg^{-1}).

Table 14. Iron content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Iron (mg kg^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	21.71^{e}	19.15^{a}	18.38^{a}	15.59^{b}	30.35^{a}
2	Forest non flooded (FNF)	17.22^{f}	16.23^{a}	21.13^{a}	20.60^{ab}	18.66^{ab}
3	Rubber flood affected (RF)	32.77^{a}	15.52^{a}	19.88^{a}	22.48^{ab}	21.75^{ab}
4	Rubber non flooded (RNF)	33.47^{a}	15.13^{a}	15.03^{a}	13.23^{b}	14.96^{b}
5	Nutmeg flood affected (NF)	26.58^{bc}	17.36^{a}	23.22^{a}	28.72^{a}	27.57^{ab}
6	Nutmeg non flooded (NNF)	25.50^{c}	16.92^{a}	21.43^{a}	21.42^{ab}	22.10^{ab}
7	Coconut flood affected (CF)	25.10^{cd}	22.99^{a}	26.24^{a}	23.96^{ab}	30.17^{a}
8	Coconut non flooded (CNF)	26.81^{bc}	22.34^{a}	26.42^{a}	20.88^{ab}	14.62^{b}
9	Open flood affected (OF, Control-1)	22.90^{de}	21.33^{a}	17.73^{a}	14.84^{b}	18.51^{ab}
10	Open non flooded (ONF, Control-2)	28.33^{b}	22.66^{a}	19.61^{a}	17.64^{ab}	14.68^{b}
	P value	<0.01	0.94	0.94	0.26	0.15
	C.D (0.05)	2.47	16.88	19.81	11.95	13.81

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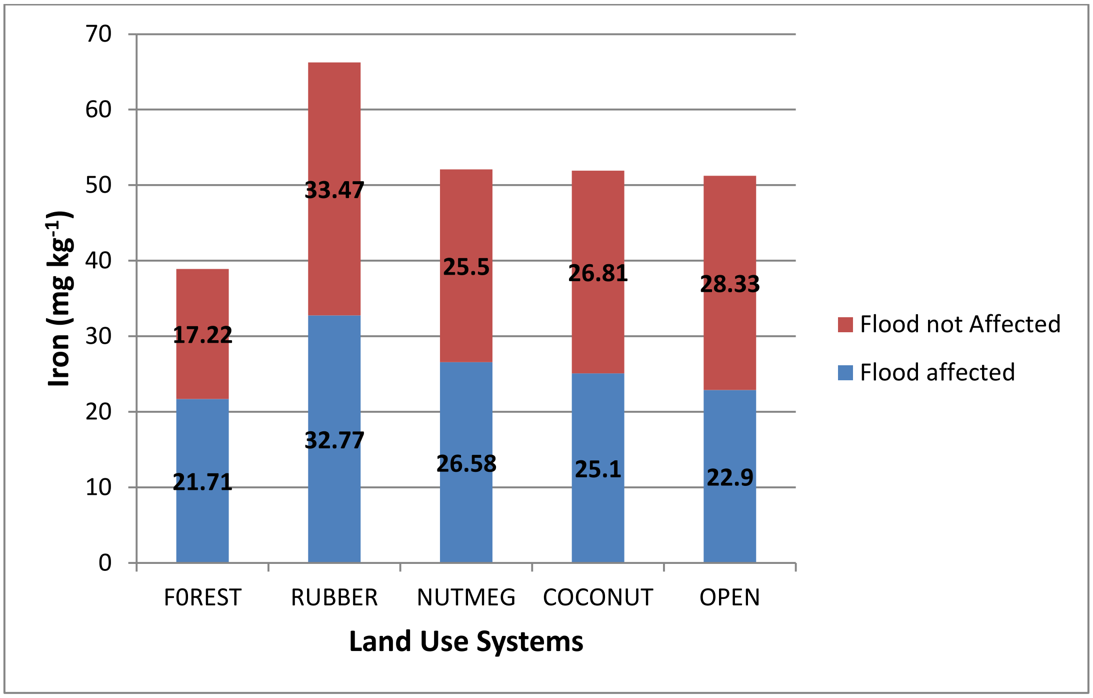

Figure 12. Iron content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

4.1.2.11 Manganese

Variation in the manganese content under different depths on five different land use systems under flood affected and non flooded conditions have been listed in the Table 15. Table 15 showed a significant difference between the all same land use systems under flood affected and non flooded conditions at the top layer (0- 20 cm). The maximum manganese was recorded in nutmeg flood affected (122.1 mg kg^{-1}) followed by coconut non flooded (92.61 mg kg^{-1}) and minimum was recorded in open flood affected (29.47mg kg^{-1}) followed by forest non flooded (32.1 mg kg^{-1}). Fig.13 showed the manganese content (mg kg^{-1}) in five different land use systems under flood affected and non floodedconditions at the depth of 0-20 cm. In 21- 40 cm depth, only forest land use systems had significant difference under flood affected and non flooded conditions. Here, rubber flood affected (25.8 mg kg^{-1}) is on par with rubber non flooded (25.0 mg kg^{-1}). Also nutmeg flood affected (34.4 mg kg^{-1}) is par on with nutmeg non flooded (36.9 mg kg^{-1}) and open flood affected (27.0 mg kg $^{-1}$) is on par with open non flooded (19.6 mg kg^{-1}). At 41- 60 cm depth, all land use systems showed non-significance. Here, forest flood affected (20.3 mg kg^{-1}) is on par with forest non flooded (15.5 mg kg^{-1}). Also, nutmeg flood affected (28.3 mg kg^{-1}) is par on with nutmeg non flooded (38.8 mg kg^{-1}) and open flood affected (27.1 mg kg $^{-1}$) is on par with open non flooded (22.8 mg kg^{-1}). At depth 61- 80 cm, only nutmeg plantation had showed significant difference under flood affected and non flooded conditions, all other land use systems are non-significant under flood affected and non floodedconditions. At the depth of 81- 100 cm, there is a significant difference between the all same land use systems under flood affected and non flooded conditions except open land use systems. Also open flood affected (19.0 mg kg $^{-1}$) is on par with open non flooded (20.9 mg kg^{-1}).

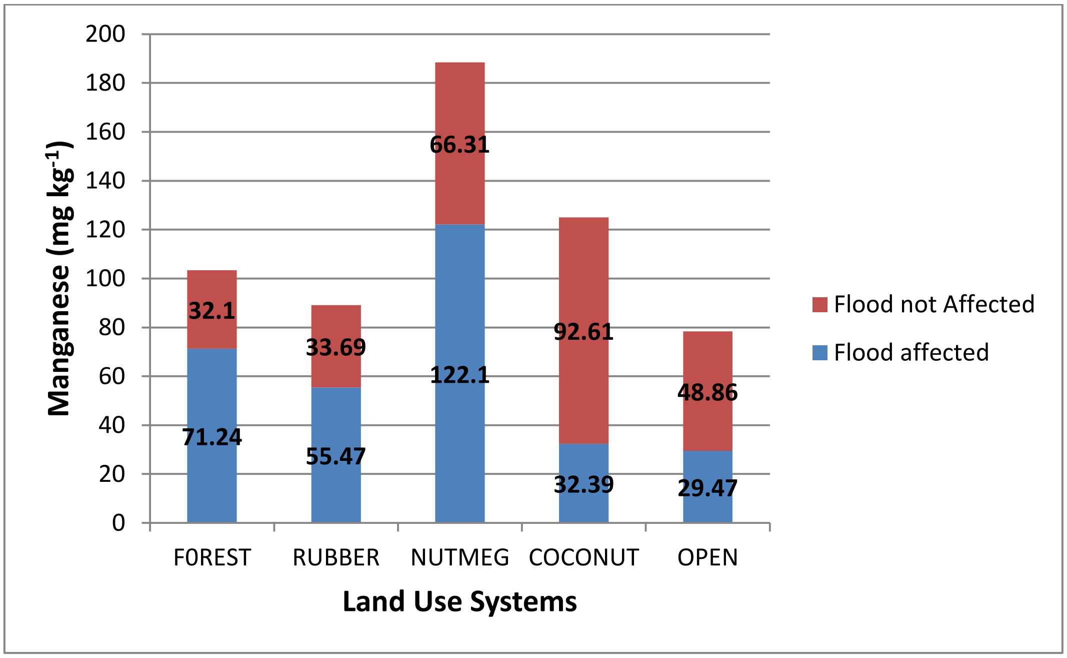

Figure 13. Manganese content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at the soil depth of 0-20 cm

Table 15. Manganese content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Manganese (mg kg^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	71.24^{c}	40.42^{a}	20.35^{bc}	13.47^{d}	18.10^{f}
2	Forest non flooded (FNF)	32.10^{f}	20.94^{d}	15.53^{c}	15.64^{d}	12.59^{e}
3	Rubber flood affected (RF)	55.47^{d}	25.85^{bcd}	21.93^{bc}	22.96^{c}	24.11^{d}
4	Rubber non flooded (RNF)	33.69^{f}	25.02^{cd}	23.39^{bc}	23.89^{c}	15.36^{g}
5	Nutmeg flood affected (NF)	122.10^{a}	34.36^{abc}	28.39^{ab}	35.53^{b}	32.61^{c}
6	Nutmeg non flooded (NNF)	66.31^{c}	36.95^{ab}	38.85^{a}	48.72^{a}	51.89^{b}
7	Coconut flood affected (CF)	32.39^{f}	25.76^{bcd}	36.90^{a}	41.91^{ab}	59.43^{a}
8	Coconut non flooded (CNF)	92.61^{b}	27.96^{bcd}	38.48^{a}	42.01^{ab}	20.94^{e}
9	Open flood affected (OF, Control-1)	29.47^{f}	27.05^{bcd}	27.17^{abc}	24.46^{c}	19.04^{ef}
10	Open non flooded (ONF, Control-2)	48.86^{c}	19.68^{d}	22.85^{bc}	23.15^{c}	20.98^{e}
	P value	<0.01	0.03	0.015	<0.01	<0.01
	C.D (0.05)	6.32	11.31	12.31	7.08	2.64

Same superscripts in columns do not differ significantly

4.1.2.12 Copper

Variation in the copper content under different depths on five different land use systems under flood affected and non flooded conditions have been listed in the Table 16. Table 16 shows there is a significant difference in rubber plantation, nutmeg plantation and open land use systems under flood affected and non flooded conditions at the depth of 0-20cm. Here, forest flood affected (1.5 mg kg^{-1}) is on par with forest non flooded (0.6 mg kg^{-1}) and coconut flood affected (2.0 mg kg^{-1}) is on par with coconut non flooded (1.3 mg kg^{-1}). The highest copper content was recorded for rubber flood affected (88.9 mg kg^{-1}) followed by rubber non flooded (48.4 mg/ kg). The lowest copper was recorded in forest non flooded (0.6 mg kg^{-1}) followed by coconut non flooded (1.3 mg kg^{-1}). Fig.14 presented the copper content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at the depth of 0-20 cm. In the depth 21- 40 cm, rubber plantation, nutmeg plantation and coconut plantation had significant difference under flood affected and non flooded conditions. Here, forest flood affected (1.5 mg kg^{-1}) is on par with forest non flooded (0.5 mg kg^{-1}) and open flood affected (9.0 mg kg $^{-1}$) is on par with open non flooded (9.9 mg kg^{-1}). At the depth of 41- 60 cm, rubber plantation and nutmeg plantation had significant difference under flood affected and non flooded conditions. Here, forest flood affected (1.1 mg kg^{-1}) is on par with forest non flooded (0.4 mg kg^{-1}), coconut flood affected (2.4 mg kg^{-1}) is on par with coconut non flooded (3.6 mg kg^{-1}) and open flood affected (2.2 mg kg $^{-1}$) is on par with open non flooded (3.0 mg kg^{-1}). At the depth 61- 80 cm, only nutmeg plantation and open land system had significant difference under flood affected and non flooded conditions. Here, coconut flood affected (2.8 mg kg^{-1}) is on par with coconut non flooded (1.8 mg kg^{-1}). At the depth of 81- 100cm, all land use systems shows significant difference under flood affected and non flooded conditions.

Table 16. Copper content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Copper (mg kg^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	1.55^{fg}	1.43^{de}	1.10^{fg}	0.92^{d}	1.16^{f}
2	Forest non flooded (FNF)	0.64^{g}	0.54^{e}	0.52^{g}	0.54^{d}	0.57^{g}
3	Rubber flood affected (RF)	88.86^{a}	8.21^{b}	5.10^{b}	4.45^{a}	4.16^{b}
4	Rubber non flooded (RNF)	48.40^{b}	3.60^{c}	6.83^{a}	4.82^{a}	6.63^{a}
5	Nutmeg flood affected (NF)	9.89^{d}	4.31^{c}	3.38^{cd}	3.50^{ab}	3.31^{c}
6	Nutmeg non flooded (NNF)	2.60^{e}	1.92^{d}	1.41^{efg}	1.27^{d}	1.20^{f}

Table 16. Continued

Sl. No.	**Land use systems**	**Copper (mg kg^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
7	Coconut flood affected (CF)	2.07^{ef}	3.33^{c}	2.45^{cde}	2.86^{bc}	2.77^{d}
8	Coconut non flooded (CNF)	1.34^{fg}	2.23^{d}	3.60^{c}	1.87^{cd}	0.61^{g}
9	Open flood affected (OF, Control-1)	10.19^{d}	9.07^{ab}	2.23^{def}	1.12^{d}	1.78^{e}
10	Open non flooded (ONF, Control-2)	19.58^{c}	9.94^{a}	3.00^{cd}	3.34^{abc}	2.81^{d}
	P value	<0.01	<0.01	<0.01	<0.01	<0.01
	C.D (0.05)	0.96	1.00	1.18	1.57	0.10

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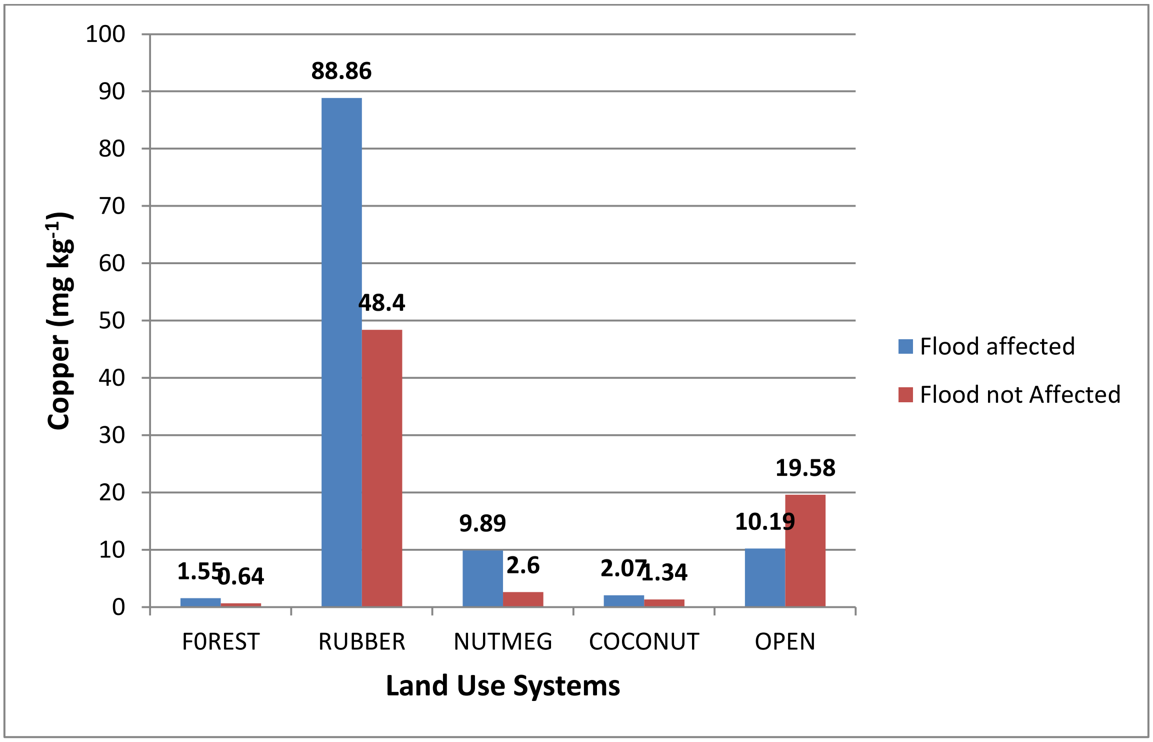

Figure 14. Copper content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at the soil depth of 0-20 cm

4.1.2.13 Zinc

Variation in the zinc content under different depths on five different land use systems under flood affected and non flooded is presented in the Table 17**.** Table 17 shows there is a significant difference in all land use systems under flood affected and non flooded conditions at the depth of 0-20 cm. The highest zinc was recorded in Nutmeg (21.5 mg kg^{-1}) flood affected followed by coconut non flooded (7.7 mg kg^{-1}). The lowest was recorded in coconut flood affected (1.3 mg kg^{-1}) and followed by rubber non flooded (1.6 mg kg^{-1}). Fig.15 recorded the zinc content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at a depth of 0-20 cm. At the depth of 21- 40 cm and 41- 60 cm, there is a significant difference in all land use systems under flood affected and non flooded conditions except coconut plantation. At the depth of 61- 80 cm, only nutmeg plantation were significant under flood affected and non flooded conditions all others are non-significant. At the depth of 81- 100 cm, forest, rubber plantation and nutmeg plantation showed a significant difference between flood affected and non flooded conditions. Also coconut flood affected (0.8 mg kg^{-1}) is on par with coconut non flooded (0.7 mg kg^{-1}) and open flood affected (1.2 mg kg $^{-1}$) is on par with open non flooded (1.1 mg kg^{-1}).

Table 17. Zinc content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Zinc (mg kg^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	3.60^{c}	2.72^{b}	1.65^{b}	1.22^{b}	1.38^{b}
2	Forest non flooded (FNF)	2.53^{d}	1.07^{f}	1.11^{ef}	1.18^{b}	1.11^{cdef}
3	Rubber flood affected (RF)	3.78^{c}	2.42^{c}	1.51^{bc}	1.16^{b}	1.18^{bcd}
4	Rubber non flooded (RNF)	1.65^{ef}	1.24^{ef}	1.27^{de}	1.06^{b}	0.90^{efg}
5	Nutmeg flood affected (NF)	21.59^{a}	3.40^{a}	2.44^{a}	2.67^{a}	2.47^{a}

Table 17. Continued

Sl. No.	Land use systems	Zinc (mg kg^{-1})				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
6	Nutmeg non flooded (NNF)	4.27^{c}	1.63^{d}	1.08^{ef}	1.07^{b}	0.92^{defg}
7	Coconut flood affected (CF)	1.30^{f}	1.17^{f}	1.00^{f}	1.13^{b}	0.86^{fg}
8	Coconut non flooded (CNF)	7.74^{b}	1.01^{f}	0.96^{f}	0.88^{b}	0.76^{g}
9	Open flood affected (OF, Control-1)	2.13^{de}	2.16^{c}	1.36^{cd}	1.15^{b}	1.28^{bc}
10	Open non flooded (ONF, Control-2)	3.69^{c}	1.47^{de}	0.92^{f}	1.00^{b}	1.15^{bcde}
	P value	<0.01	<0.01	<0.01	<0.01	<0.01
	C.D (0.05)	0.77	0.30	0.21	0.37	0.27

Same superscripts in columns do not differ significantly

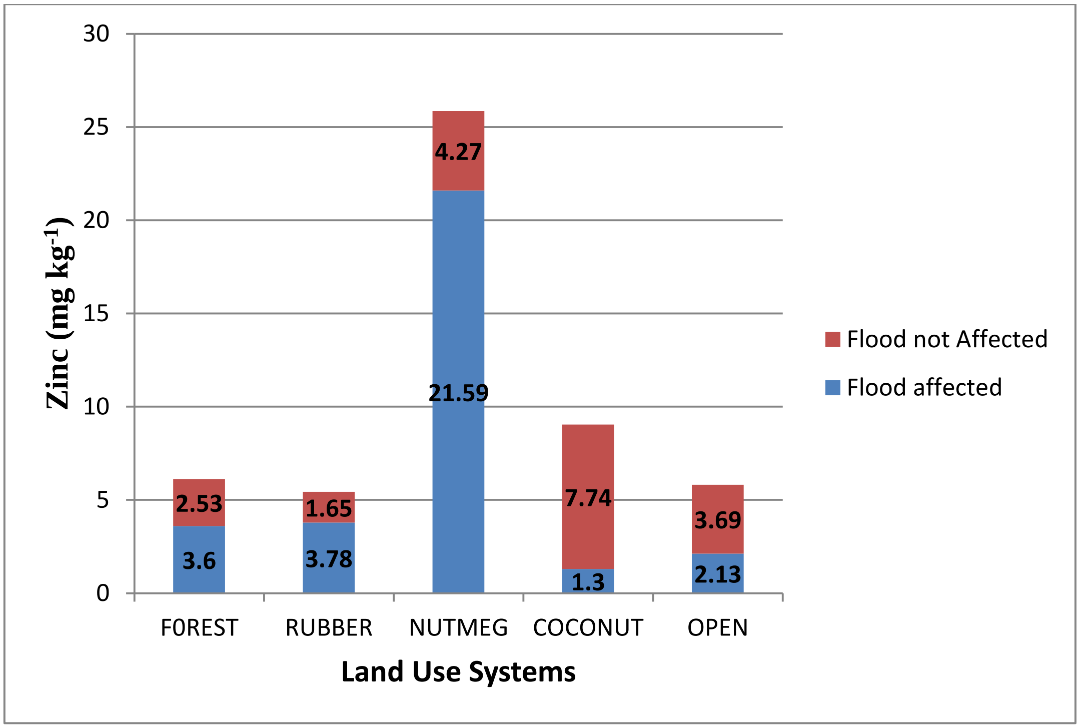

Figure 15. Zinc content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

4.1.2.14 Boron

Variation in the boron content under different depths on five different land use systems under flood affected and non flooded conditions are given Table 18. In the depth of 0-20 cm, only rubber plantation shows significant difference under flood affected and non flooded conditions. Here coconut flood affected (0.34 mg kg^{-1}) is on par with coconut non flooded(0.19 mg kg^{-1}) and open flood affected (0.19mg kg^{-1}) is on par with open non flooded (0.29 mg kg^{-1}). The Maximum boron content was recorded in nutmeg flood affected (0.56mg kg^{-1}) followed by nutmeg non flooded (0.55mg kg^{-1}) and minimum was recorded in Coconut non flooded (0.19 mg kg^{-1}) and Open flood affected (0.19mg kg^{-1}). Fig.16 showed the boron content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at a depth of 0-20 cm. At a depth 21- 40 cm, only Open land use systems had significant difference under flood affected and non flooded conditions. Here forest flood affected (0.61 mg kg^{-1}) is on par with forest non flooded (0.38 mg kg^{-1}). In 41-60 cm depth, all land use systems showed significant difference under flood affected and non flooded conditions except in nutmeg and coconut plantations. Here, nutmeg flood affected (0.66 mg kg^{-1}) is on par with nutmeg non flooded (0.44 mg kg^{-1}). In 61- 80 cm in the rubber plantation, nutmeg plantation and open land use systems, B content showed significant difference under flood affected and non flooded conditions while forest flood affected (0.65 mg kg^{-1}) is on par with forest non flooded(0.34 mg kg^{-1}) and coconut flood affected (0.40 mg kg^{-1}) is on par with coconut non flooded(0.09 mg/ kg).

At 81-100cm depth, rubber and nutmeg plantations had significant difference under flood affected and non flooded conditions, whereas forest flood affected (0.47 mg kg^{-1}) is on par with forest non flooded (0.40 mg kg^{-1}).

Table 18. Boron content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Boron (mg kg^{-1})**				
		Soil Depth (cm)				
		0-20	21-40	41-60	61-80	81-100
1	Forest flood affected (FF)	0.54^{ab}	0.60^{b}	0.44^{bcd}	0.65^{ab}	0.47^{b}
2	Forest non flooded (FNF)	0.55^{ab}	0.37^{bc}	0.24^{de}	0.34^{bcd}	0.40^{bc}
3	Rubber flood affected (RF)	0.25^{c}	0.37^{bc}	0.31^{cde}	0.23^{cd}	0.18^{ce}
4	Rubber non flooded (RNF)	0.53^{ab}	0.51^{bc}	0.91^{a}	0.62^{ab}	0.65^{a}
5	Nutmeg flood affected (NF)	0.56^{a}	0.53^{bc}	0.66^{b}	0.79^{a}	0.73^{a}
6	Nutmeg non flooded (NNF)	0.55^{a}	0.50^{bc}	0.44^{bcd}	0.41^{bcd}	0.30^{cd}
7	Coconut flood affected (CF)	0.34^{abc}	0.14^{c}	0.20^{e}	0.40^{bcd}	0.10^{e}
8	Coconut non flooded (CNF)	0.19^{c}	0.10^{c}	0.08^{e}	0.09^{d}	0.03^{e}
9	Open flood affected (OF, Control-1)	0.19^{c}	0.15^{a}	0.53^{bc}	0.57^{abc}	0.03^{e}
10	Open non flooded (ONF, Control-2)	0.29^{bc}	0.24^{bc}	0.17^{e}	0.13^{d}	0.04^{e}
	P value	0.01	0.01	<0.01	0.01	<0.01
	C.D (0.05)	0.25	0.45	0.23	0.37	0.16

Same superscripts in columns do not differ significantly

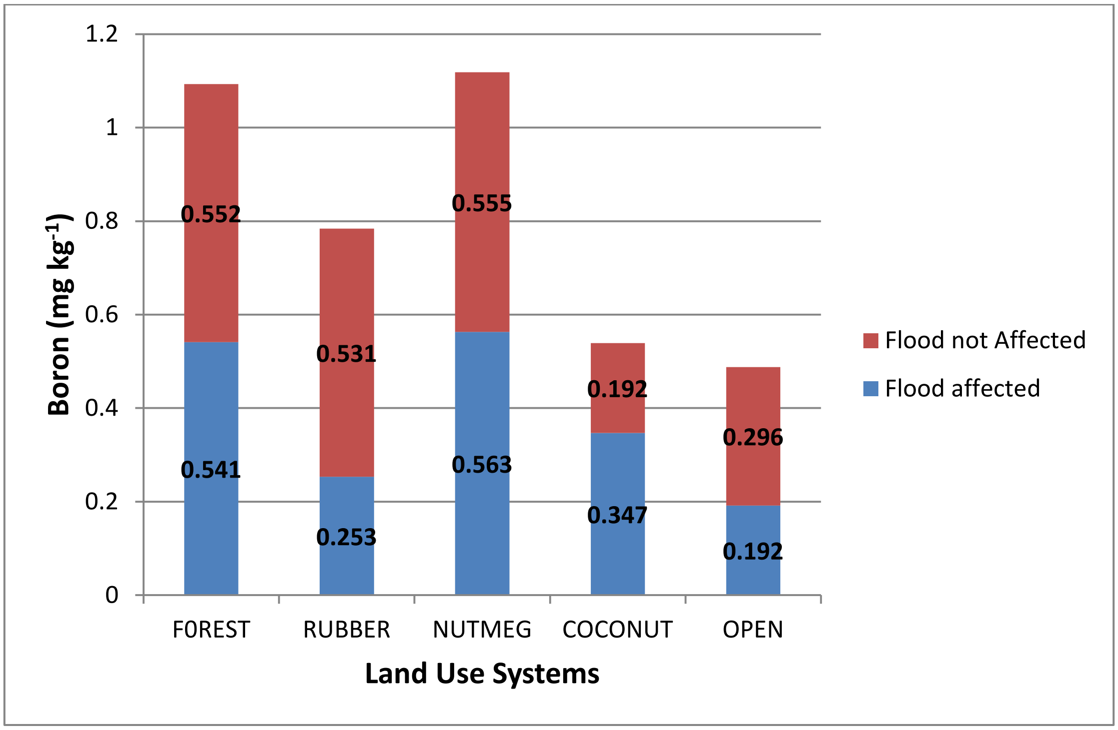

Figure 16. Boron content (mg kg^{-1}) in five different land use systems under flood affected and non flooded conditions at a soil depth of 0-20 cm

4.1.3 Impact of Flood ion Biological Properties of Soil

4.1.3.1 Total Microbial Count

Table 19 presented the bacterial count in various land use systems under flood affected and non flooded condition in the top layer of soil. The bacterial count had non-significant difference in all land use systems under flood affected and non flooded conditions. Here nutmeg flood affected (8.33cfu g^{-1}**)** is on par with nutmeg non flooded (8.24 cfu g^{-1}**).** Also the highest bacterial count was recorded in nutmeg flood affected (8.33cfu g^{-1}**)** followed by nutmeg non flooded (8.24 cfu g^{-1}**),** whereas the lowest bacterial count was recorded in open flood affected (6.86 cfu g^{-1}**)** followed by open non flooded (6.94 cfu g^{-1}**).**

Table 19. Bacterial Count (cfu g^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Total Bacterial Count (cfu g^{-1})**	
		Flood Affected	Non flooded
1	FOREST	7.53^{bc}	7.56^{bc}
2	RUBBER	7.30^{c}	7.21^{c}
3	NUTMEG	8.33^{a}	8.24^{ab}
4	COCONUT	8.25^{ab}	8.23^{ab}
5	OPEN	6.86^{c}	6.94^{c}
Log transformed data			

Same superscripts in rows do not differ significantly

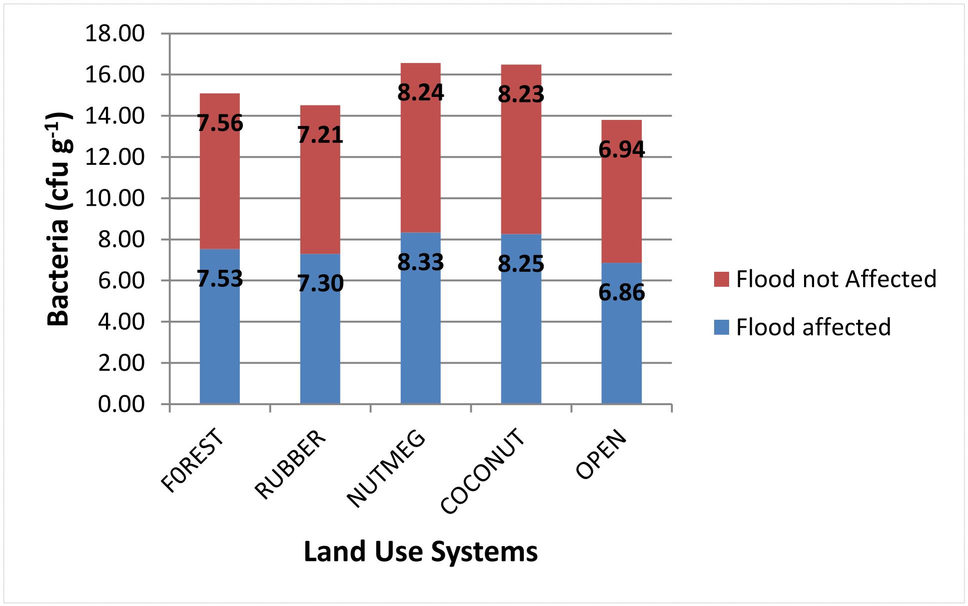

Figure 17. Bacterial Count (cfu g^{-1}) in five different land use systems under flood affected and non flooded conditions

Analysis showed asignificant difference between the different land use systems under non flooded conditions. Here open flood affected had significant difference with nutmeg and coconut flood affected systems. Also, open non flooded had significant difference with nutmeg and coconut non flooded systems. Fig.17 recorded the bacterial count (cfu g^{-1}) in five different land use systems under flood affected and non flooded conditions.

Table 20 presented the fungal count in various land use systems under flood affected and non flooded conditions in the top layer of soil. The fungal count had non-significant difference in all land use systems under flood affected and non flooded conditions. Here coconut flood affected (4.34cfu g^{-1}) is on par with coconut non flooded (4.43 cfu g^{-1}) and open flood affected (4.05cfu g^{-1}) is on par with open non flooded (4.32 cfu g^{-1}). The maximum fungal count was recorded in rubber non flooded (4.55 cfu g^{-1}) followed by rubber flood affected (4.54 cfu g^{-1}).

Table 20. Fungal Count (cfu g^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Total Fungal Count (cfu g^{-1})**	
		Flood Affected	**Non flooded**
1	FOREST	3.60^{c}	3.70^{c}
2	RUBBER	4.54^{a}	4.55^{a}
3	NUTMEG	4.20^{bc}	4.07^{bc}
4	COCONUT	4.34^{abc}	4.43^{ab}
5	OPEN	4.05^{bc}	4.32^{abc}
Log transformed data			

Same superscripts in rows do not differ significantly

Analysis showed a significant difference between the different land use systems. Rubber flood affected had significant difference between forest flood affected, nutmeg flood affected and open flood affected. Also, forest non flooded had significant difference with rubber non flooded and coconut non flooded. Rubber non flooded had significant difference with nutmeg non flooded. Fig.18 recorded the fungal count (cfu g^{-1}) in five different land use systems under Flood affected and non flooded conditions

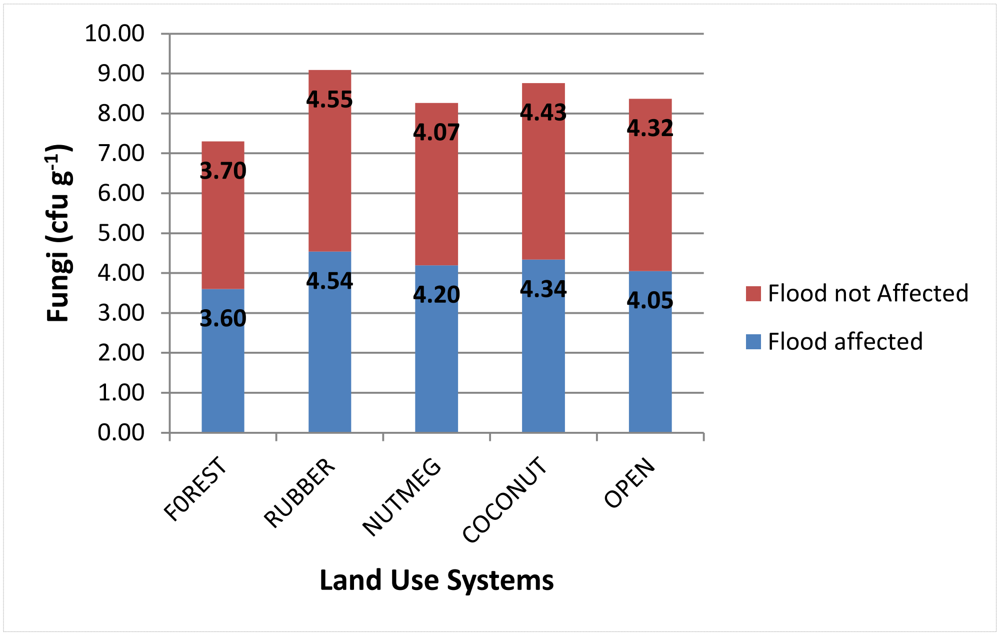

Figure 18. fungal Count (cfu g^{-1}) in five different land use systems under flood affected and non flooded conditions.

Table 21 presented the actinomycetes count in various land use systems under flood affected and non flooded conditions in the top layer of soil. The actinomycetes count had non-significant difference in all land use systems under flood affected and non flooded conditions. Here all same land use systems are on par in the flood affected and non flooded conditions except in nutmeg land use systems. The highest actinomycetes count was found in open non flooded (6.24 cfu g^{-1}) followed by open flood affected (6.13 cfu g^{-1}); whereas the lowest count was found in nutmeg non flooded (0.00 cfu g^{-1}) followed by nutmeg flood affected (4.48 cfu g^{-1}).

Table 21. Actinomycetes Count (cfu g^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Total Actinomycetes Count (cfu g^{-1})**	
		Flood Affected	**Non flooded**
1	FOREST	4.78^{c}	5.92^{abc}
2	RUBBER	5.48^{c}	5.85^{bc}
3	NUTMEG	4.48^{c}	0^{c}
4	COCONUT	5.95^{abc}	5.11^{c}
5	OPEN	6.13^{ab}	6.24^{a}
Log transformed data			

Same superscripts in rows do not differ significantly

Analysis showed a significant difference between the different land use systems. Open flood affected had a significance difference with forest, rubber and nutmeg flood affected systems. Also open non flooded had a significance difference with rubber, nutmeg and coconut non flooded systems. Fig.19 showed the actinomycetes count (cfu g^{-1}) in five different land use systems under flood affected and non flooded conditions.

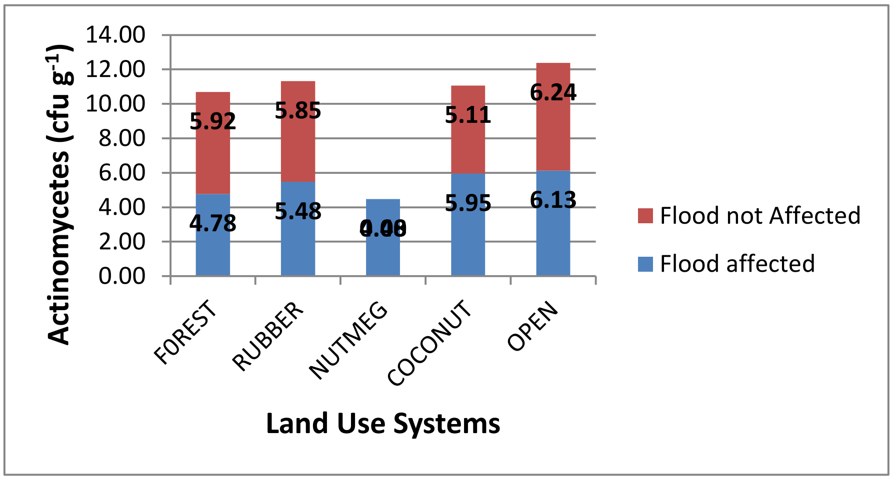

Figure 19. Actinomycetes count (cfu g^{-1}) in five different land use systems under flood affected and non flooded conditions

4.1.3.2 Dehydrogenase Activity

Table 22 recorded the dehydrogenase activity in various land use systems under flood affected and non flooded conditions in the top layer of soil. The data showed a significant difference in open land use systems only. Other land use systems shows non-significant difference in dehydrogenase activity. Also rubber flood affected (32.71 μg TPF g^{-1} 24 hr^{-1}) is on par with rubber non flooded (39.10 μg TPF g^{-1} 24 hr^{-1}). The maximum dehydrogenase activity was observed in nutmeg non flooded (45.07μg TPF g^{-1} 24 hr^{-1}) affected followed by coconut non flooded (40.91 μg TPF g^{-1} 24 hr^{-1}). The minimum dehydrogenase activity was observed in open non flooded (17.63 μg TPF g^{-1} 24 hr^{-1}) followed by forest non flooded (27.02 μg TPF g^{-1} 24 hr^{-1}).

Analysis showed a significant difference between the different land use systems in non flooded conditions only. Open non flooded had a significant difference with all other four land use systems. Fig.20 presented the dehydrogenase activity (μg TPF g^{-1} 24 hr^{-1}) in five different land use systems under flood affected and non flooded conditions.

Table 22. Dehydrogenase activity (μg TPF g^{-1} 24 hr^{-1}) in five different land use systems under flood affected and non flooded conditions

Sl. No.	**Land use systems**	**Dehydrogenase activity (μg TPF g^{-1} 24 hr^{-1})**	
		Flood Affected	**Non flooded**
1	FOREST	38.19^{a}	27.02^{a}
2	RUBBER	32.71^{ab}	39.1^{a}
3	NUTMEG	37.37^{a}	45.07^{a}
4	COCONUT	36.01^{a}	40.91^{a}
5	OPEN	33.98^{a}	17.63^{b}

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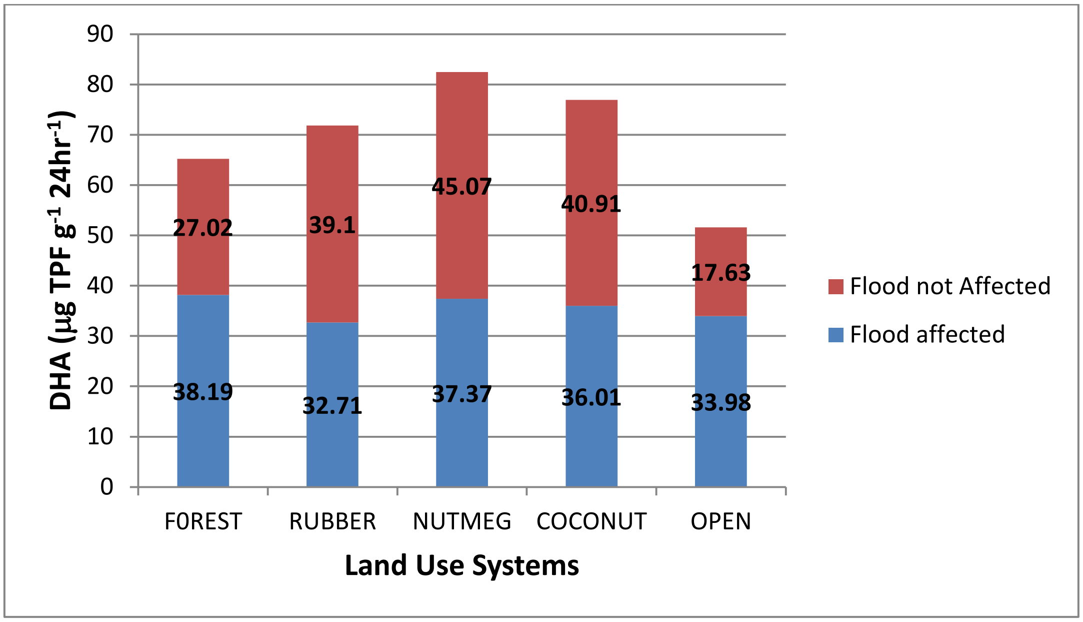

Figure 20. Dehydrogenase activity (μg TPF g^{-1} 24 hr^{-1}) in five different land use systems under flood affected and non flooded conditions

4.1.3.3 Microbial Biomass Carbon (MBC)

Table 23 showed the MBC of five different land use systems under flood affected and non flooded conditions in the top layer of soil. The highest MBC was recorded in rubber flood affected (280.48 μg g^{-1}) followed by open non flooded (163.76 μg g^{-1}) while lowest was recorded in coconut flood affected (11.16 μg g^{-1}) followed by open flood affected (42.32μg g^{-1}). The presented data showed a difference in flood affected and non flooded conditions. Comparing same land use systems, forest flood affected, rubber flood affected and nutmeg flood affected showed a higher value than forest non flooded, rubber non flooded, respectively. In other two land use systems (coconut and open, MBC is higher in non flooded conditions. Fig.21 showed the microbial biomass carbon (μg g^{-1}) in five different land use systems under flood affected and non flooded conditions.

Table 23. Microbial Biomass Carbon (μg g^{-1}) in five different land use systems under Flood affected and non flooded conditions

Sl. No.	Land use systems	MBC (μg g^{-1})	
		Flood Affected	**Non flooded**
1	FOREST	101.89	92.22
2	RUBBER	280.48	216
3	NUTMEG	138.08	112.19
4	COCONUT	11.16	102.14
5	OPEN	42.32	163.76

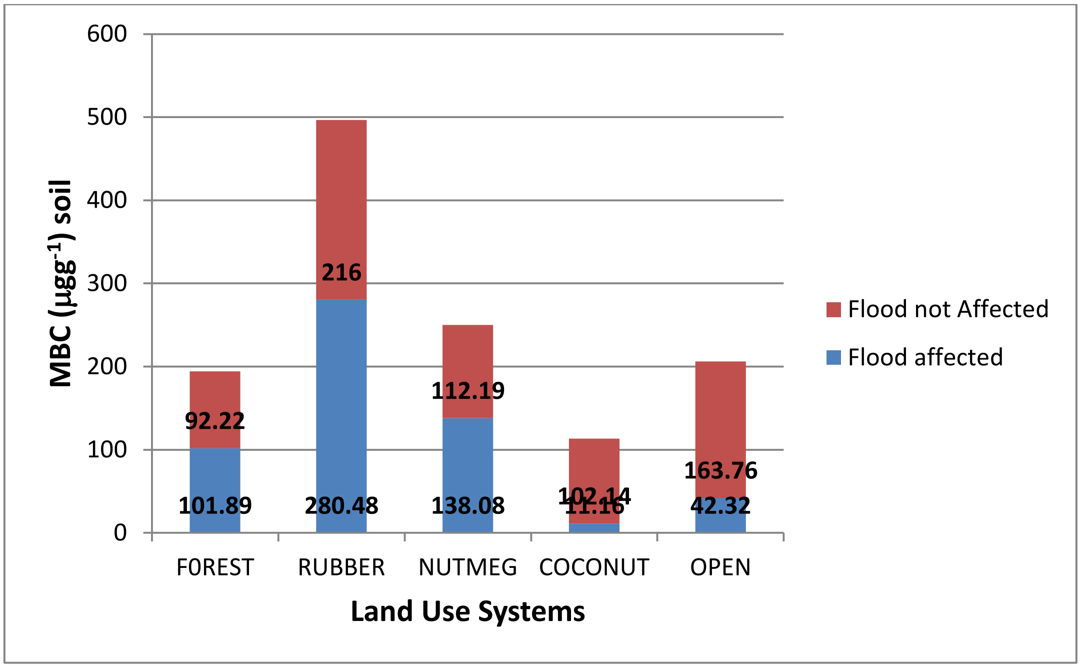

Figure 21. Microbial Biomass Carbon (μg g^{-1}) in five different land use systems under flood affected and non flooded conditions

4.2 IMPACT OF FLOOD ON SEED BANK

4.2.1 Forest

Results of the soil seed bank, under both flood affected and non flooded forest lands, in the pre monsoon (April 2019) and post monsoon (November, 2019) seasons are given in Table 24 and Table 25, respectively. In pre monsoon, the forest flood affected land use systems shown only two herb species; and *Ruellia prostrata* had highest seed density of 6 seeds m^{-2}. Forest non flooded conditions showed a total number of four species has germinated of 62 total individuals. The result showed no tree species, only showed one shrub, 2 herb, and one climber. *Bambusa bambos* shrub, herb such as *Commelina benghalensis* and *Eragostis tenella. Mikania micrantha* as the climber. Here *Bambusa bambos* has got highest seed density of 29 seeds m^{-2} followed by *Mikania micrantha* (12 seeds m^{-2}).

Table 24.Soil seed bank of Forest land use systems during Pre monsoon season (April, 2019)

Land use systems					
Forest Flood Affected (FF)			**Forest Non flooded (FNF)**		
Species	**Seed Density / m^2**	**Habit**	**Species**	**Seed Density / m^2**	**Habit**
Ruellia prostrata	6	Herb	*Bambusa bambos*	29	Shrub
Geophila cordifolia	3	Herb	*Eragrostis tenella*	11	Herb
			Commelina benghalensis	10	Herb
			Mikania micrantha	12	Climber

Table 25 showed the results of Seed bank of both flood affected and non flooded in Forest land use systems from November 2019 to March 2020. Here also Forest flood affected showed 14 individuals of 3 herb species. Out of this, *Eragrostis tenella* had a higher seed density of 9 seeds m^{-2}. Forest non flooded conditions showed a total number of three species germinated of 34 total individuals. Here also we didn't find a tree species in the seed bank; it has only three herb species (*Cyanotis cristata*, *Commelina benghalensis* and *Eragrostis tenella*). *Commelina benghalensis* has got highest seed density of 15 seeds m^{-2} followed by *Cyanotis cristata* (12 seeds m^{-2}).

Table 25.Soil seed bank of forest land use systems during post monsoon season (November 2019)

Land use systems					
Forest Flood Affected (FF)			**Forest Non flooded (FNF)**		
Species	**Seed Density / m^2**	**Habit**	**Species**	**Seed Density / m^2**	**Habit**
Eragrostis tenella	9	Herb	*Commelina benghalensis*	15	Herb
Eclipta prostrate	3	Herb	*Cyanotis cristata*	12	Herb
Crassocephalus crepidioides	2	Herb	*Eragrostis tenella*	7	Herb

4.2.1 Rubber plantation

Results of the soil seed bank of Rubber plantation in the month of April and November are given in Table 26 and Table 27, respectively. Table 28 showed the results of seed bank of both flood affected and non flooded in Rubber plantation from April 2019 to July 2019. In this, Rubber flood affected showed a total of 3 species of 48 individuals composed of both herb and climber. It has *Mikania micrantha* as climber and *Linder niarotundifolia, Kyllingane moralis* as herb. Here *Mikania micrantha* has got highest seed density of 25 seeds m^{-2}. Rubber non flooded conditions showed two herb species and one climber of total 99 individuals. Herb species such as *Peperomia pellucida* and *Cyanotis cristata* was observed, and *Peperomia pellucida* was recorded with highest seed density (88 seeds m^{-2}).

Table 26. Seed bank of Rubber land use systems during Pre monsoon season (April, 2019)

Land use systems					
Rubber Flood Affected (RF)			**Rubber Non flooded (RNF)**		
Species	**Seed Density / m^2**	**Habit**	**Species**	**Seed Density/ m^2**	**Habit**
Mikania micrantha	25	Climber	*Cyanotis cristata*	8	Herb
Lindernia rotundifolia	15	Herb	*Peperomia pellucida*	88	Herb
Kyllinga nemoralis	8	Herb	*Centrosema pubescens*	3	Climber

Table 27. Seed bank of Rubber land use systems during Post monsoon season (November 2019)

Land use systems					
Rubber Flood Affected (RF)			**Rubber Non flooded (RNF)**		
Species	**Seed Density/ m^2**	**Habit**	**Species**	**Seed Density/ m^2**	**Habit**
Alternanthera bettzickiana	7	Herb	*Peperomia pellucida*	185	Herb
Peperomia pellucida	98	Herb	*Gynandropsis gynandra*	6	Herb
Gynandropsisgynandra	9	Herb	*Kyllinga nemoralis*	5	Herb
Synedrella nodiflora	22	Herb			

Table 29 showed the results of Seed bank of both flood affected and non flooded in Rubber plantation from November 2019 to March 2020. Rubber flood affected has a total of four herb species of 136 individuals. Among the four herbs *Peperomia pellucida* has got highest seed density of 98 seeds m^{-2}. In Rubber non flooded conditions, a total of 3 herb species was founded where two species was similar with flood affected condition. Here also *Peperomia pellucida* has got highest seed density of 185 seeds m^{-2}.

4.2.3 Nutmeg plantation

Results of the soil seed bank of Nutmeg plantation in the month of April and November are given in Table 28 and Table 29, respectively. Table 28 showed the results of seed bank of both flood affected and non flooded conditions in Nutmeg plantation from April 2019 to July 2019. In Nutmeg flood affected, total of 4 speceis of 14 individuals has been founded. Out of this, three were herbs and one is climber. Herbs such as *Tragia involucrata*, *Kyllingane moralis* and *Commelina benghalensis,* and climbers such as *Mukia maderaspatana* were found. *Tragia involucrate* has got highest seed density of 5 seeds m^{-2}. In Nutmeg non flooded system, total of 7 speceis were found, having one shrub and 6 herb species. Here highest seed density was recorded for *Synedrella nodiflora* with a figure of 23seeds m^{-2}.

Table 28. Seed bank of Nutmeg land use systems during Pre monsoon season (April, 2019)

Land use systems					
Nutmeg Flood Affected (NF)			**Nutmeg Non flooded (NNF)**		
Species	**Seed Density / m^2**	**Habit**	**Species**	**Seed Density / m^2**	**Habit**
Tragia involucrata	5	Herb	*Mimosa diplotricha*	6	Shrub
Commelina benghalensis	4	Herb	*Cyathula prostrata*	18	Herb
Kyllinga nemoralis	4	Herb	*Alternanthera sessilis*	15	Herb
Mukia maderaspatana	1	Climber	*Andrographis paniculata*	13	Herb
			Acanthospermum hispidum	8	Herb
			Amaranthus spinosus	7	Herb
			Synedrella nodiflora	23	Herb

Table 29 showed the results of Seed bank of both flood affected and non flooded in Nutmeg plantation from November 2019 to March 2020. Nutmeg flood affected has a total of four species consists of one shrub (*Capsicum annuum*) and three herb (*Alloteropsis cimicina*, *Kyllingane moralis* and *Peperomia pellucida*). Among this highest seed density was for *Alloteropsis cimicina* (13 seeds m^{-2}). In nutmeg non flooded system, total of five species was recorded with 91 total individuals. One shrub and three herbs were founded. *Synedrella nodiflora* has got highest seed density of 35 seeds m^{-2}.

Table 29. Seed bank of Nutmeg land use systems during Post monsoon season (November 2019)

Land use systems					
Nutmeg Flood Affected (NF)			**Nutmeg Non flooded (NNF)**		
Species	**Seed Density / m^2**	**Habit**	**Species**	**Seed Density/ m^2**	**Habit**
Capsicum annuum	1	Shrub	*Alternanthera bettzickiana*	27	Shrub
Alloteropsis cimicina	13	Herb	*Biophytum reinwardtiii*	8	Herb
Kyllinga nemoralis	3	Herb	*Synedrella nodiflora*	35	Herb
Peperomia pellucida	2	Herb	*Commelina benghalensis*	18	Herb
			Oxalis corniculata	3	Herb

4.2.4 Coconut plantation

Results of the soil seed bank of Coconut plantation in the month of April and November are given in Table 30 and Table 31, respectively. Table 30 showed the results of seed bank of both flood affected and non flooded in Coconut plantation from April 2019 to July 2019. In Coconut flood affected, total of 15 species were founded of total 137 individuals. Three shrubs, eleven herbs and one climber were recorded. *Kyllingane moralis* was recorded for highest seed density (27 seeds m^{-2}) followed by *Oxalis corniculata* (19 seeds m^{-2}). Coconut non flooded system had a total of 154 individuals of 12 species were observed. Out of this, one is shrub and others are herb species. Also, five species were found to be same with flood affected system. *Synedrella nodiflora* was recorded for highest seed density (44 seeds m^{-2}) followed by *Eragrostis tenella* (29 seeds m^{-2}).

Table 30. Seed bank of Coconut land use systems during Pre monsoon season (April, 2019)

Land use systems					
Coconut Flood Affected (CF)			**Coconut Non flooded (CNF)**		
Species	**Seed Density / m^2**	**Habit**	**Species**	**Seed Density / m^2**	**Habit**
Sida rhomboidea	13	Shrub	*Sida cordifolia*	6	Shrub
Sida cordifolia	7	Shrub	*Synedrella nodiflora*	44	Herb
Urena lobata	5	Shrub	*Biophytum sensitivum*	7	Herb
Biophytum sensitivum	5	Herb	*Ruellia prostrate*	5	Herb
Mimosa pudica	10	Herb	*Mimosa pudica*	3	Herb
Kyllinga nemoralis	27	Herb	*Kyllinga nemoralis*	24	Herb
Mitracarpus hirtus	16	Herb	*Gynandropsis gynandra*	6	Herb
Cyrtococcum trigonum	6	Herb	*Eragrostis tenella*	29	Herb
Phyllanthus niruri	4	Herb	*Catharanthus pusillus*	6	Herb
Centotheca lappacea	4	Herb	Centotheca lappacea	9	Herb
Oxalis corniculata	19	Herb	*Scoparia dulcis*	3	Herb
Dactyloctenium aegyptium	4	Herb	*Dactyloctenium aegyptium*	12	Herb
Cyperus cyperinus	6	Herb			
Ruellia prostrata	8	Herb			
Centrosema pubescens	3	climber			

Table 31 showed the results of seed bank of both flood affected and non flooded in Coconut plantation from november 2019 to march 2020. Coconut flood affected has a total of 76 individuals of four herb species. *Eragrostis tenella* was recorded for highest seed density (48 seeds m^{-2}) followed by *Mimosa pudica* (15 seeds m^{-2}). In coconut non flooded system, total of 37 individuals of two herb species were founded. *Mitracarpus hirtus* had the highest seed density (23 seeds m^{-2}).

Table 31. Seed bank of Coconut land use systems during post monsoon season (November 2019)

Land use systems					
Coconut Flood Affected (CF)			**Coconut Non flooded (CNF)**		
Species	**Seed Density / m^2**	**Habit**	**Species**	**Seed Density / m^2**	**Habit**
Mimosa pudica	15	Herb	*Mitracarpus hirtus*	23	Herb
Eragrostis tenella	48	Herb	*Aerva lanata*	14	Herb
Axonopus compressus	10	Herb			
Commelina benghalensis	3	Herb			

4.2.5 Open land use systems

Results of the soil seed bank of open land use systems (control) in the month of april and november are given in Table 32 and Table 33, respectively. Table 32 showed the results of seed bank of both flood affected and non flooded in Open land use systems from april 2019 to july 2019. In open flood affected (control 1), total 89 individuals from five species were recorded. Out of this, four were herb and one is climber. The highest seed density was recorded for *Kyllinga nemoralis* (68 seeds m^{-2}) followed by *Mimosa pudica* (7 seeds m^{-2}). In open non flooded system (control 2), total of 40 individuals from three species were observed. Out of this, two were herbs and one was a climber. *Mimosa pudica* had the highest seed density (17 seeds m^{-2}) followed by *Mikania micrantha* (15 seeds m^{-2}).

Table 32. Seed bank of open land use systems during pre monsoon season (April, 2019)

Land use systems					
Open Flood Affected (OF)			**Open Non flooded(ONF)**		
Species	**Seed Density / m^2**	**Habit**	**Species**	**Seed Density/ m^2**	**Habit**
Mimosa pudica	7	Herb	*Mimosa pudica*	17	Herb
Cyperus rotundus	4	Herb	*Cyperus rotundus*	8	Herb
Kyllinga nemoralis	68	Herb	*Mikania micrantha*	15	Climber
Oxalis corniculata	4	Herb			
Mikania micrantha	6	Climber			

Table 33 showed the results of seed bank of both flood affected and non flooded in open land use systems from November 2019 to March 2020. Open flood affected has a total of 64 individuals from 3 species. Out of this two was shrub and other two were herb.*Cyathula prostrate* had recorded the maximum seed density (33 seeds m^{-2}) followed by *Kyllinga nemoralis* (16 seeds m^{-2}). Open non flooded systems showed a total 64 individuals from seven species. Out of this 6 were herb and one was shrub. The maximum seed density was observed in *Peperomia pellucida* (23 seeds m^{-2}) followed by *Commelina benghalensis* (12 seeds m^{-2}).

Table 33. Seed bank of open land use systems during post monsoon season (November 2019)

Land use systems					
Open Flood Affected (OF)			**Open Non flooded (ONF)**		
Species	**Seed Density/ m^2**	**Habit**	**Species**	**Seed Density/ m^2**	**Habit**
Alternanthera bettzickiana	9	Shrub	*Alternanthera bettzickiana*	3	Shrub
Sida rhomboidea	6	Shrub	*Cyrtococcum trigonum*	8	Herb
Cyathula prostrata	33	Herb	*Commelina benghalensis*	12	Herb
Kyllinga nemoralis	16	Herb	*Synedrella nodiflora*	4	Herb
			Cynodon dactylon	4	Herb
			Peperomia pellucida	23	Herb
			Mimosa pudica	8	Herb

4.3 IMPACT OF FLOOD ON VEGETATION

4.3.1 Floristic Diversity

4.3.1.1 Tree diversity

The floristic diversity, in plot size of 20 m x 20 m, in terms of Simpson's index and Shannon Wiener index is presented in Table 34. The maximum Simpson's index was recorded in forest non flooded (0.91) condition followed by forest flood affected (0.94) condition. The minimum was recorded for coconut flood affected (0.53) followed by coconut non flooded (0.75). Nutmeg flood affected and non flooded had Simpson's index of 0.81 and 0.85 respectively. Fig. 22 figured the Simpson's index of plot size 20 m x 20 m**.** Simpson's index showed a lower value in flood affected than non flooded conditions with respect to same land use systems.

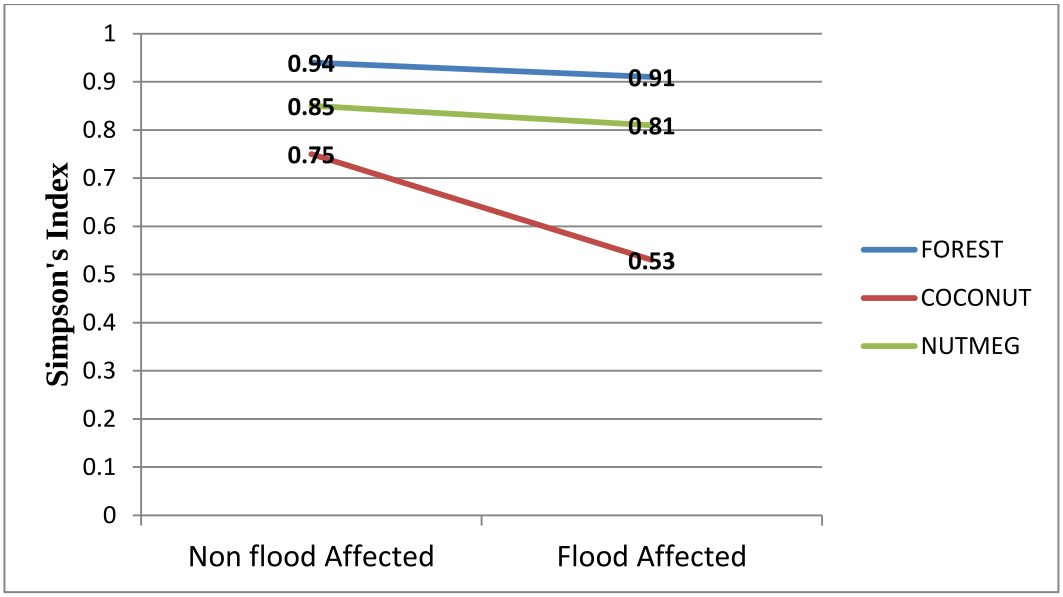

Figure 22. Simpson's index of Plot size 20 m x 20 m

Shannon Wiener index recorded highest for forest non flooded (2.80) followed by forest flood affected (2.58). The lowest was recorded for coconut flood affected (1.11) followed by coconut non flooded (1.79). Fig. 23 showed the Shannon Wiener index of Plot size 20 m x 20 m**.** Shannon Wiener index showed a lower value in flood affected than non flooded conditions with respect to same land use systems.

Table 34. Tree species diversity in different land use systems under flood affected and non flooded conditions

Land use systems	**Diversity Indices (20 m x 20 m)**			
	Shannon Wiener Index		**Simpson's Index**	
	Flood Affected	Non flooded	**Flood Affected**	**Non-flooded**
FOREST	2.58	2.8	0.91	0.94
NUTMEG	1.82	2.24	0.81	0.85
COCONUT	1.11	1.79	0.53	0.75

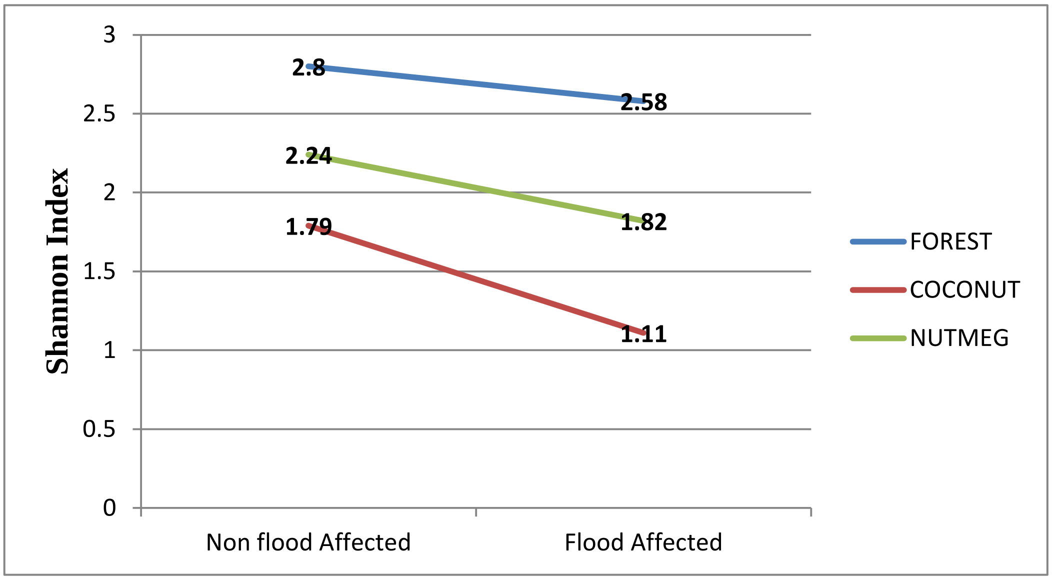

Figure 23. Shannon Wiener index of tree

4.3.1.2 Shrub Diversity

The shrub diversity calculated, in plot size of 3 m x 3 m, and expressed as Simpson's index and Shannon Wiener index in Table 35. The maximum Simpson's index was recorded in forest non flooded (0.88) condition followed by forest flood affected (0.83) condition and nutmeg non flooded (0.83) condition. The minimum was recorded for coconut flood affected (0.67) followed by Rubber flood affected (0.69). Fig. 24 recorded the Simpson's index of plot size 3 m x 3 m. Simpson's index showed a lower value in flood affected than non flooded conditions with respect to same land use systems

Table 35. Shrub species diversity in different land use systems under flood affected and non flooded conditions

Land use systems	Diversity Indices (20 m x 20 m)			
	Shannon Wiener Index		Simpson's Index	
	Flood Affected	Non-flooded	Flood Affected	Non-flooded
FOREST	1.86	2.21	0.83	0.88
RUBBER	1.28	1.53	0.69	0.77
NUTMEG	1.63	1.91	0.77	0.83
COCONUT	1.47	1.89	0.67	0.8
OPEN	1.67	1.78	0.79	0.8

Shannon wiener index was recorded highest for forest non flooded (2.21) followed by nutmeg non flooded (1.91). The lowest was recorded for Rubber flood affected (1.28) followed by coconut flood affected (1.47). Fig. 25 presented the Shannon Wiener Index of Plot size 3x3m. Shannon wiener index showed a lower value in flood affected than non flooded conditions with respect to same land use systems.

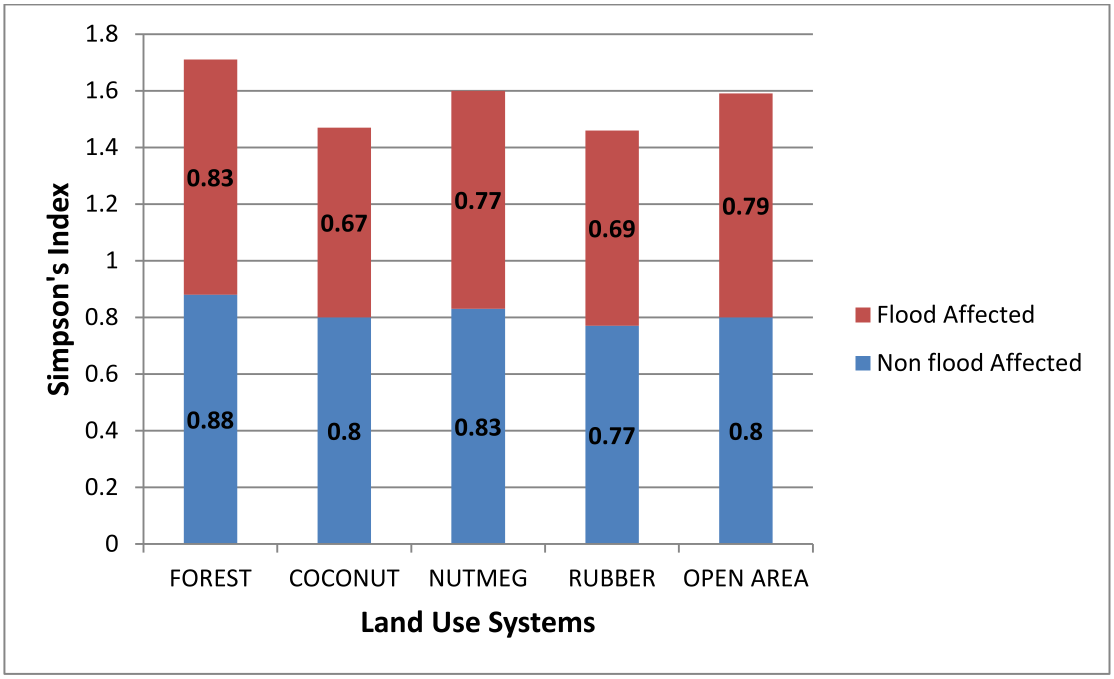

Figure 24. Simpson's index of Shrub

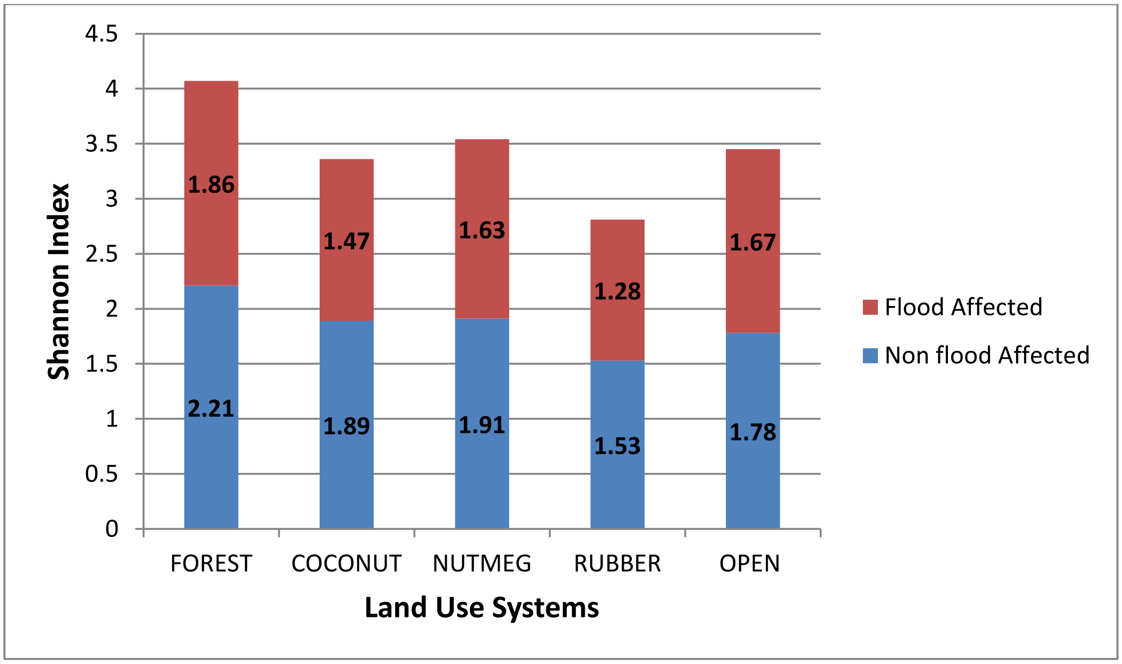

Figure 25. Shannon Wiener index of shrub

4.3.1.3 Herb Diversity

Herb diversity is assessed, in plot size of 1 m x 1 m, and presented interms of Simpson's and Shannon Wiener indices. Simpson's index was tabulated in Table 36. Coconut non flooded (0.84) had the highest Simpson's index followed by forest non flooded (0.83). Forest flood affected (0.52) had the lowest Simpson's index followed by rubber non flooded (0.61). Fig 26 showed the Simpson's index of plot size 1 m x 1 m. Simpson's index showed a lower value in flood affected condition than non flooded conditions with respect to same land use systems except in rubber, open and nutmeg. Nutmeg showed an equal observation in both conditions.

Table 36. Herb species diversity in different land use systems under flood affected and non flooded conditions

Land use systems	**Diversity Indices (20 m x 20 m)**			
	Shannon Wiener Index		**Simpson's Index**	
	Flood Affected	**Non-flooded**	**Flood Affected**	**Non-flooded**
FOREST	1.16	1.92	0.52	0.83
RUBBER	1.4	1.2	0.71	0.61
NUTMEG	1.4	1.57	0.71	0.71
COCONUT	1.6	1.96	0.76	0.84
OPEN	1.64	1.2	0.75	0.61

Shannon Wiener index was presented in Table 36. Coconut non flooded (1.96) had the highest Shannon Wiener index followed by forest non flooded (1.92). Forest flood affected (1.16) had the lowest Shannon Wiener index followed by rubber non flooded (1.20) and open non flooded (1.20). Fig. 27 presented the Shannon Wiener Index of plot size 1 m x 1 m. Shannon wiener index showed a lower value in flood affected condition than non flooded condition with respect to same land use systems except in rubber and open land use systems.

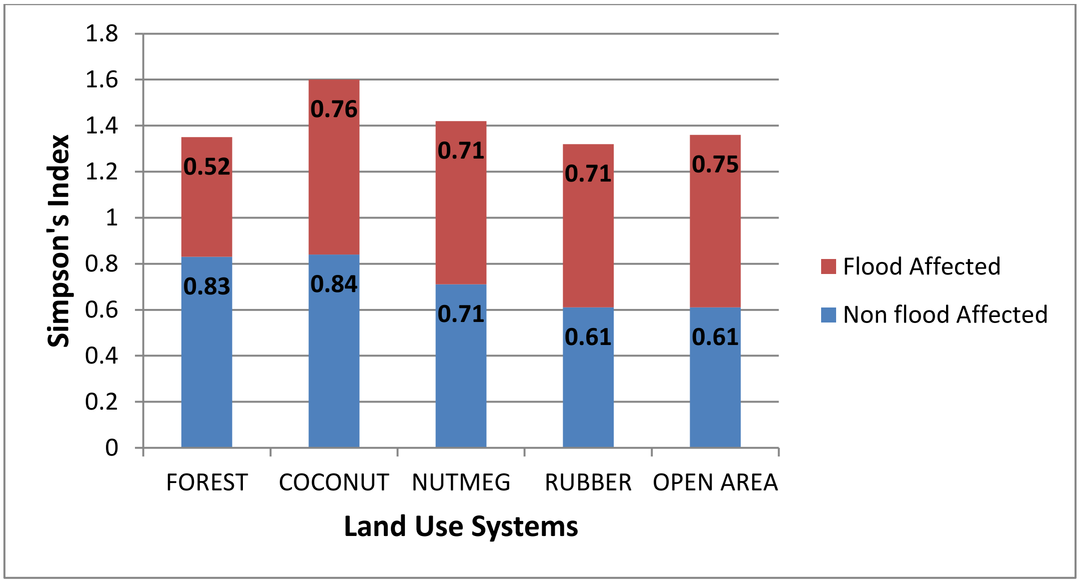

Figure 26. Simpson’s index of herb

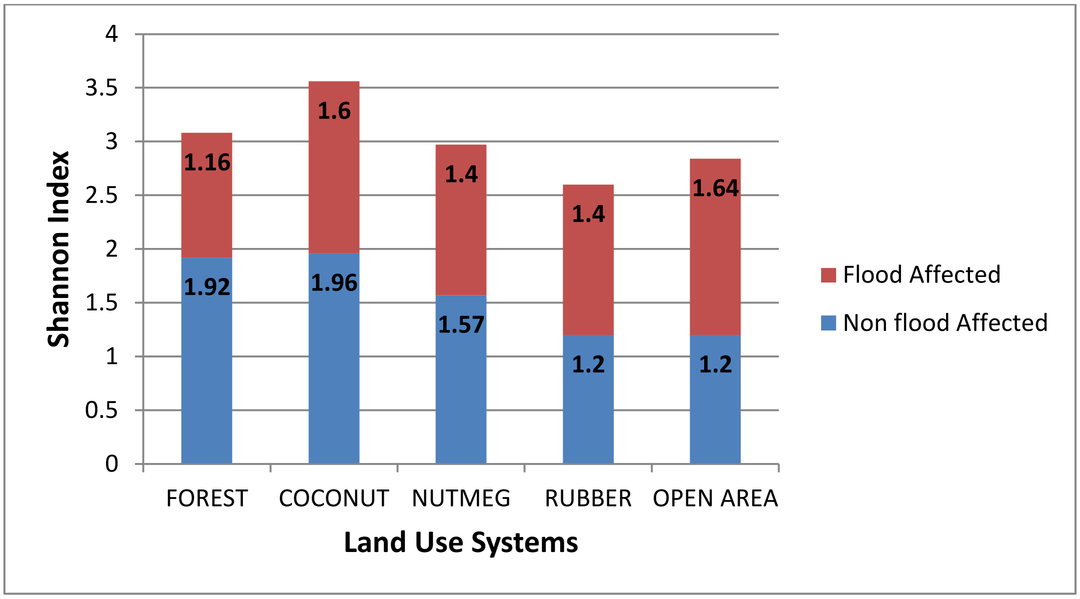

Figure 27. Shannon Wiener index of herb

4.3.2 Abundance and Frequency

Table 37 showed the data regarding abundance and frequency of tree species in plot size 20 m x 20 m in forest flood affected condition. Total of 15 different species was recorded in 3 plot size of 20 m x 20 m. *Neolamarckia cadamba* had the highest abundance (4.00), relative frequency (14.29), relative density (16.00), and relative basal area (17.41). All these parameters made its higher IVI (80.32). The second highest abundance (3.00) was recorded for *Holarrhena pubescens.* The second highest relative frequency was recorded for *Bombax ceiba* (9.52), *Artocarpus hirsutus* (9.52), *Holarrhena pubescens* (9.52) and *Callicarpa tomentosa* (9.52). Also second highest IVI was recorded for *Bombax ceiba* (29.77) followed by *Artocarpus hirsutus* (26.55) and *Holarrhena pubescens* (24.51). Fig. 28 recorded the IVI of forest flood affected land use systems in plot size of 20 m x 20 m

Table.37. Abundance, frequency and species composition in forest flood affected of plot size 20 m x 20 m

Sl.no	**Species**	**RD**	**RF**	**RBA**	**IVI**	**A**
1	*Neolamarckia cadamba*	16.00	14.29	17.41	80.32	4
2	*Bombax ceiba*	8.00	9.52	4.26	29.77	2
3	*Artocarpus hirsutus*	8.00	9.52	3.14	26.55	2
4	*Holarrhena pubescens*	12.00	9.52	1.04	24.51	3
5	*Callicarpa tomentosa*	8.00	9.52	1.07	20.61	2
6	*Madhuca longifolia*	8.00	4.76	2.35	19.51	2
7	*Ficus exasperata*	8.00	4.76	1.52	17.12	2
8	*Lannea coromandelica*	4.00	4.76	0.77	10.97	1
9	*Alstonia scholaris*	4.00	4.76	0.75	10.93	1
10	*Dillenia pentagyna*	4.00	4.76	0.66	10.67	1
11	*Bauhinia malabarica*	4.00	4.76	0.53	10.28	1
12	*Olea dioica*	4.00	4.76	0.52	10.24	1
13	*Aporosa lindleyana*	4.00	4.76	0.40	9.90	1

Table 37. Continued

Sl.no	Species	RD	RF	RBA	IVI	A
14	*Xylia xylocarpa*	4.00	4.76	0.30	9.63	1
15	*Ficus hispida*	4.00	4.76	0.10	9.04	1

RD- Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI-Importance Value Index, A-abundance

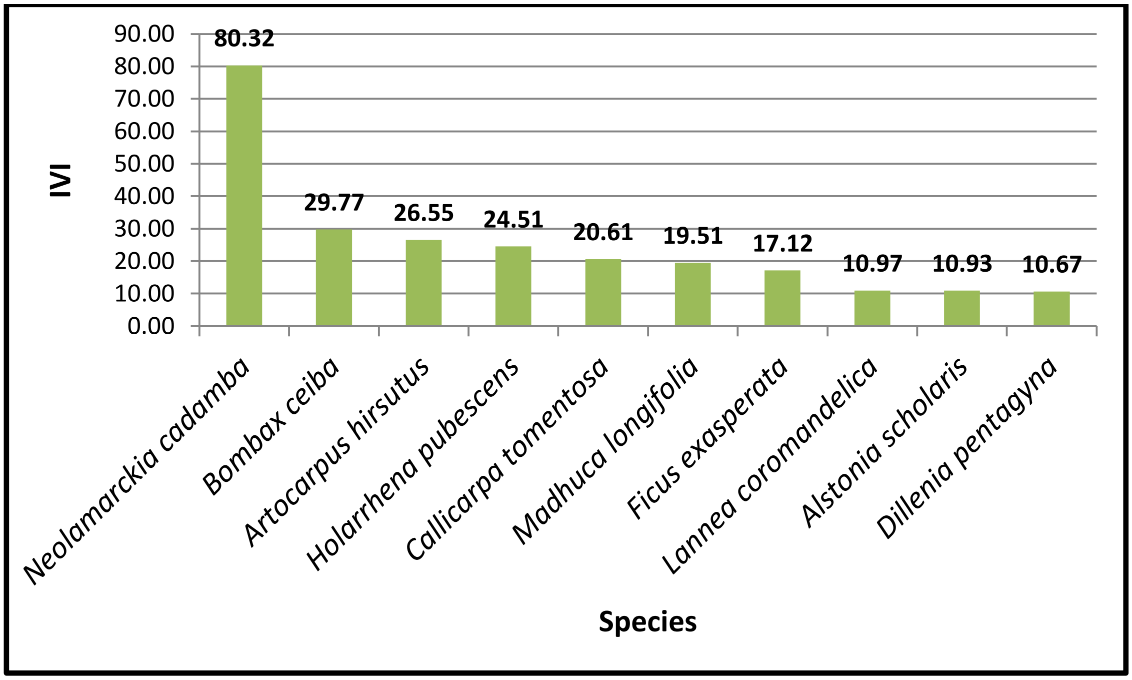

Figure 28. IVI of forest flood affected land use systems in plot size of 20 m x 20 m

Table 38 showed the data regarding abundance and frequency of tree species in plot size 20 m x 20 m in Forest non flooded condition. Total of 18 different species was recorded in 3 plot size of 20 m x 20 m. *Bauhinia malabarica* had the highest frequency (12.00). *Schleichera oleosa* and *Bauhinia malabarica* had the highest abundance (3). *Schleichera oleosa* had the highest IVI (38.99) and relative basal area (10.23). *Schleichera oleosa* and *Bauhinia malabarica* had the highest relative density (10.71). The second highest IVI was recorded for *Bauhinia malabarica* (38.35) followed by *Persea macrantha* (25.10) *Chukrasia tabularis* (24.59). Fig.29 presented the IVI of Forest non flooded land use systems in plot size of 20 m x 20 m.

Table 38. Abundance, frequency and species composition in forest non flooded of plot size 20 m x 20 m

Sl.no	Species	RD	RF	RBA	IVI	A
1	*Schleichera oleosa*	10.71	8.00	10.23	38.99	3
2	*Bauhinia malabarica*	10.71	12.00	7.89	38.35	3
3	*Persea macrantha*	7.14	8.00	5.02	25.10	2
4	*Chukrasia tabularis*	7.14	4.00	6.79	24.59	2
5	*Anogeissus latifolia*	7.14	8.00	2.35	19.80	2
6	*Hydnocarpus pentandra*	7.14	8.00	2.24	19.59	2
7	*Careya arborea*	7.14	8.00	1.27	17.66	2
8	*Spondias pinnata*	3.57	4.00	4.15	15.80	1
9	*Holarrhena pubescens*	7.14	4.00	1.84	14.79	2
10	*Dillenia pentagyna*	3.57	4.00	2.06	11.66	1
11	*Hymenodictyon orixense*	3.57	4.00	1.81	11.17	1
12	*Dalbergia latifolia*	3.57	4.00	1.35	10.24	1
13	*Diospyros melanoxylon*	3.57	4.00	1.33	10.20	1
14	*Aporosa lindleyana*	3.57	4.00	0.66	8.89	1
15	*Ficus tinctoria*	3.57	4.00	0.66	8.89	1
16	*Casearia tomentosa*	3.57	4.00	0.44	8.45	1
17	*Artocarpus hirsutus*	3.57	4.00	0.27	8.11	1
18	*Cinnamomum verum*	3.57	4.00	0.10	7.76	1

RD- Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI-Importance Value Index, A-abundance

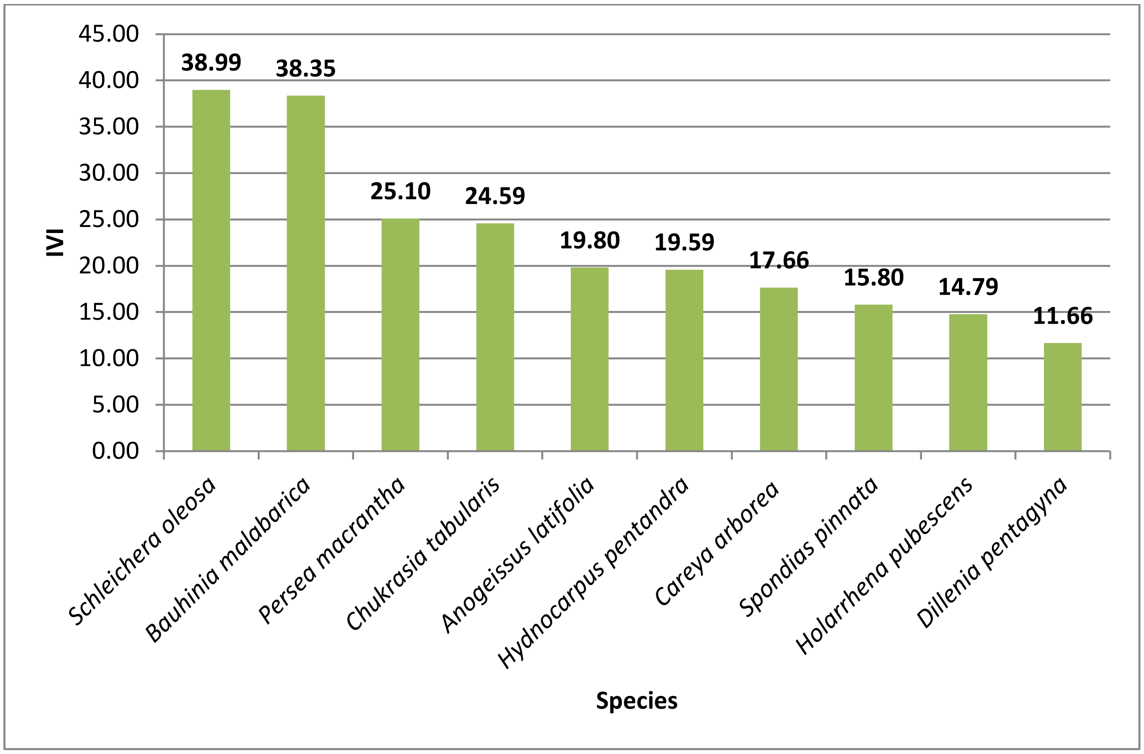

Figure 29. IVI of forest non flooded land use systems in plot size of 20 m x 20 m

Table 39 presented the data of abundance and frequency of tree species in plot size 20 m x 20 m in nutmeg flood affected condition. Total of 8 species was recorded in 3 plots. *Myristica fragrance* had the highest abundance (9.00) followed by *Areca catechu* (8.00). Highest Relative Frequency (18.76) was recorded for *Myristica fragrance* and *Artocarpus heterophyllus*. *Myristica fragrance* had the highest IVI (91.82) followed by *Mangifera indica* (54.11) and *Areca catechu* (45.18). Fig.30 showed the IVI of nutmeg flood affected land use systems in plot size of 20 m x 20 m.

Table 39. Abundance, frequency and species composition in nutmeg flood affected of plot size 20 m x 20 m

Sl.no	Species	RD	RF	RBA	IVI	A
1	*Myristica fragrance*	28.12	18.76	44.94	91.82	9.00
2	*Mangifera indica*	15.62	12.51	25.98	54.11	5.00
3	*Areca catechu*	25.00	12.51	7.67	45.18	8.00
4	*Tamarindus indica*	9.37	12.51	7.67	32.69	3.00
5	*Artocarpus heterophyllus*	9.37	18.76	10.81	30.14	*3.00*
6	*Tectona grandis*	6.25	12.51	2.00	23.45	2.00
7	*Phyllanthus embilica*	3.12	6.25	4.70	12.44	1.00
8	*Garuga pinnata*	3.12	6.25	3.06	10.23	1.00

RD- Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, A-abundance

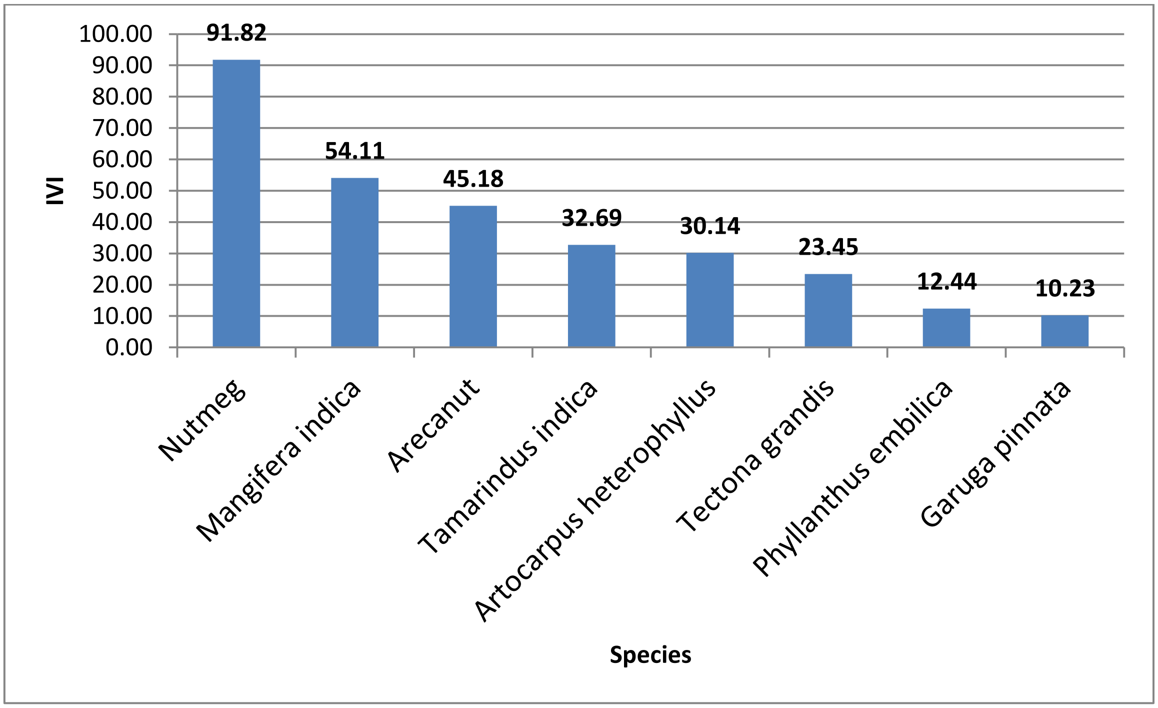

Figure 30. IVI of nutmeg flood affected land use systems in plot size of 20 m x 20 m

Table 40 presented the data of abundance and frequency of tree species in plot size 20 m x 20 m in Nutmeg non flooded condition. Total of 13 species was founded in 3 plots. *Myristica fragrance* had the highest abundance (12.00) followed by *Areca catechu* (7.00). Highest Relative Frequency (12.50) was recorded for *Myristica fragrance, Areca catechu* and *Glyricidia sepium. Myristica fragrance* had the highest IVI (97.13) followed by *Areca catechu* (44.37) and *Artocarpus heterophyllus* (23.93). Fig.31 showed the IVI of nutmeg non flooded land use systems in plot size of 20 m x 20 m.

Table 40. Abundance, frequency and Species composition in Nutmeg non flooded of plot size 20 m x 20 m

Sl.no	**Species**	**RD**	**RF**	**RBA**	**IVI**	**A**
1	*Myristica fragrance*	27.91	12.50	56.72	97.13	12.00
2	*Areca catechu*	16.28	12.50	15.59	44.37	7.00
3	*Artocarpus heterophyllus*	4.65	8.33	10.95	23.93	2.00
4	*Glyricidia sepium*	9.30	12.50	0.87	22.68	4.00
5	*Mangifera indica*	9.30	8.33	0.30	17.93	4.00
6	*Swietenia macrophylla*	6.98	8.33	1.39	16.70	3.00
7	*Artocarpus hirsutus*	6.98	8.33	0.35	15.66	3.00
8	*Pongamia pinnata*	4.65	4.17	5.23	14.05	*2.00*
9	*Garuga pinnata*	4.65	8.33	1.04	14.03	2.00
10	*Schleichera oleosa*	2.33	4.17	4.35	10.84	*1.00*
11	*Phyllanthus embilica*	2.33	4.17	1.91	8.40	1.00
12	*Cananga odorata*	2.33	4.17	1.29	7.78	1.00
13	*Annona squamosal*	2.33	4.17	0.03	6.52	1.00

RD- Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, A-abundance

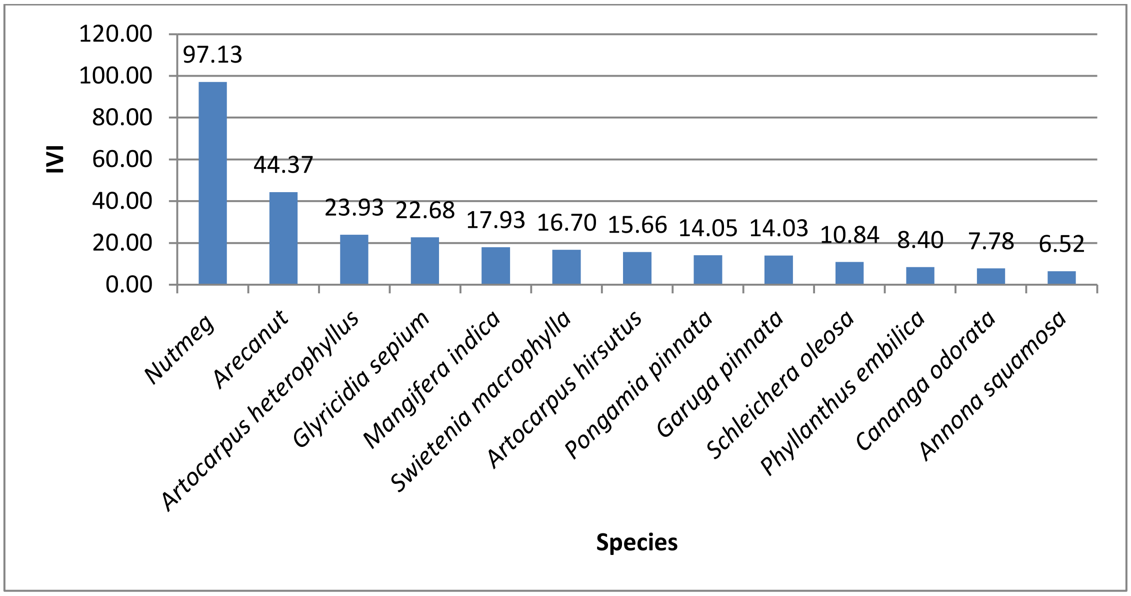

Figure 31. IVI of Nutmeg non flooded land use systems in plot size of 20 m x 20 m

Table 41 presented the data of abundance and frequency of tree species in plot size 20 m x 20 m in coconut flood affected condition. Total of six species were founded in 3 plots of size 20 m x 20 m. *Cocos nucifera* had the highest Abundance (20.00), Relative Frequency (30.03) Relative Basal Area (95.50) and IVI (190.05). *Glyricidia sepium* had the second highest abundance (6.00) followed by *Mangifera indica* (2.00). *Glyricidia sepium* and *Mangifera indica* had the second highest Relative Frequency (20.02). Fig.32 presented the IVI of coconut flood affected land use systems in plot size of 20 m x 20 m

Table 41 Abundance, frequency and species composition in coconut flood affected of plot size 20 m x 20 m

Sl.no	**Species**	**RD**	**RF**	**RBA**	**IVI**	**A**
1	*Cocus nucifera*	64.52	30.03	95.50	190.05	20
2	*Glyricidia sepium*	19.36	20.02	2.20	41.58	6
3	*Mangifera indica*	6.45	20.02	1.44	27.91	2
4	*Macaranga peltata*	3.23	10.01	0.41	13.64	1

Table 41. Continued

Sl.no	Species	RD	RF	RBA	IVI	A
5	*Zanthoxylum rhetsa*	3.23	10.01	0.38	13.62	1
6	*Psidium guajava*	3.23	10.01	0.07	13.31	1

RD- Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, A-abundance

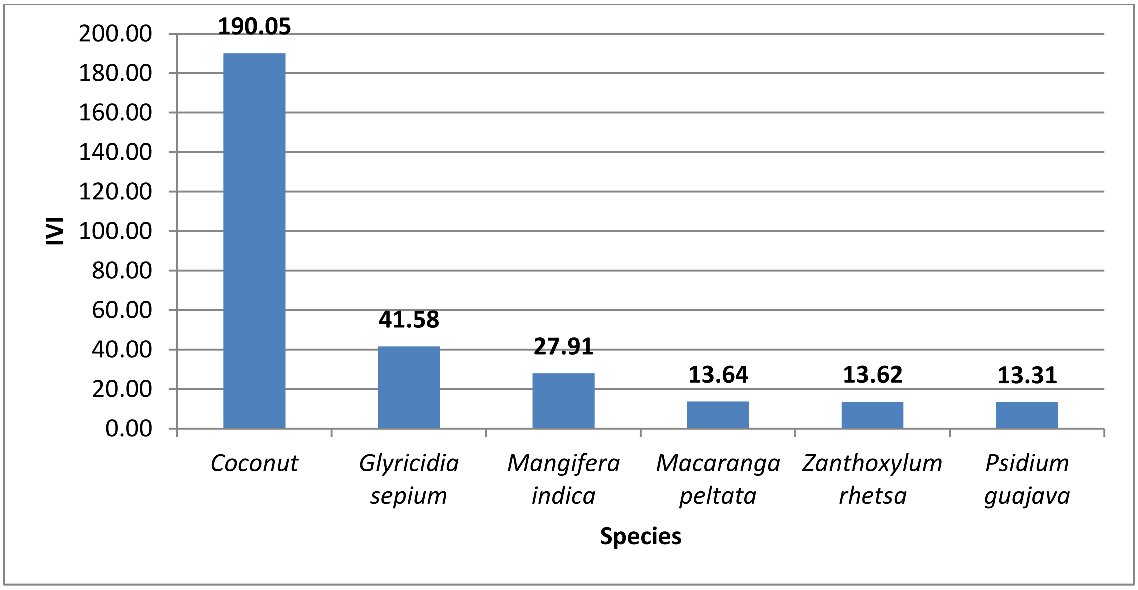

Figure 32. IVI of Coconut flood affected land use systems in plot size of 20 m x 20 m

Table 42 presented the data of abundance and frequency of tree species in plot size 20 m x 20 m in coconut non flooded condition. Total of 11 species was founded in 3 plots of size 20 m x 20 m. *Cocos nucifera* had the highest Abundance (17.00), Relative Frequency (17.64) Relative Basal Area (77.27) and IVI (134.26). *Areca catechu* had second highest Abundance (12.00). The second highest Relative Frequency (11.76) was recorded for *Areca catechu*, *Mangifera indica*, *Artocarpus heterophyllus* and *Glyricidia sepium*. Fig.33 presented the IVI of coconut non flooded land use systems in plot size of 20 m x 20 m

Table 42. Abundance, frequency and species composition in coconut non flooded of plot size 20 m x 20 m

Sl.no	**Species**	**RD**	**RF**	**RBA**	**IVI**	**A**
1	*Cocus nucifera*	39.35	17.64	77.27	134.26	17
2	*Areca catechu*	27.78	11.76	10.57	50.10	12
3	*Mangifera indica*	9.26	11.76	4.74	25.76	4
4	*Artocarpus heterophyllus*	4.63	11.76	4.05	20.43	2
5	*Glyricidia sepium*	4.63	11.76	0.17	16.55	2
6	*Tectona grandis*	4.63	5.88	0.98	11.49	2
7	*Artocarpus hirsutus*	2.31	5.88	0.89	9.08	1
8	*Zanthoxylym rhetsa*	2.31	5.88	0.67	8.86	1
9	*Cananga odorata*	2.31	5.88	0.25	8.45	1
10	*Phyllanthus embilica*	2.31	5.88	0.24	8.43	1
11	*Cassia fistula*	2.31	5.88	0.19	8.39	1

RD- Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, A-abundance

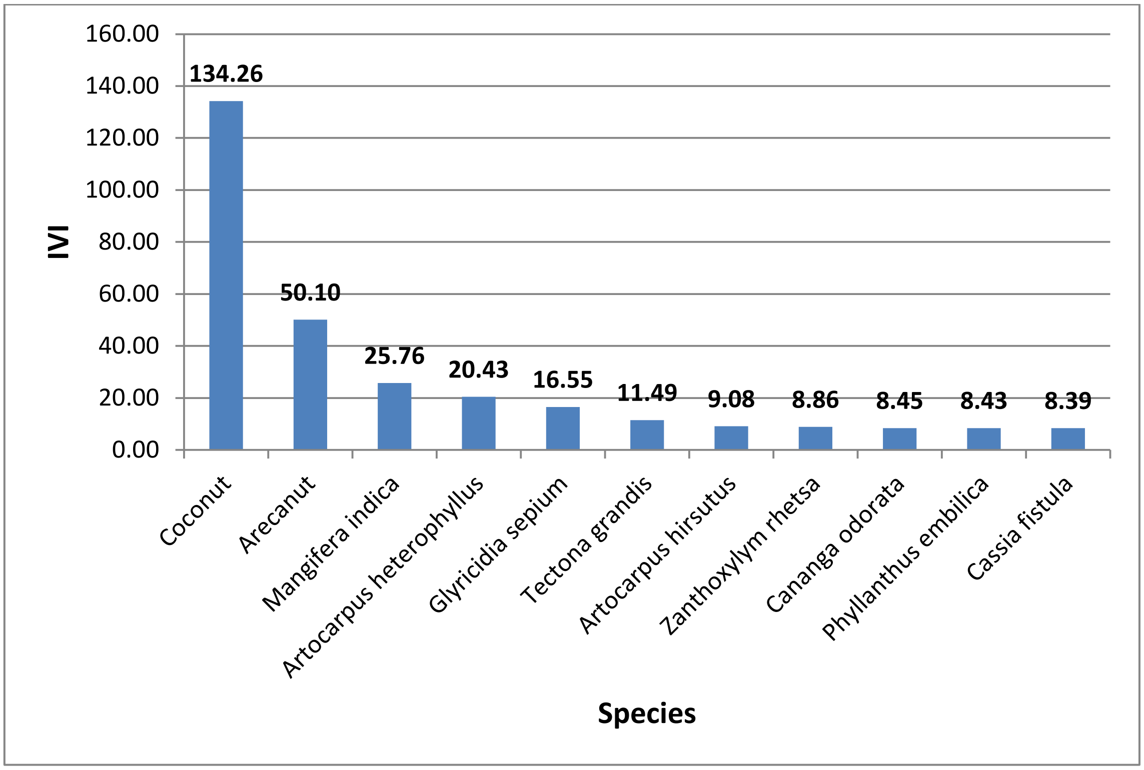

Figure 33. IVI of Coconut non flooded land use systems in plot size of 20 m x 20 m

DISCUSSION

The results obtained in this study aimed at assessing the changes in physical, chemical, and biological properties in the flood affected soils under five major tree based land use systems with reference to related research works and available literature in these lines are discussed in this chapter.

5.1 IMPACT OF FLOOD ON SOIL PROPERTIES

5.1.1 Impact of flood on physical properties of soil in different land use systems

5.1.1.1 Bulk Density and Porosity

Impact of bulk density showed a higher difference only in tree less systems at the depth of 0-20 cm as showed in fig.34. That is in coconut and open land use systems (0.14g $cc^{-1}$and 0.03g cc^{-1} respectively). The other three tree dominating systems (forest, rubber and nutmeg) have showed a decrease (0.02g cc^{-1}, 0.08g $cc^{\mathbf{-1}}$ and 0.06g cc^{-1}) in bulk density and that too in small magnitude. Coconut and open land use systems showed a higher bulk density from non flooded condition. The effect of water on this parameter is intensified by increase in bulk density and/or the presence of small pores. Modification of these factors also affects the geometry of the pores, producing a decrease in macropores and an increase in micropores (Letey, 1985). The tree dominating systems were affected very less or might have recovered to the original situation within 6-7 months due to high resilience. Porosity impact is negative of that bulk density and plotted in Fig.35. Soil bulk density is intimately related to soil porosity, which is the volume of space within a soil filled with air and water. Chaudhari *et al.* (2013) found negative correlation between porosity and soil bulk density.

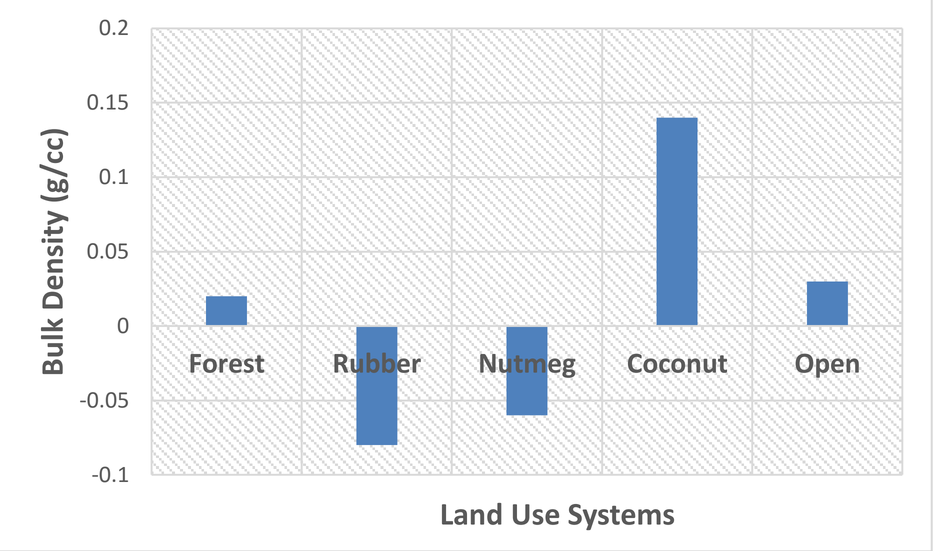

Figure 34.Changes in bulk density of different land use systems after flood

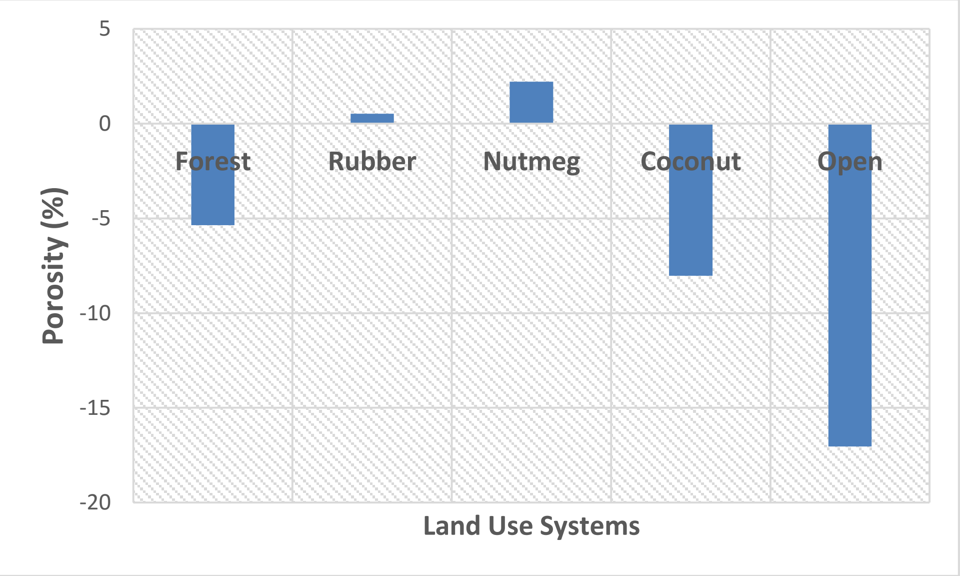

Figure 35.Changes in soil porosity of different land use systems after flood

5.1.1.2 Soil Texture

Soil texture showed a difference in forest, coconut and open land use systems at the depth of 0-20 cm. In forest, the sandy clay loam is changed to clay loam may be due to the deposition of more clay particles during flood. In coconut, it is changed to sandy clay loam from loamy sand and in control 1, it is changed to silt clay loam from loamy sand. This may be due to the deposition of sand, silt and clay from the sediments from flood, since control 1 is located to the banks of river, it probably brought silt.

5.1.2Impact of flood on chemical properties of soil in different land use systems

5.1.2.1 Soil pH

Soil pH showed a greater significant decrease in coconut flood affected from coconut non flooded (6.28 to 4.94) at a depth of 0-20 cm as showed in fig.36. This may be due to lowest OC or in active iron (easily reducible) or in high acid reserves of soil. Acid soils low in organic matter or in active iron slowly attains pH values which are less than 6.5. The decrease in pH shortly after submergence is probably due to the accumulation of CO_2 produced by respiration of aerobic bacteria, because CO_2 depresses the pH even of acid soils (Nicol and Turner, 1957). Other land use systems also showed significant difference but magnitude of change is negligible.

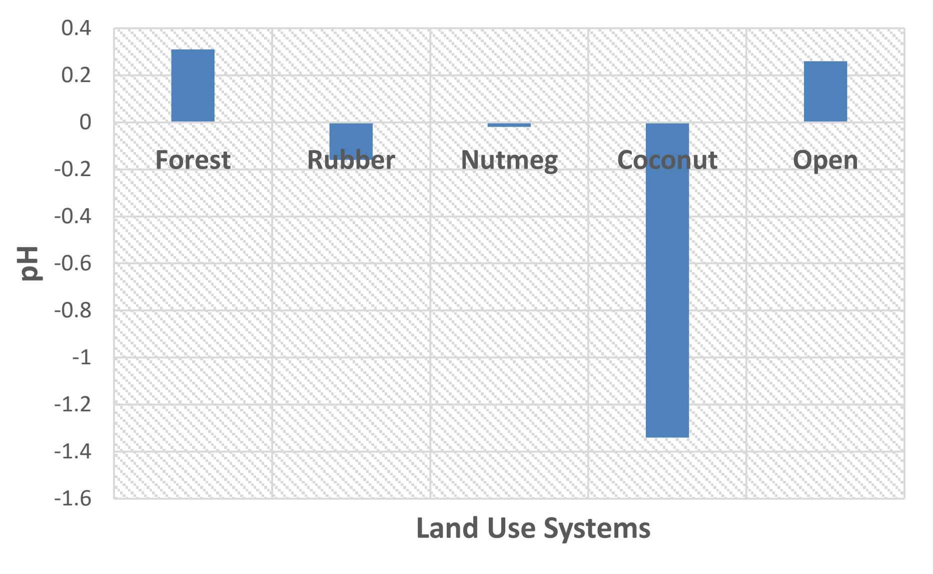

Figure 36. Change in soil pH of different land use systems after flood

5.1.2.2 Soil EC

Soil EC of the solutions of most soils increases after submergence, attains a maximum, and declines to a fairly stable value, which varies with the soil (Ponnamperuma, 1984). The changes in conductance reflect the balance between reactions that produce ions and those that inactivate them or replace them with slower moving ions. Fig. 37 showed the change in EC after flood in each land use systems. Here a significant decrease of EC was seen in case of rubber, coconut and open land use systems (0.9dS m^{-1}, 0.8 dS m^{-1}, and0.37dS m^{-1}respectively) at a depth of 0-20 cm. Rubber plantation showed a decrease (0.9dS m^{-1}) may be due to the impact from low pH, which decrease the availability of highly mobile H+ ion can be seen from Table 5. In coconut plantation, decrease may be due to decrease in pH as well as in Calcium as showed in Tables 5 and 11, respectively. In open land use systems (control 1) showed a decrease and it may be due to decrease in iron (5.43mg kg^{-1}), manganese (19.39mg kg^{-1}**)** and calcium (117.7mg kg^{-1}) accumulation as showed in Tables 14, 15 and 11, respectively. Other two land use systems (forest and nutmeg) may be also affected with flood in EC in the earlier period, may be these land use systems may cop up with the situation later, since soil sample was collected seven months after the flood.

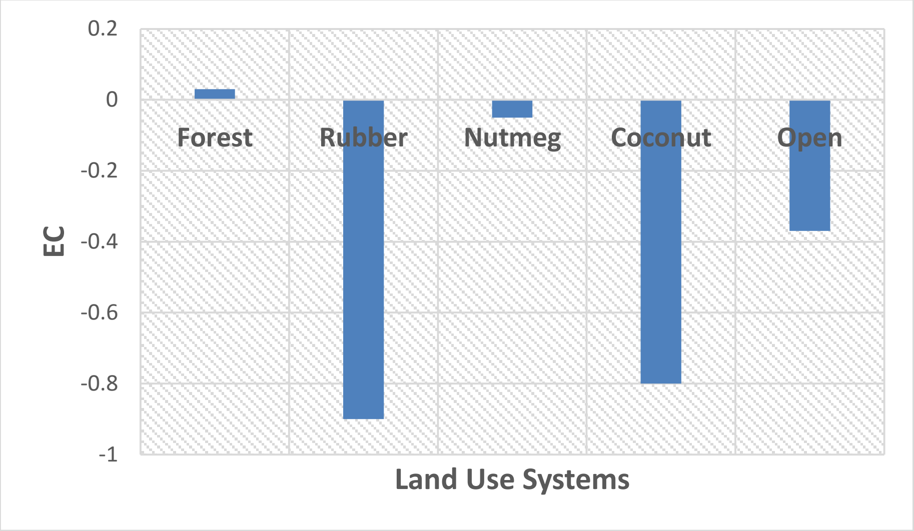

Figure 37. Change in soil EC of different land use systems after flood

5.1.2.3 Organic carbon

Organic carbon (OC) is important because it supports vegetation growth and is directly related to the organic matter content. Organic matter is one of the major sources of soil fertility particularly for nitrogen and phosphorous (Tesfai, 2001). In the present study, OC results showed a significant difference between all the five land use systems studied under their flood affected and non floodedcondition at the soil depth of 0-20 cm. That is there is a difference (increase or decrease) in OC due to flood occurrence. Fig. 38 showed the change in OC after flood in each land use systems. Forest, rubber and nutmeg plantation showed a higher amount of OC (0.22%, 0.77 & 0.45% increase respectively) after flood while other two (coconut plantation and open) land use systems showed a decrease in OC (1.25% and 0.74% decrease respectively) in comparison with the respective non floodedcondition. Since Forest, rubber and nutmeg plantations are intense tree dominating systems, the flowing water is failed to carry away the sediments in the soil instead they got deposited the silt in these soil leading to a higher OC content or the wide spreading tree root networkmight have physically arrested the possible loss of organic matter during flood. Both Simpson’s and Shannon Wiener index had a higher value for both forest and nutmeg plantation land use systems. It indicates a high diversity as well as the tree dominance in these systems. In rubber plantation which is well managed with close canopy and without any disturbance might have caused an increase in silt deposition from the river, which increased OC of the soil; while coconut plantations are with less tree cover and wider spacing leads a washing away of soil sediments and thus by existing OC from flood affected condition. Similarly, open land use systems (control) without any tree cover also caused a higher decrease in OC from the flood affected soil. Also under normal condition or non flooded condition, OC is higher for Forest (2.3%) as expected. The higher initial content of organic matter in coconut plantation (2.2%) may be due to high inputs of organic matter as part of the management of coconut plantation.

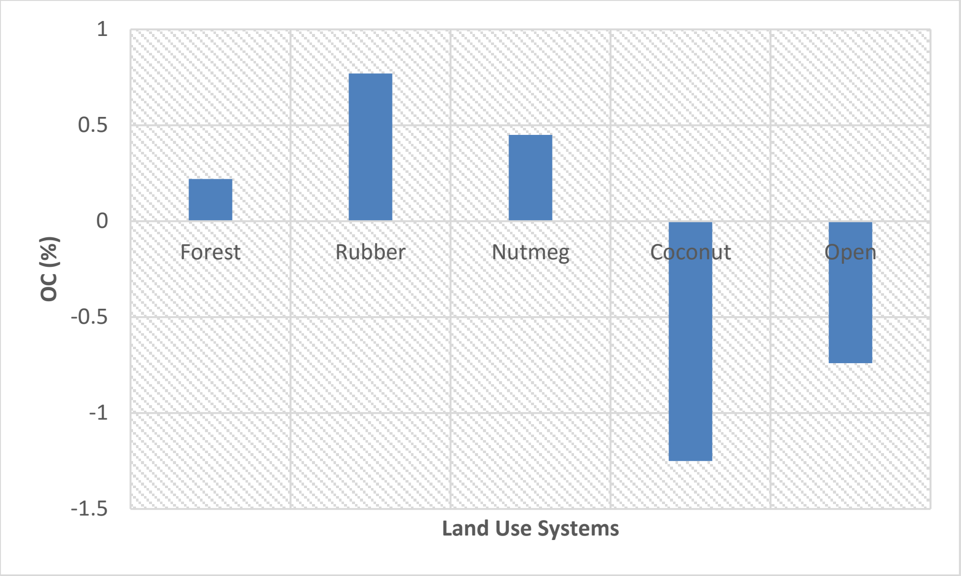

Figure 38. Change in OC of different land use systems after flood

With respect to the differential soil depths, forest showed a nearly same range of organic carbon values over five different soil depth layers up to one meter depth while in all other land use systems it varied significantly. This could be attributed to the addition of silt noticed at higher depths in the forest condition. The changes in OC in control 1 however was very irregular and an inconspicuous trend from top layer to the bottom layer. This may be due to the easiness and vulnerability of this system to various elluvial and illuvial types of soil deposition of this open land from and out of higher elevation near to the river bank under flood affected situation. In non flooded condition, all the five land use systems showed a similar trend in OC from top to bottom layer. That is a higher OC in the surface layer with a gradual decreasing trend from top layer to bottom layer.

5.1.2.4 Available Nitrogen

Available nitrogen has increased significantly in forest flood affected from forest non flooded condition in the top layer (0-20 cm). While in rubber, nutmeg, and open land use systems, a significant decrease from non flooded condition as showed in fig.39. Also coconut is non-significant in the top layer. Forest flood affected condition showed a higher content of available nitrogen in the top two depths (84 kg ha^{-1} and 98 kg ha^{-1} increase, respectively). This can be viewed and better related to its texture change from sandy clay loam to fine textured soil or clay loam as presented in Table 4. The data of dehydrogenase activity and microbial biomass carbon in tables 22 and 23, respectively, showed that higher dehydrogenase activities as well as microbial biomass carbon were founded forest flood affected condition (11.17 μg TPF g^{-1} 24 hr^{-1} and 9.67μg g^{-1} increases, respectively). These factors may be behind the higher nitrogen content in forest flood affected than forest non flooded condition. The Rubber, nutmeg and open land use systems shows a decrease in available N (201.6 kg ha^{-1},107.1 kg ha^{-1} and 207.9 kg ha^{-1}, respectively). This may be due to the anaerobic situation created by the flood loss of N from the soil or a shift in the type of inorganic-N found in the soil with inundation has been reported in other studies. For instance, Lockaby *et al.* (1996) reported a general loss of N under flooding treatments; the greatest loss of N occurred under continuous flooding for 3 months, however, all flood treatments resulted in a loss of N relative to the control. Under anaerobic conditions, three main N transformations occur: (i) ammonification (the conversion of organic N into NH4–N), (ii) nitrate reduction (conversion of NO3–N into NH4–N), or (iii) denitrification (conversion of NO3–N into N2). Therefore, under flooded conditions, NH4–N is being produced (ammonification and nitrate reduction) while NO3–N is being lost (nitrate reduction anddenitrification). Nitrate is a mobile form of N and thus it can also be leached from the system under flooded conditions. Ponnamperuma (1984) reported that under hypoxia, denitrification was the main cause of the depletion of nitrate.

From top to bottom layer, available N showed a significant difference in all land use systems except in nutmeg flood affected and coconut flood affected. This may be due to irregular deposition of soil sediments from top to bottom.

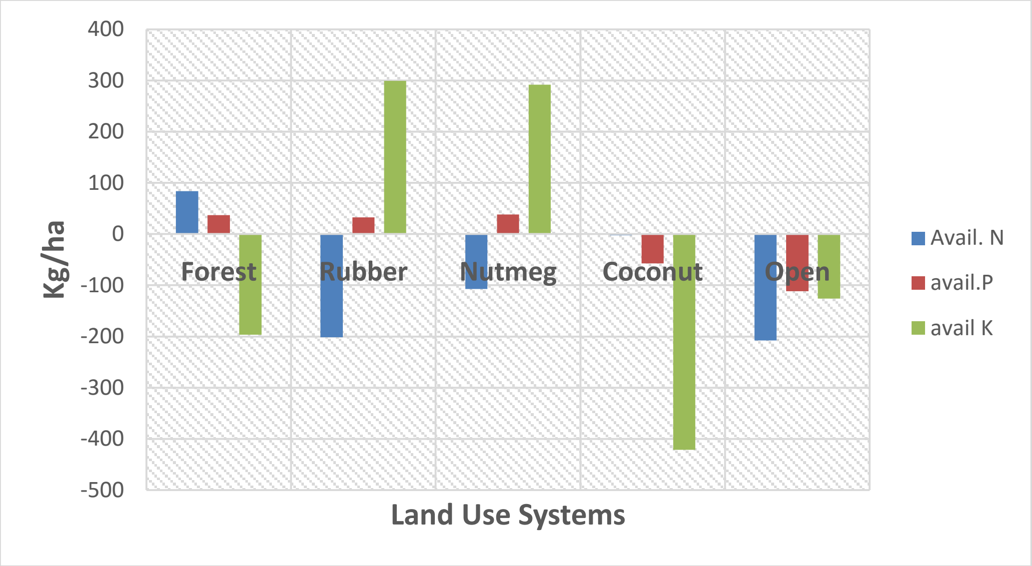

Figure 39. Change in available NPK of different land use systems after flood

5.1.2.5 Available Phosphorus

Available Phosphorous has shown similar trend as organic carbon in the top layer (0-20 cm) of the soil as figured in fig. 39. That is, it showed as significant increase in forest, rubber and nutmeg land use systems (36.85 kg ha^{-1}, 32.6 kg ha^{-1}, 38.42 kg ha^{-1} respectively) under flood affected condition. Also, coconut and open land use systems showed a significant decrease (57.2 kg ha^{-1}, 111.52 kg ha^{-1} respectively) in available phosphorus. Based on some reports, organic matter in the soil can increase soil phosphorous availability through its effect on soil biological activity and phosphorous adsorption capacity of the soil (Palm *et al.*, 1996). This would be the reason behind a higher significant value as well as lower significant value. Also the solubility of Fe oxides should be reason for higher and lower significant value in flood affected soils. Results of Fe are showed in Table 14 also showed a similar trend as available P. Several authors support this condition. The amount of P released to the soil solution depends on soil characteristics involved in the reduction process (abundance of Fe oxides, their crystalinity, and the soil organic-matter (SOM) content), and the degree of soil saturation with P. Organic matter (OM) favors reduction as it is the main electron donor (Scalenghe *et al.*, 2002). Organic C may enhance the release of P because it acts as the main electron donor favouring soil reduction and because its oxidation may produce some organic-P release. In a soil under reducing conditions, Scalenghe *et al.* (2002) observed that P release to solution was related to soil OC, amorphous Al, and the Fe-crystallinity ratio. Open non flooded land use systems showed highest available phosphorus content in the first two top depths (204.55 kg ha^{-1} and132.42 kg ha^{-1}respectively). This may be due to absence of tree component for efficient use of nutrients. The rubber and nutmeg showed a higher value (164.09 kg ha^{-1} and 167.59 kg ha^{-1}respectively). This may be due to the addition of fertilizers in these fields.

From top depth to bottom depth it showed significant difference in all cases except in coconut flood affected system. This may be due to irregular deposition and washing away of sediments in the system.

5.1.2.6 Available potassium

The original source of K in soils is from weathering of rocks containing K-bearing minerals. Available potassium has showed significant decrease in forest, coconut and open land use systems (196.6 kg ha^{-1}, 421.5 kg ha^{-1}, and 125.8 kg ha^{-1} respectively) under flood affected condition from non flooded condition at the depth of 0-20 cm as showed in Fig.39. This was explained by its texture change from sandy clay loam to clay loam in forest, from loamy sand to sandy clay loam in coconut and from loamy sand to silt clay loam in open land use systems. Studies show that, larger K losses were found from the clay than from the sand or loam soils. Coconut shows a higher loss (421.5 kg ha^{-1}) in K which may be due to its texture change from loamy sandy to sandy clay loam. This probably resulted from leaching by preferential flow at the beginning of the drainage season in the clay soil (Hallsworth series). Potassium ion is small and can be easily trapped inside cervices within the clay particles. And significant increase was recorded in rubber and nutmeg plantations (299.4 kg ha^{-1}and 292 kg ha^{-1}, respectively) in flood affected condition. This may be due to either fertilizer application or nature of parent material. Igwe *et al.* (2008) studied some soils on the flood plain of river Niger and concluded that some factors like mineralogy, leaching, CEC, particle size distribution, and phosphate compounds affect K forms distribution.

5.1.2.7 Calcium and magnesium

Calcium and magnesium data also showed a significant difference in coconut plantation and nutmeg plantation. In coconut plantation Ca & Mg showed (Fig. 40) a significant decrease (1840.6mg kg^{-1}and 131.4mg kg^{-1}) due to inundation compared with non flooded condition. This may be due to the leaching and dilution to the lower depth, it is evident from the Tables 11 and 12, respectively. Another factor could lead to the less Ca & Mg content may be the lesser OC content of this land use systems as showed in Table 7. Under anaerobic conditions, the rate of decomposition of organic matter declines, resulting in low soil nutrient content (Gallardo, 2003). Even though Control treatments didn't show any significant difference, a decrease has been found from Control 2. Also leaching and dilution to the lower depth is also evident from Tables 11 and 12. Day (1982) reported that it could be expected that during a high flood more soil nutrients dissolve in water and are lost through leaching as water infiltrates the soil. But nutmeg plantation showed a significant increase from non floodedcondition at the depth of 0-20 cm may be due to the increased organic carbon decomposition as showed in Table 7. Tsheboeng *et al.* (2014) reported that high K, Mg, Na and pH after high floods could be attributed to increased organic matter decomposition rates, evapotranspiration and lateral flow deposition.

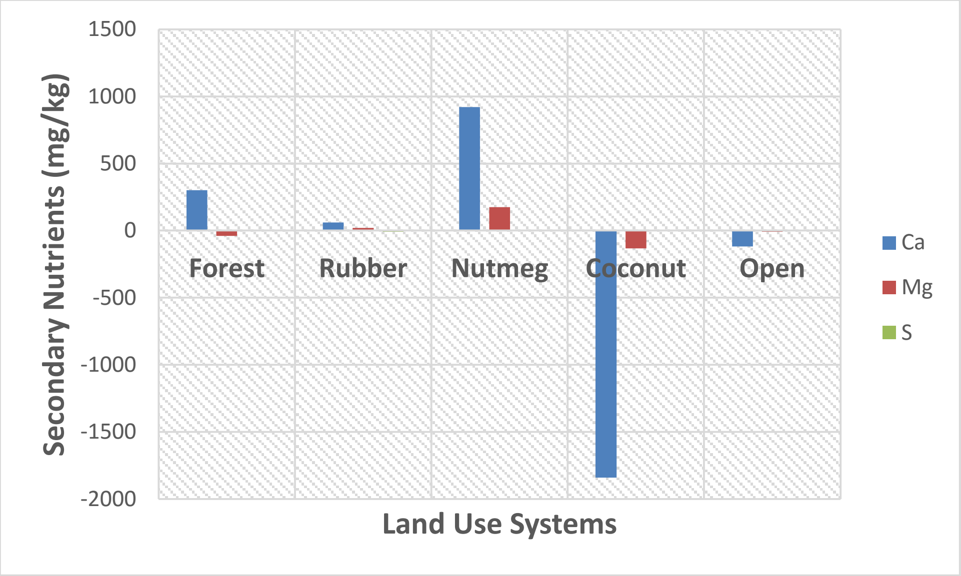

Figure 40. Change in secondary nutrients of different land use systems after flood

5.1.2.8 Sulphur

Sulphur showed a significant decrease in rubber plantation (7.744mg kg^{-1}) only at the depth of 0-20 cm as figured in Fig. 40. This may be due to the reduction of SO_4^{2-} as reported by other studies In anaerobic media, the main changes are the reduction of SO_4^{2-} to sulfide and the dissimilation of the amino acids, cysteine, cystine, and methionine (derived from the hydrolysis of proteins) to H, S, thiols, ammonia, and fatty acids (Barker, 1961; Freney, 1967). Open land use systems didn't showed any significant difference. This may be due to irregular deposition in different depths.

5.1.2.9 Iron

Iron showed a significant difference in forest and open (4.49 mg kg^{-1}, 5.43 mg kg^{-1} respectively) condition only at the depth of 0-20 cm (Fig. 41). In Forest, it showed a significant increase in Iron due to the reduction of Fe (III). The most important chemical change that takes place when a soil is submerged is the reduction of iron and the accompanying increase in its solubility (Ponnamperuma, 1984). Soils high in organic matter but low in iron give high concentrations that persist for several months. (Ponnamperuma, 1984). The reduction of iron is a consequence of the anaerobic metabolism of bacteria and appears to be chiefly a chemical reduction by bacterial metabolites (Bloomfield, 1951). The kinetics of iron (II) follows a roughly asymptotic course (Takai *et al.*, 1963; IRRI, 1964). Five to 50% of the free iron oxides present in a soil may be reduced within a few weeks of submergence depending on the temperature, the organic matter content, and the crystallinity of the oxides. The lower the degree of crystallinity, the higher is the reduction percentage (Asami, 1970). In open land use systems (control 1) data showed a significant decrease in iron concentration.This may be due to poor microbial growth as well as root activity.

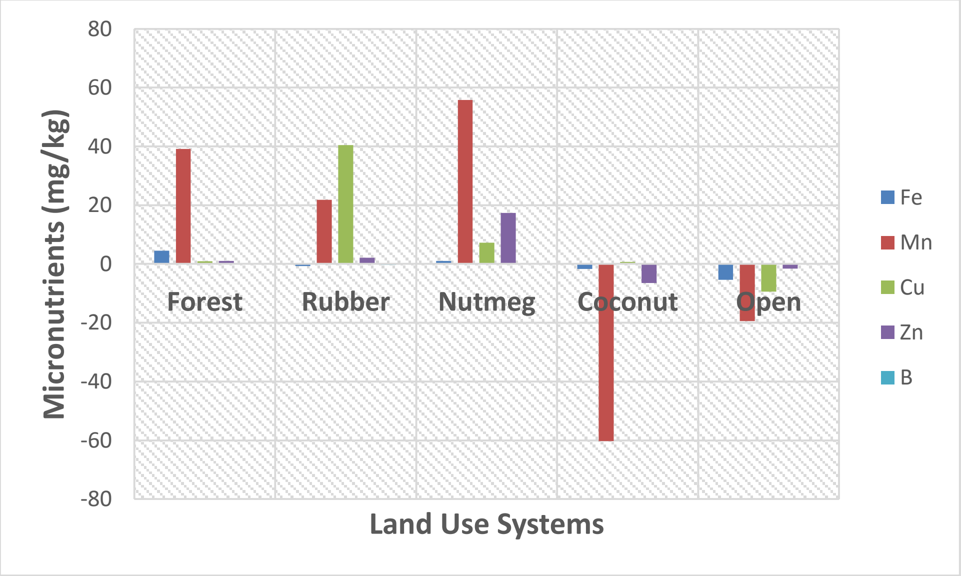

Figure 41. Change in micronutrients of different land use systems after flood

5.1.2.10 Manganese

Manganese showing a significant difference in all land use systems at the depth 0-20 cm. Forest, rubber and nutmeg land use systems showed a significant increase (39.14 mg kg^{-1}, 21.78 mg kg^{-1}, 55.79 mg kg^{-1}respectively) in manganese from non flooded condition (Fig.41). This may be due to the reduction of Mn (IV) to

Mn (II). The main transformations of manganese in submerged soils are the reduction of Mn (IV) oxides to Mn (II), an increase in the concentration of water-soluble Mn^{2+}, precipitation of manganese carbonate, and reoxidation of Mn^{2+} diffusing or moving by mass flow to oxygenated interfaces in the soil. In coconut and open (control 1) showed a significant decrease (60.22 mg kg^{-1}, 19.39 mg kg^{-1}) from non flooded condition may be due to the decrease in organic matter as showed in table 7. Within 1-3 weeks of flooding, almost all the EDTA-dithionate extractable manganese present in soils, except those low in organic matter, is reduced (IRRI, 1964).

5.1.2.11 Copper& Zinc

Fig. 41 showed the change in copper concentration in soil after flood in five land use systems. Rubber and nutmeg showed a significant increase (40.46 mg $kg^{-1}$and 7.29 mg kg^{-1}) in copper content of soil at the depth of 0-20 cm. This may be due to the reduction of Mn (IV) as shown in the Table 16. Also open land use systems (control 1) showed a significant decrease (9.39 mg kg^{-1}) in copper content may be due to loss reduction of Mn (IV) and Fe (II1) as shown in Tables 15 and 14, respectively. However, forest also showed an increase reduction in Mn (IV), but not showed any significant increase may be due to its cop up ability of Forest. Coconut plantation showed no significant difference even though it showed a higher magnitude of lesser solubility of Mn (IV) as showed in Table 15. This may be due to the decrease in pH would mask its effect as shown in Table 5. Although the forms of boron, cobalt, copper, molybdenum, and zinc present in soils are probably not involved in oxidation-reduction reactions, their mobility may be affected by some of the consequences of soil submergence. Thus the reduction of the hydrous oxides of Fe (III) and Mn (IV) and the production of organic complexing agents should increase the solubility of Co, Cu, and Zn**.** The increase in pH of acid soils and the formation of sulfides should lower their solubility. The net result of soil submergence is to increase the availability of Co and Cu (Mitchell, 1964; Adams and Honeysett, 1964) and of Mo (Jenne, 1968) and to depress that of zinc (IRRI, 1970).

Zinc also showed a similar result as copper except in forest and coconut plantation the depth of 0-20 cm as figured in Fig.41. The same reason would hold for the Zn also in all land use systems. Here forest, rubber and nutmeg showed a significant increase (1.07 mg kg^{-1}, 2.13 mg kg^{-1}and17.32 mg kg^{-1} respectively) in Zn from non flooded condition. This may be due to the higher reduction of Mn (IV) as stated above paragraph. Coconut and open (control 1) land use systems showed a significant decrease (6.44 mg kg^{-1}and 1.53 mg kg^{-1} respectively) non flooded condition. In coconut plantation this may be due to the lesser reduction Mn (IV) as showed in Table 15. In control 1 situation, decrease may be due to the lesser reduction of both Fe (III) and Mn (IV) as showed in Tables 14 and 15, respectively.

5.1.2.12 Boron

In rubber plantation only, boron showed a significant decrease (0.278mg/ kg) at the depth of 0- 20 cm (Fig. 41). Generally flooding will not affect the boron concentration in Soil. Here it was showing difference may be due to leaching. Since leaching of boron was found in all flood affected conditions. Also, rubber showed only minimal difference. So, generally boron concentration will not be affected by the flood.

5.1.3 Impact of flood on soil biological properties

5.1.3.1 Microbial count

Bacteria are typically most numerous in surface layers that are rich in organic material or in the rhizosphere where plant roots release sugars, amino acids and other organic compounds. In addition, mycorrhizae are associated with plant roots that will likewise be concentrated in the upper soil layers.

In non flooded condition, bacterial count showed higher in nutmeg and coconut plantation. This may be due to their higher pH as well as higher OC, avail. N, avail K as mentioned in Tables 5, 7, 8 and 9, respectively. Minimum bacterial count was showed by open land may be due to low content of Mn (48.86 mg kg^{-1}) and Zn (3.69 mg kg^{-1}) as mentioned in Tables 15 and 17, respectively. Fungal count in non flooded condition, maximum was recorded in rubber plantation. This may be due to its higher acidic pH (4.46) and lower OC (1.97 %), avail. P (131.49kg ha^{-1}), avail. K (169.1 kg ha^{-1}) as mentioned in table 5, table 6, table 7, table 9 and table 10 respectively. Minimum fungal count was founded in forest may be due to its higher OC content (2.30%) and higher available potassium (566.2 kg ha^{-1}) content as mentioned in Tables 7 and 10, respectively. Actinomycetes count in non flooded condition showed maximum in open land may be due to its lower Ca content (397.7 mg kg^{-1}) and low Mn (48.86 mg kg^{-1}) content as mentioned in table 11 and table 15 respectively. And minimum was recorded in nutmeg plantation may be due to its higher pH (5.95), organic carbon content (1.56 %), avail. K (537.2 kg ha^{-1}) as mentioned in Tables 5, 7 and 10, respectively.

Bacterial count in flood affected condition, maximum was recorded in nutmeg plantation. This may be due to its higher pH, OC, avail. P, avail. K as mentioned in Tables 5, 7, 9 and 10, respectively. Fungal count in flood affected condition followed same trend as in non floodedcondition. Also actionmycetes count in flood affected condition followed the same trend as in non flooded condition.

In the present study we did not find a significance difference between flood affected and non flooded in any of the land use systems. This may be due to the effect of time of soil sample collected, as it was collected seven months after the flood occurrence. There may be initial change in the microbial count only at the beginning. May be at a later stage, the upper vegetation and all neutralized the effect of flooding after seven months or another possibility was laid here that, there may be a decrease in the count of aerobic bacteria which would be neutralized by the increase in the no. of anaerobic bacteria after the flood.

5.1.3.2 Dehydrogenase Activity

Dehydrogenase activity shown a significant increase between open flood affected/control 1 condition (33.98 μg TPF g^{-1} 24 hr^{-1}) and open non flooded condition /control 2 (17.63 μgTPF g^{-1} 24 hr^{-1}). Other land use systems also may be showed a significant difference in dehydrogenase activity between flood affected and non flooded condition as open land use systems. But may be other land use systems may be neutralized or masked the flood affected impact over the time because of the tree component. A significant increase in open land use systems may be due to rise in pH. Also dehydrogenase activity showed a significant decrease. In open land use systems having non flooded condition with all other four land use systems having non flooded condition. This may be due to the tree component present in all other four land use systems which might have enhanced the dehydrogenase activity. The dehydrogenase activity decreased in the following order: sacred grove > alder planation > fern-dominated site > 16-year-old regrowth > 13-year-old regrowth > jhum fallow > 7-year-old regrowth > grassland (Arunachalam and Arunachalam, 1999). This could be attributed to increasing plant cover which produced a greater amount of litter that was ultimately incorporated into the soil (Maithani *et al.*, 1998), thus improving the soil nutrient pool in the ecosystem.

5.1.3.3 Microbial Biomass Carbon (MBC)

MBC showed an increase in forest (9.67 μg g^{-1}), rubber (64.48 μg g^{-1}) and nutmeg (25.89μg g^{-1}) from non-flood affected. Coconut and open land use systems showed a decrease (90.98 μg g^{-1} and 121.44 μg g^{-1} respectively) in MBC from non flooded condition (Fig. 42). This increase as well as decrease may be due increase and decrease of OC of each land use systems as shown in Table 7 at the depth of 0-20 cm. Studies shows that OC is directly related to MBC.Water-soluble organic carbon in the soil solution is then consumed by microbes in-so-far-as nitrogen is available to combine with the carbon to build microbial biomass. Alternatively, the water-soluble organic carbon will be exported from the ecosystem via surface waters or groundwater if nitrogen availability is not sufficient to meet local demand for microbe growth (Aitkenhead and Mcdowell, 2000).

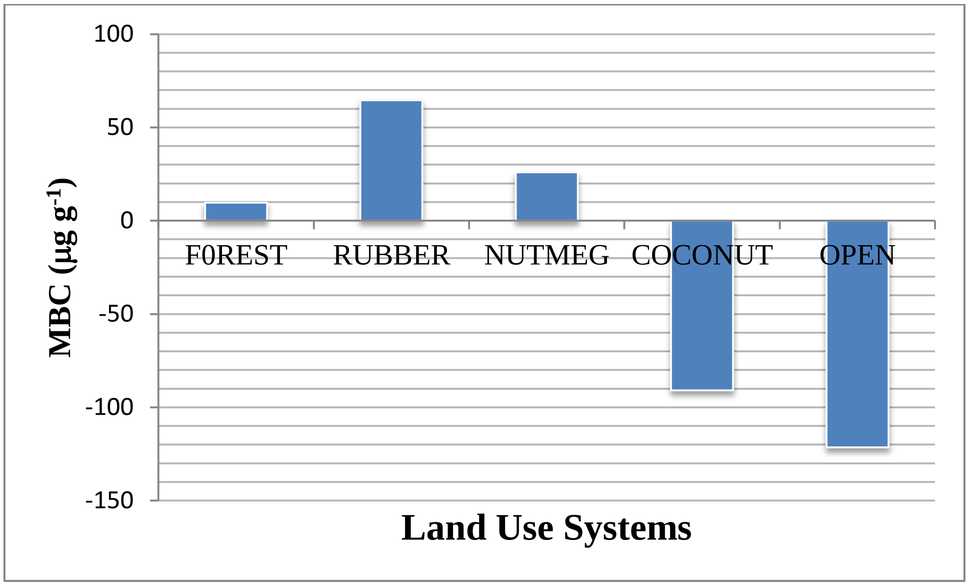

Figure 42. Change in MBC of different land use systems after flood

5.2 SOIL SEED BANK

Flood didn't make any serious impact on any of the land use systems with respect to land use systems. In fact we can't saythat different in species could be from the impact of flood since seed bank were collected after 7 months of flood. According to many authors flood have impact on seed bank where herbaceous species dominated after flood. Among all life forms, herbs (annual and perennial) had the highest richness and abundance in PF, reflecting a tendency for these species to respond positively to flooding (Capon & Brock, 2006; Capon, 2007), and highlights the importance of the seed bank of such species for post-flood recovery of vegetation (Middleton 2003; Hölzel & Otte 2004; Lu *et al*., 2010). But here we couldn't find a tree species in non flooded condition also. This may be due to the dormancy of the tree seeds in the two seasons in non flooded condition or it may not contain any tree seeds especially in forest condition. In all other systems herbaceous species got higher seed density may be due to its easiness of germination and seed dispersal and of minute seed size and easy establishment, since we got most of them as a weed in land use systems.

5.3 IMPACT OF FLOOD ON VEGETATION

5.3.1 Floristic diversity

5.3.1.1 Tree diversity in plot size

Flooding did not shown any vivid impact on the tree diversity, even though they showed a difference in diversity indices. This may be due to short flood duration and low intensity in present study comparing to other studies, which may not be enough to affect the higher vegetation like trees.

5.3.1.2 Shrub diversity in plot size

Shrub diversity was recorded to be decreased in flood affected land use systems. This may be due to the death of shrubs during flood or may be due to difference in specific upperstorey vegetation and soil characteristics.

5.3.1.3 Herb diversity in plot size

Herb diversity was increased in open flood affected condition only. This may be due to the deposition of flood water into the system. Other four land use systems showed a decrease in diversity indices (both Simpsons and Shannon) may be due to the flooding intensity may affected its survival and may be flood would washed away some seeds with water and soil.

SUMMARY

The salient results of the study entitled "Soil and vegetation characteristics in the post flood scenario in selected tree based land use systems in Thrissur, Kerala'' are presented in a detailed manner in previous chapters. The soil samples were collected from five major land use systems and carried outthe soil and vegetation analysis in the college of Forestry, Thrissur. The key findings of the present study are summarized as below;

6.1 IMPACT OF FLOOD ON SOIL PROPERTIES

6.1.1 Impact of flood on soil physical properties

1. Generally the porosity had an inverse trend of bulk density. In this study also, we observed the reverse trend in soil porosity from above discussed bulk density. Forest flood affected (48.23%) has showed a decrease in porosity due to floodas compared to thenon flooded (53.60%) condition. Rubber and nutmeg flood affected also showed an increase (0.52% and 2.2%, respectively) in porosity due to flood as compared to the non flooded condition; whereas coconut and open flood affected system showed a decrease (8.03% and 17.04%, respectively) in porosity due to flood as compared to the non flooded condition.
2. The bulk density after flood was changed in all land use systems in the depth of 0- 20 cm. Forest showed a negligible increase (0.02 g cc^{-1}) in bulk density in flood affected condition from non flooded condition. Rubber and nutmeg flood affected condition had a decreased (0.08 g cc^{-1}and 0.06 g cc^{-1}respectively) bulk density due to flood; whereas coconut and open flood affected system showed an increase (0.14 g cc^{-1}and 0.03 g cc^{-1}, respectively) in bulk density due to flood as compared to non flooded condition
3. The soil texture had a change in forest, coconut and open land use systems due to flood. In forest, the sandy clay loam of non flooded system had

changed to clay loam texture in flood affected system. In coconut flood affected had a change from loamy texture to sandy clay loam texture due to flood as compared to the non flooded system. In open flood affected system had got a silt clay loam texture from loamy sand of non flooded system.

6.1.2 Impact of flood on soil chemical properties

1. All land use systems was recorded with an acidic pH. pH had a significant increase after flood in forest and open land use systems (0.31 and 0.26, respectively). Rubber and coconut flood affected had a significant decrease (0.16 and 1.34, respectively) in pH due to flood as compared to the non flooded condition. Nutmeg plantation didn't show any significant difference in pH at the depth of 0-20 cm.
2. The EC had a significant decrease after flood in rubber, coconut and open land use systems (0.9dS m^{-1}, 0.8 dS m^{-1} and 0.37 dS m^{-1}, respectively) at the depth 0- 20 cm. Forest and nutmeg plantation didn't show any significant difference in EC at the depth of 0-20 cm.
3. Impact of flood on OC in different land use systems acted differently. The tree dominating systems that is forest, rubber and nutmeg flood affected land use systems showed a significant increase in flooded condition (0.2 %, O.8 % and 0.4 %, respectively) as compared to non flooded condition. Whereas coconut and open flood affected land use systems had showed a significant decrease (1.3 % and 0.7 %, respectively) in flooded condition. Also from top layer to bottom layer (0-20 cm to 81-100 cm) all land use systems showed a significant decrease in OC.
4. Impact of flood on Available N in different land use systems varied differently. Forest flood affected showed a significant increase (84kg ha^{-1}) in avail. N due to flood as compared to the non flooded condition. While rubber, nutmeg and open flood affected system showed a significant decrease (201.6 kg ha^{-1}, 35.7 kg ha^{-1} and 207.9 kg ha^{-1}, respectively) in available N due to

flood as compared to the non flooded condition. Coconut land use systems didn’t show a significant difference. Also when the trend was observed from top layer to bottom layer (0- 20 cm to 81- 100 cm) in each land use systems, it showed a decreasing trend or significant decrease in avail. N except in nutmeg flood affected and coconut flood affected.

5. The effect of flood on avail. P also showed similar trend of OC at the depth of 0-20 cm. Forest, rubber and nutmeg flood affected land use systems had showed a significant increase (36.95 kg ha^{-1} 32.6 kg ha^{-1}and 38.42 kg ha^{-1}respectively) in avail. P due to flood as compared to the non flooded system at the depth of 0- 20 cm. Whereas coconut and open flood affected system showed a significant decrease (57.2 kg ha^{-1}and 111.52 kg ha^{-1}, respectively) in avail. P due to flood as compared to the non flooded system. Also when the trend was observed from top layer to bottom layer (0- 20 cm to 81- 100 cm) in each land use systems, it showed a decreasing trend or significant decrease in avail. P.
6. Forest, coconut and open flood affected land use systems had a significant decrease (196.6 kg ha^{-1} 421.5 kg ha^{-1}and 125.8 kg ha^{-1}, respectively) in avail. K due to flood as compared to the non flooded system; while Rubber and Nutmeg flood affected system showed a significant increase (299.4 kg ha^{-1}and 292.0 kg ha^{-1}, respectively) in avail. P. Also when the trend was observed from top layer to bottom layer (0- 20 cm to 81- 100 cm) in each land use systems, it showed a decreasing trend or significant decrease in avail. K.
7. Nutmeg plantation had a significant increase (9193 mg kg^{-1}) while coconut had significant decrease (1840.6 mg kg^{-1}) in calcium content of soil due to flood at the soil depth of 0-20 cm.

8. Nutmeg plantation had a significant increase (174.1 mg kg^{-1}) whereas coconut plantation had a significant decrease (131.4 mg kg^{-1}) in magnesium content of soil due to flood at the soil depth of 0-20 cm.
9. Only in rubber plantation, a significant difference in sulphur content of the soil was observed. The rubber had a significant decrease (7.744mg kg^{-1}) after flood in sulphur content of the soil. The other four land use systems did not shown any significant difference sulphur content.
10. The iron (Fe) content of soil showed a significant difference in forest and open land use systems only. Forest had a significant increase (4.49 mg kg^{-1}) in Fe content due to flood while open land use systems had a significant decrease (5.43 mg kg^{-1}) at the depth of 0- 20 cm.
11. Forest, rubber and nutmeg had showed a significant increase (39.14 mg kg^{-1}, 21.78 mg $kg^{-1}$and 55.71 mg kg^{-1}respectively) after flood in manganese content in soil. While coconut and open land use systems had a significant decrease (60.22 mg kg^{-1} and 19.39 mg kg^{-1}, respectively) in manganese content after flood.
12. Rubber and nutmeg had a significant increase (40.46 mg kg^{-1} and 7.29 mg kg^{-1} respectively) in copper content of soil after flood. Open land use systems was recorded with a significant decrease (9.39 mg kg^{-1}) in copper content of soil due to flood. Forest and coconut had no significant difference in copper content at the depth of 0-20 cm.
13. Forest, rubber and nutmeg had a significant increase (1.07 mg kg^{-1}, 2.13 mg kg^{-1} and 17.32 mg kg^{-1}, respectively) in zinc content due to flood. While, coconut and open land use systems had a significant decrease (6.44 mg kg^{-1} and 1.56 mg kg^{-1}, respectively).
14. Boron content has showed a significant decrease (0.278 mg kg^{-1}) after flood in rubber plantation. Other four land use systems were not observed with any significant difference.

15. Concluding to the chemical properties, comparing to control treatment, forest showed a remarkably better resilience or masked the ill effect of flood very quickly compared to other systems. In most of the soil chemical nutrient contents rubber and nutmeg plantations followed the forest. The coconut plantations and the open lands were hit hard by the flood effect with respect to the soil nutrient contents

6.1.3 Impact of flood on soil biological properties

1. Total microbial count (Bacteria, Fungi and Actinomycetes) had no significant difference after flood in any of the land use systems. Bacterial count showed significant difference between the land use systems. Rubber non flooded had a significantly higher bacterial count (8.24cfu g^{-1}) as compared with rubber flood affected and open non-flood affected land use systems (7.21 cfu $g^{-1}$and 6.94 cfu g^{-1}, respectively).
2. Fungi had no significant difference due to flood. However, fungal count showed significant difference between land use systems in non-flood affected conditions. Rubber non flooded (4.55 cfu g^{-1}) had showed higher fungal count followed by forest and nutmeg non flooded system (3.7 cfu $g^{-1}$and 4.07 cfu g^{-1}, respevtively).
3. Actinomycetes count had no significant difference after flood in respective land use systemss. However, it showed a significant difference between different land use systems in non flooded condition. Open non flooded (6.24 cfu g^{-1}) had significantly higher count followed by rubber, nutmeg and coconut non-flood affected land use systems (5.85 cfu g^{-1}, 0.00 cfu $g^{-1}$and 5.11 cfu g^{-1}, respectively) in actinomycetes count.
4. Dehydrogenase activity had a significant difference after flood only in open land use systems. Open land use systems had a significant increase (16.35 μg TPF g^{-1} 24 hr^{-1}) in dehydrogenase activity after flood. Also when

compared with different land use systems open non flooded had a significantly lower dehydrogenase activity as compared with all other four land use systems in non flooded condition.

5. Forest, rubber and nutmeg had an increase (9.67μg g^{-1}, 64.48 μg $g^{-1}$and 25.89μg g^{-1}, respectively) in microbial biomass carbon after flood; while nutmeg, coconut and open land use systems had a decrease (104.11μg g^{-1}, 90.98 μg $g^{-1}$and 121.44 μg g^{-1} , respectively) in MBC after flood.

6.2 IMPACT ON SOIL SEED BANK

1. A seed bank source of any ofthe tree species was not recorded under both flood affected and non flooded conditions in any of land use systems under observation in both the seasons.
2. More herbaceous plant species in the seed bank were noticed of in all land use systems.
3. However, difference in seed bank as an effect of flooding was not observed in any of the land use systems.
4. Seed density was recorded high for herbaceous species in all the five land use systems as compared to shrubs and tree species.

6.3 VEGETATION ANALYSIS

1. Simpson's and Shannon Wiener index of tree had a decrease in forest, nutmeg and coconut plantation after flood.
2. Also in shrubs and herbs, Simpson's and Shannon Wiener had showed a decrease after flood in all land use systems except open land use systemsfor herb. In herb diversity of open land use systems had an increase in both Simpson's and Shannon Wiener index after flood.
3. A high abundance (4) and frequency (14.29) was observed for *Neolamarckia cadamba* in forest flood affected system in plot size of 20

m x 20 m. Highest abundance (3) was recorded for *Schleichera oleosa* and *Bauhinia malabarica* while highest frequency (12) was recorded for *Bauhinia malabarica* in forest non flooded condition.

4. Highest abundance as well as frequency was observed for *Myristica fragrance* in nutmeg plantation, while it is highest for *Cocus nucifera* in coconut plantation.

REFERENCE

Adams, S. N. and Honeysett, J.L. 1964. Some effects of waterlogging on the cobalt and copper status of pasture plants in pots. *Aust. J. Soil Res.* 15: 357-367.

Aitkenhead, J.A. and McDowell, W.H. 2000. Soil C: N ratio as a predictor of annual riverine DOC flux at local and global scales. *Glob. Biogeochem. Cycles*, *14*(1): 127-138.

Ali, H., Mishra, V., and Pai, D. S. 2014. Observed and projected urban extreme rainfall events in India, *J. Geophys. Res. Atmos.* 119(22):621-641. doi:10.1002/2014JD022264.

Ali, S., Begum, F., Hayat, R., and Bohannan, B. J. M. 2017. Variation in soil organic carbon stock in different land uses and altitudes in Bagrot Valey, Northern Karakoram, *Acta Agr. Scand*.: 551-561. https:// doi.org/10.1080/09064710.2017.1317829

Ammara, M. and Shumaila, N. A. 2012. Review: Waterlogging effects on morphological, anatomical, physiological and biochemical attributes of food and cash crops. *Int. J. Water. Res. Environ. Sci*. 1(4):113-120.

Andersen, P. A. 2007. Review of micronutrient problems in the cultivated soil of Nepal: An issue with implications for agriculture and human health. *Mountain Res. Dev.*7(4): 331–335. doi:10.1659/mrd.0915

Arunachalam, K. and Arunachalam, A. 1999. Recovery of a felled subtropical humid forest: microclimate and soil properties. *Ekologia*,18 (3): 287–300.

Asami, T. 1970. Behavior of free-iron oxide in paddy soil (Part 4) Reduction of free-iron oxide and metabolisms of various gases in paddy soil. *Jpn. J. Soil Sci. Plant Nutr.*, 41*:* 48-55.

Ayoubi, S., Khormali, F., Sahrawat, K. L., and Ro drigues de Lima, A. C. 2011. Assessing Impacts of Land Use Change on Soil Quality Indicators in a Loessial Soil in Golestan Province.*Iran. J. Agr. Sci. Tech*., 13:727-742.

Baker III, T.T., Lockaby, B.G., Conner, W.H., Meier, C.E., Stanturf, J.A., and Burke, M.K. 2001. Leaf litter decomposition and nutrient dynamics in four southern forested floodplain communities. *Soil Sci. Soc. Am. J.* , 65:1334–1347.

Baker, H.G. 1989. Some aspects of the natural history of seed banks. In: Leck, M.A., Parker, V.T., and Simpson, R.L. (eds). *Ecology of Soil Seed Banks*. London, Academic Press. pp.5-19.

Baldwin, D.S. and Mitchell, A.M. 2000. The effects of drying and re-flooding on the sediment and soil nutrient dynamics of lowland river-floodplain systems: a synthesis. *Regul. Rivers: Res. Manag*. , 16: 457–467.

Bandyopadhyay, P.K., Saha, S., Mani, P.K., and Mandal, B. 2010. Effect of organic inputs on aggregate associated organic carbon concentration under long term rice wheat cropping system. *Geoderma*. 154:379-386.

Barker, H. A. 1961. Microbiology. In: Gunsalus, I.C. and Stanier, R.Y. (eds) *The Bacteria*, Academic Press, New York, pp.151-207.

Battaglia, L.L. and Collins, B.S. 2006. Linking hydroperiod and vegetation response in Carolina bay wetlands. *Plant Ecol.* 184:173–185. doi: 10.1007/s11258-005-9062-7.

Benz, B.R., Rhode, J.M. and Cruzan, M.B., 2007. Aerenchyma development and elevated alcohol dehydrogenase activity as alternative responses to hypoxic soils in the Piriqueta caroliniana complex. *Am. J. Bot.*, 94(4): 542-550.

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L., and Clark, F.E. 1965. *Methods of Soil Analysis*. Part I. American Society of Agronomy Inc., Madison, USA, 1569p.

Bloomfield, C. 1951. Paddy and rice seed production. *J .Soil. Sci*., 2 :196-211.

Bossio, D.A. and Scow, K.M. 1998. Impacts of carbon and flooding on soil microbial communities: phospholipid fatty acid profiles and substrate utilization patterns. *Microb. Ecol*. , 35:265–278.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.*, 59(1): 39-46.

Capon, S.J. 2007. Effects of flooding on seedling emergence from the soil seed bank of a large desert flood plain. *Wetlands*. 27:904–914.

Capon, S.J. and Brock, M.A. 2006. Flooding, soil seed bank dynamics and vegetation resilience of a hydrologically variable desert floodplain. *Freshw. Biol*.51: 206–223. doi: 10.1111/j.1365-2427.2005.01484.x

Carmona, R. 1992. Problemática e manejo de bancos de sementes de invasoras em solos agrícolas. *Planta Daninha*. 10:5-16.

Casanova, M. and Brock, M.A. 2000. How do depth, duration and frequency of flooding influence the establishment of wetland communities? *Plant Ecol.* , 147 :237–250.

Casida Jr, L.E., Klein, D.A. and Santoro, T. 1964. Soil dehydrogenase activity. *Soil Sci*., *98*(6): 371-376.

Celik, I. 2005. Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. *Soil Tillage Res.*, 83:270–277.

Chandrashekara, U. M. and Sankar, S. 1998. Ecology and management of sacred groves in Kerala, India. *For. Ecol. Manag.*, 112: 165–177.

Chaudhari, P.R., Ahire, D.V., Ahire, V.D., Chkravarty, M., and Maity, S. 2013. Soil Bulk Density as related to Soil Texture, Organic Matter Content and available total. *Nutrients*. 3: 1–8.

Chesnin, L. and Yien, C.H., 1951. Turbidimetric determination of available sulfates. *Soil Sci. Soc. Am. J.*, *15*(C): 149-151.

Corwin, D. L., Kffka, S. R., Hopmans, J. W., Mori, Y., vanGroenigen, J. W., van Kessel, C., and Oster, J. D. 2003. Assessment and field-scale mapping of soil quality properties of a saline–Sodic soil. *Geoderma*. 114: 231–259.

Cosentino, D., Chenu, C., Le-bissonnais, Y. 2006. Aggregate stability and microbial community dynamics under drying-wetting cycles in a silt loam soil. *Soil Biol.Biochem.*, 38(8): 2053-2062.

Costa, R. C. and Araujo, F.S. 2003. Densidade, germinação e flora do banco de sementes do solo no final da estação seca, em uma área da Caatinga, Quixadá, CE. *Acta Bot. Bras*., 17: 259–264.

Coumou, D. and Rahmstorf, S.2012. A decade of weather extremes. *Nat. Clim. Chang*. 2(7) : 491–496, doi:10.1038/nclimate1452.

Crozier, M. J. 2010. Deciphering the effect of climate change on landslide activity: A review. *Geomorphology*. 124(3–4):260– 267, doi:10.1016/j.geomorph.2010.04.009.

Curtis, J.T. and Mc Intosh .1950. The interrelation of certain analytic and phytosociological characters. *Ecology*, 31: 434-455.

Dat, J.F., Capelli, N., Folzer, H., Bourgeade, P and Badot, P.M. 2004. Sensing and signalling during plant flooding. *Plant Physiol. Biochem.*, 42:273-282.

Day, F.P. 1982. Litter decomposition rates in the seasonally flooded great dismal swamp. *Ecol.* , 63:670–678. http://dx.doi.org/10.2307/1936787

Deekor, T.N. 2012. Changes in soil properties under different land use covers in parts of Odukpani, Cross River State, Nigeria. *J. Environ. Ecol.* , 3: 2157-6092.

Drenovsky, R.E., Vo, D., Graham, K.J., and Scow, K.M. 2004. Soil water content and organic carbon availability are major determinants of soil microbial community composition. *Microb. Ecol.* , 48:424–430.

Elhottova, D., Kristufek, V., Triska, J., Chrastny, V., Uhlirova, E., Kalcik, J., and Picek, T. 2002. Immediate impact of the flood (Bohemia, August 2002) on selected soil characteristics. *Water Air Soil Pollut.* , 173: 177–193.

Fahmi, A., Susilawati, A., and Rachman, A. 2014. Influence of height waterlogging on soil physical properties of potential and actual acid sulphate soils. *J. Trop. Soils*.19(2): 77-83.

Fernandez-quintanilla, C., Saavedra, M.S., and Garcia torre, L. 1991. Ecologia de las malas hierbas. In: Garcia torre, L., Fernandez- quintanilla, C. (eds) *Fundamentos Sobre Malas HierbasY Herbicidas*. Mundi-Prensa, Madrid. pp. 49-69.

Fesha, I.G., Shaw, J.N., Reeves, D.W., Wood, C.W., Feng, Y., Norfleet, M.L., and Van Santen, E. 2002. Land use effects on soil quality param eters for identical soil taxa. In: van Santen, E. (ed.). *Making Conservation Tillage Conventional: Building a Future on 25 Years of Research*. Proc. 25th Ann. Southern Conserv. Till. Conf. Sust. Agric., Auburn. Special Report no. 1. Alabama Agric. Expt. Stn. and Auburn University, AL 36849. USA. pp.24-26.

Focht, T. and Pillar, V.D. 2003: Spatial patterns and relations with site factors in a Campos grassland under grazing. *Braz. J. Biol.* , 63: 423–436.

Fowler, H. J., Cooley, D., Sain, S. R., and Thurston, M. 2010. Detecting change in UK extreme precipitation using results from the climate prediction.net BBC climate change experiment, *Extremes,* 13(2) : 241–267, doi:10.1007/s10687-010-0101-y.

Freitas, R.R. 1990. *Dinâmica Do Banco De Sementes Em Uma Comunidade De Plantas Daninhas Com Aspectos Da Germinação E Dormência De Sementes De Capim Marmelada (Brachiaria Plantaginea (Link) Hitc.)*. Lavras, Dissertação (Mestrado) – Escola Superior de Agricultura de Lavras. 118p.

Freney, J. R. 1967. The retention of organic matter in soil. In: McLaren, A.D. and Peterson, G. H. (eds) *Soil Biochemistry*. Dekker, New York, pp. 229-259.

Fu , B., Chen, L., Ma, K., Zhou, H., and Wang, J. 2000. The relationships between land use and soil conditions in the hilly area of the loess plateau in northern Shaanxi, China. *Catena*, 39: 69-78.

Gadgil, M. and Chandran, S.M.D. 1992. Sacred Groves. In: Sen, G. (ed.) *Indigenous Vision. People of India. Attitudes to the Environment.* Sage Publications, New Delhi and India International Centgoire, New Delhi. Pp.183–187.

Gallardo, A. 2003. Spatial variability of soil properties in a floodplain forest in Northwest Spain. *Ecosyst*., 6: 564–576.

Grieve, A.M., Dunford, E., Marston, D., Martin, R.E., and Slavich, P. 1986. Effects of waterlogging and soil salinity on irrigated agriculture in the Murray Valley: a review. *Aust.J. Exp. Agric.*,26(6): 761 – 777.

Grogan, P., Lalnunmawia, F., and Tripathi, S. K. 2012. Shifting cultivation in steeply sloped regions: A review of management options and research priorities for

Mizoram state, Northeast *India. Agrofor. Syst.*, 84:163-177. https://doi.org/10.1007/s10457- 011-9469-1

Gupta, R.P. and Dakshinamoorthy, C.1980. *Procedures for Physical Analysis of Soil*. Indian. Agricultural Research Institute. New Delhi. 150p.

Gupta, U. C. 1967. A simplified method for determining hot water-soluble boron in podzol soils. *Soil Sci.*, 103(6): 424-428.

Hackl, E., Pfeffer, M., Donat, C., Bachmann, G., and Zechmeister-Boltenstern, S. 2005. Composition of the microbial communities in the mineral soil under different types of natural forest. *Soil Biol. Biochem.*, 37: 661–671.

Hălbac-Cotoară-Zamfir, R., Keesstra, S., and Kalantari, Z. 2019. The impact of political, socio-economic and cultural factors on implementing environment friendly techniques for sustainable land management and climate change mitigation in Romania. *Sci. Total. Environ.*, 654: 418–429. doi:10.1016/j.scitotenv.2018.11.160

Hirabayashi, Y., Kanae, S., Emori, S., Oki, T., and Kimoto, M. 2008. Global projections of changing risks of floods and droughts in a changing climate, *Hydrol. Sci. J.*, 53(4):754–772. doi:10.1623/hysj.53.4.754.

Hirschboeck, K. K. 1988. Flood Hydroclimatology. In: Baker, V., Kochel, R. C., and Patton, P. C (eds) *Flood Geomorphology*, John Wiley & Sons, Inc. pp.212-234.

Hölzel, N. and Otte, A. 2004. Inter-annual variation in the soil seed bank of flood-meadows over two years with different flooding patterns. *Plant Ecol.*,174: 279-291.

Hosner, J.F. 1958. The effects of complete inundation of 14 bottomland tree species. *For. Sci.*, 6:246--251.

Hosner, J.F. 1960. Relative tolerance to complete innundation of 14 bottomland tree species. *For. Sci*., 6 (3):246-251.

Hou, Z.Y., Xie, Y.H., and Yu, X.Y. 2008. Research method, content, and prospecting seed bank of fresh water wetland. *Chin. J.Ecol*. , 27:1400–1405.

Huguenin-Elie, O., Kirk, G. J. D., and Frossard, E. 2003. Phosphorus uptake by rice from soil that is flooded, drained or flooded then drained. *Eur. J. Soil Sci*. , 54: 77–90.

Igwe, C.A., Zarei, M., and Stahr, K. 2008. Factors affecting potassium status of flood plain soils, eastern Nigeria. *Arch. Agron. Soil Sci.*, 54(3): 309-319, DOI: 10.1080/03650340801927051

Iqbal, M. A., Hossen, M. S. and Islam, M. N. 2014. Soil organic carbon dynamics for different land uses and soil management practices in Mymensingh. Proceedings of 5th International Conference on Environmental Aspects of Bangladesh; Bangladesh: 16-17

Irfan, M., Hayat, S., Hayat, Q., Afroz, S., and Ahmad, A.2010. Physiological and biochemical changes in plants under waterlogging. *Protoplasma*, 241: 3-17.

IRRI. 1964. *Annual Report of International Rice Research Institute,* International rice research Institute, Philippines, 334p.

IRRI. 1970. *Annual Report of International Rice Research Institute*, International rice research Institute, Philippines, 289p.

Islam, K. R. and Weil, R. R. 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. *Agric. Ecosyst. Environ.*,79:9-16. https:// doi.org/10.1016/S0167-8809(99)00145-0

Jackson, M.L. 1958. *Soil Chemical Analysis.* Prentice Hall, Inc., Englewood Cliffs, 498p.

Jackson, M. L. 1973. *Soil Chemical Analysis* (2nd Ed.). Prentice- Hall of India (Pvt) Ltd., New Delhi, 498 p.

Jackson, M.B., and Colmer, T.D. 2005. Response and adaptation by plants to flooding stress. *Ann. Bot.* , 96:501-505.

Jafarian, J. Z., Shabanzadeh, S., Kavian, A., and Shokri, M. 2014. Spatial variability of soil features affected by landuse type using geostatistics. *Ecopersia,* 2(3):667–679.

Jeb, D.N. and Aggarwal, S.P. 2008. Flood Inundation Hazard Modeling of the River Kaduna Using Remote Sensing and Geographic Information Systems. *J. Appl. Sci. Res.,* 4:1822-1833.

Jenkinson, D.S. and Powlson, D.S. 1976. The effects of biocidal treatments on metabolism in soil: A method for measuring soil biomass. *Soil Biol. Biochem., 8*(3): 209-213.

Jenne, E. A. 1968. Controls on Mn, Fe, Co, Ni, Cu and Zn concentrations in soils and water: The significant role of hydrous Mn and Fe oxides: *Advan. Chem. Ser.* , 73: 337–388.

Johnson, L.F. and Curl, E.A. 1971. *Methods for Research on the Ecology of Soil-Borne Plant Pathogens,* Burgess Publishing Company, 247p.

Joshi, B.K. 2002. Effect of landuse and elevation on soil properties of Betagad watershed – a case study from Indian central Himalaya. *J. Soil Water Conserv.,* 1: 109-117.

Kerala tragedy partly man made: Madhav Gadgil, expert who headed Western Ghats report. (2018). Retrieved from The Indian Express:

https://indianexpress.com/article/india/kerala-floods-rains-disaster-western-ghats-report-5314873/.

Khan, M.L., Khumbongmayum, A.D. and Tripathi, R.S. 2008. The sacred groves and their significance in conserving biodiversity. An overview. *Int. J. Ecol. Environ. Sci.* , 34: 277–291.

Kharal, S., Khanal, B. R., and Panday, D. 2018. Assessment of soil fertility under different land-use systems in Dhading District of Nepal. *Soil Syst.* , 2: 57.

Kilic, K., Kilic, S., and Kocyigit, R. 2012. Assessment of spatial variability of soil properties in areas under different land use. *Bulg. J. Agric. Sci.* , 18:722–732.

Kozlowski, T.T. 1985. Soil aeration, flooding, and tree growth. *J. Arboriculture*. 11(3):85-96.

Kuriakose, S. L. 2009. History of landslide susceptibility and a chorology of landslide-prone areas in the Western Ghats of Kerala, India. Springer Link, 40p.

Lal, R. 1996. Deforestation and land-use effects on soil degradation and rehabilitation in Western Nigeria. I. Soil physical and hydrological properties. *Land Degrad.Develop.*, 7: 19-45.

Letey, J. 1985. Relationship between soil physical properties and crop production. *Adv. Soil Sci.* , 1:276-294.

Li, Y.Y. and Shao, M.A. 2006. Change of soil physical under long term natural vegetation restoration in the loess plateau of China. *J. Arid Environ.* , 64: 77-96.

Liu, X.L., He, Y.Q., Zhang, H.L., Schroder, J.K., Li, C.L., Zhou, J., and Zhang, Z.Y. 2010. Impact of land use and soil fertility on distributions of soil aggregate fractions and some nutrients. *Pedosphere*, 20(5):666–673.

Lockaby, B.G., Murphy, A.L., and Somers, G.L. 1996. Hydroperiod influences on nutrient dynamics in decomposing litter of a floodplain forest. *Soil Sci. Soc. Am. J.*, 60 :1267–1272.

Lu, Z.J., Li, L.F., Jiang, M.X., Huang, H.D., and Bao, D.C. 2010. Can the soil seed bank contribute to revegetation of the drawdown zone in the Three Gorges Reservoir Region? *Plant Ecol.* , 209: 153-165.

Madhusoodhanan, C. G. 2019. Can floods lead to drought? After the flood, severe drought looming over Kerala. [online] SANDRP, Available: https://sandrp.in/2019/02/13/after-the-flood-severe-drought-looming-over-kerala/ [Accessed on: 4th March 2020].

Mahabaleshwara, H. and Nagabhushan, H.M. 2014. A study on soil erosion and its impacts on floods and sedimentation. *Int. J. Res. Eng. Technol.* , 3(3):443-451.

Maia, F.C., Medeiros, R.B., Pillar, V.D., and Focht, T. 2004: Soil seed bank variation patterns according to environmental factors in a natural grassland. *Rev. Bras. Sementes*., 26: 126–137.

Maithani, K., Arunachalam, A., Tripathi, R.S., and Pandey, H.N. 1998. Nitrogen mineralization as influenced by climate, soil and vegetation in a subtropical humid forest in northeast India. *For. Ecol. Manag.*, 109: 91–101.

Martin, J.P. 1950. Use of acid, rose bengal, and streptomycin in the plate method for estimating soil fungi. *Soil Sci.*, 69(3): 215-232.

Martins, C.C and Silva, W.R. 1994. da. Estudos de bancos de sementes do solo. *Informativo Abrates*. 4(1):49-56.

Maurya, B., Singh, V., Dhyanib, P., and Kashyap, S. 2014. Impact of altitudes on soil characteristics and enzymatic activities in the forest and Fallow lands of Almora District of Central Himalaya. *Oct. Jour. Env. Res.* ,: 2: 1-9.

McBratney, A. B. and Pringle, M. J. 1997. Spatial variability in soil – Implications for precision agriculture. In: Stafford, J. V. (eds) *Precision Agriculture 1997*, Proceedings of the 1st European Conference on Precision Agriculture, Oxford, UK. 3:639-643.

Mentzer, J.L., Goodman, R.M., and Balser, T.C. 2006. Microbial response over time to hydrologic and fertilization treatments in a simulated wet prairie. *Plant Soil*. 284: 85–100.

Middleton, B.A. 2003. Soil seed banks and the potential restoration of forested wetlands after farming. *J. Appl. Ecol.* , 40: 1025- 1034.

Mishra, V., Aaadhar, S., Shah, H., Kumar, R., Pattanaik, D.R., and Tiwari, A.D. 2018. The Kerala flood of 2018: combined impact of extreme rainfall and reservoir storage. *Hydrol. Earth System Sci. Disc.*, pp.1-13.

Mitchell, R. L. 1964. Soil chemistry in agriculture. In: Bear, F.E. *Chemistry of the Soil* (ed.), 2nd ed., Van Nostrand-Reinhold, Princeton, New Jersey, pp.320-368.

Mohapatra, P. K. and Singh, R. D. 2003. Flood management in India, *Nat. Hazards*, 28(1980): 131–143, doi: https://doi.org/10.1007/978-94-017-0137-2_6.

Moraes M.G., Alves J.D., Oliveira L.E.M., Vitorino P.F.P.G., and Magalhães, M.M. 2001. Characterization of growth and activity of alcohol and lactate dehydrogenase on six herbaceous species under hypoxia. *Ciência Agrotécnica*, 25:86-95.

Morales-olmedo, M., Ortiz, M., and Sellés, G. 2015. Effects of transient soil waterlogging and its importance for rootstock selection. *Chilean J. Agric.Res*., 75 (1): 45-56.

Mouazen, A. M., Dumont, K., Maertens, K., and Ramon, H. 2003. Two dimensional prediction of spatial variation in topsoil compaction of a sandy loam field based on measured horizontal force of compaction sensor, cutting depth and moisture content. *Soil Till Res.* , 74:91–102.

Myers, N., Mittermeier, R.A. Mittermeier, C.G., da Fonseca, G.A.B., and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature,* 403: 853–858. http://dx.doi:10.1038/35002501

Nandargi, S.S. and Aman, K. 2018. Precipitation concentration changes over India during 1951 to 2015. *Scientific Research and Essays*, *13*(3): 14-26.

Narayan, K. 2018. First post.com. Retrieved from TECH 2: https://www.firstpost.com/tech/news-analysis/what-caused-the-kerala-floods-4993041.html

Neatrour, M.A., Webster, J.R., and Benfield, E.F. 2004. The role of floods in particulate organic matter dynamics of a southern Appalachian river-floodplain ecosystem. *J. N. Am. Benthol. Soc.*, 23 (2): 198–213.

Neris, J., Jiménez, C., Fuentes, J., Morillas, G. and Tejedor, M. 2012. Vegetation and land-use effects on soil properties and water infiltration of andisols in Tenerife (Canary Islands, Spain). *Catena*, 98:55–62.

Nickum, M.T., Crane, J.H., Schaffer, B. and Davies, F.S. 2010. Reponses of mamey sapote (*Pouteria sapota*) trees to continuous and cyclical flooding in calcareous soil. *Scientia Horticulturae*, 123: 402-411.

Nicol, W. E. and Turner, R. C. 1957. Phosphorus transformations in mangrove soils under microcosm study, *Can. J. Soil Sci.*, 37:96-101.

Njoku, C. and Okoro, G.C. 2015. Effect of flooding on soil properties in Abakaliki South-Eastern Nigeria. *Schol. J. Agri. Sci*., 5(5):165-168

O'Connor. J.E., and Costa, J. E. 2004. The World Largest Floods: Past and Present – Their Causes and Magnitudes. U.S., Geological Survey, Washington D. C: 20 – 25.

Offiong, R.A., Atu, J.E., Njar, G.N. and Iwara, A.I. 2009. Effects of land use change on soil physicochemical properties in a South-Southern Nigeria. *Afr. J. Environ. Pollut. Health*, 7: 47-51.

Osunkoya, O.O., Ali, S., Nguyen, T., Perrett, C., Shabbir, A., Navie, S., Belgeri, A., Dhileepan, K. and Adkins, S. 2014. Soil seed bank dynamics in response to an extreme flood event in a riparian habitat. *Ecol. Res.*, *29*(6):1115-1129.

Palm, C.A., Swift, M.J., and Woomer, P.L. 1996. Soil biological dynamics in slash-and-burn agriculture. *Agric. Ecosyst. Environ.*, *58*(1): 61-74.

Panday, D., Maharjan, B., Chalise, D., Shrestha, R. K. and Twanabasu, B. 2018. Digital soil mapping in the Bara District of Nepal using Kriging tool in ArcGIS. *PloS One*, 13(10): 25-32.

Petersen, S.O. and Klug, M.J. 1994. Effects of sieving, storage, and incubation temperature on the phospholipid fatty acid profile of a soil microbial community. *Appl. Environ. Microbiol.*, 60:2421–2430.

Ponnamperuma, F.N. 1984. Effects of flooding on soils. In: T. Kozlawski (Eds.) Flooding and Plant Growth; Physical Ekology. A series monographs, text and treatises. Academic Press Inc. Harcourt Brace Javanovich Publisher, USA: 10-45.

Powell, W.G. 2009. Identifying Land Use/ Land Cover Using National Agriculture Imaginary Program Data as a Hydrological Model Input for Local Flood Plain Management, Applied Search Project, Texas University, 489p.

Quansah, C. 1997. Approaches to Replenishing Soil Fertility Depletion in Ghana. Poster Abstracts for the International Seminar on Approaches to Replenishing Soil Fertility in Africa: NGO Perspective, ICRAF, Nairobi, Kenya.

Raut, J.M., Pande, P.B., Gabhane, M.V., Bajad, S.P. and Khadeshwar, S.R. 2014. Effect of flood on soil and structure. *Int. J. Res. Eng. Appl. Sci.*, 2(2): 106-109.

Rebellato, L. and Cunha, C.N. 2005. Efeito do “fluxo sazonal mínimo da inundação” sobre a composição e estrutura de um campo inundável no Pantanal de Poconé, MT, Brasil. *Acta Bot. Bras.* , 19: 789–799.

Reddy, K.R., and Delaune, R.D. 2008. The Biogeochemistry of Wetlands: Science and Applications. CRC Press. New York, USA. 779 p.

Rivera, P.H. 1999. Susceptibilidad y predicción de la erosión en suelos de la ladera de la zona cafetera colombiana. Medellín (Colombia). Tesis en opción al título de Doctor en Aprovechamiento de Recursos Hidráulicos, Facultad de Minas, Univ. Nac. de Colombia sede Medellín. 525p.

Roberts, H.A.1981. *Seed Banks in the Soil. Advances in Applied Biology*, Cambridge, Academic Press, 655p.

Roxy, M. K., Ghosh, S., Pathak, A., Athulya, R., Mujumdar, M., Murtugudde, R., Terray, P. and Rajeevan, M. 2017. A threefold rise in widespread extreme rain events over central India, *Nat.Commun*., 8(1):708-810.

Sanchez, P. A., Buresh, A. J., Kwesiga, F. R., Mokwunge, A. U., Ndiritu, C. G., Shepherd, K. D., Soule, M. J. and Woomer, P. L. 1997. Soil Fertility Replenishment in Africa: An Investment in Natural Resource Capital. Proceedings of International Seminar on Fertility in Africa – NGO Perspectives ICRAF, Nairobi, Kenya.

Santra, P., Chopra, U. K. and Chakraborty, D. 2008. Spatial variability of soil properties and its application in predicting surface map of hydraulic parameters in an agricultural farm. *Curr. Sci*., 95 (7): 937-945.

Sasidharan, N. 2006. Illustrated Manual on Tree Flora of Kerala Supplemented with Computer-aided Identification. Research Report No: 282, Kerala Forest Research Institute, Peechi, 502 pp.

Scalenghe, R., Edwards, A. C., Ajmone Marsan, F. and Barberis, E. 2002. The effect of reducing conditions on the solubility of phosphorus in a diverse range of European agricultural soils. *Eur. J. Soil Sci.* , 53:1–9.

Schuur, E.A.G. and Matson, P.A. 2001. Net primary productivity and nutrient cycling across a mesic to wet precipitation gradient in Hawaiian montane forest. *Oecologia.* 128: 431–442.

Sen, S. 2018. Improved Disaster management Saves Kerala, Despite Lack of Preparedness. Observer Research Foundation.

Seng, V., Bell, R. W., Willett, I. R. and Nesbitt, H. J. 1999. Phosphorus nutrition of rice in relation to flooding and temporary loss of soil water saturation in two low land soils of Cambodia. *Plant Soil*, 207:121–132.

Shahandeh, H., Hossner, L. R. and Turner, F. T. 1994. Phosphorous relationships in flooded rice soils with low extractable phosphorous. *Soil Sci. Soc. Am. J.* , 58 : 1184–1189.

Shannon, C.E. and Weiner, W. 1963. *The Mathematical Theory of Communication*. Urbana, USA, University of Illinois press. 177 p.

Sharma, D.B. and Swarup, A. 1988. Effects of short-term flooding on growth, yield and mineral composition of wheat on sodic soil under field conditions. *Plant Soil*, 107(1):137–143.

Shepherd, G., Bureh, R.J. and Gregory, P.J. 2000. Land use affects the distribution of soil inorganic nitrogen in smallholder production systems in Kenya. *Biol. Fert. Soils,* 31: 348-355.

Sigafoos, R.S. 1964. Botanical evidence of floods and flood-plain deposition. US Geological Survey Professional Paper, 485: 1–35.

Simon, A. and Mohankumar, K. 2004. Spatial variability and rainfall characteristics of Kerala. Proceedings of the Indian Academy of Sciences (Earth and Planetary Sciences) 113: 211–221.

Simpson, E.H. 1949. Measurement of diversity. *Nature*, 163(4148): 688-688.

Simpson, R.L., Leck, M.A. and Parker, V.T. 1989. Seed Banks: General Concepts and Methodological Issues. In: Leck, M.A. Parker, V.T. Simpson, R.L. (Ed). *Ecology of soil seed banks*. London, Academic Press: 3-8.

Sims, J.T. and Johnson, G.V. 1991. Micronutrient soil tests. *Micronutr.Agric.* , 42(4): 427-476.

Smith, K. 1996. Environmental hazards: Assessing risk and reducing disaster. London, Routledge, 7p.

Spurgeon, D. J., Keith, A. M., Schmidt, O., Lammertsma, D. R. and Faber, J. H. 2013. Land-use and land-management change: Relationships with earthworm and fungi communities and soil structural properties. *BMC Ecol.* , 13(1):46.

Stephen, B. 1993. Flooding and its effect on Tree. USDA Forest Service's Press, USA, pp 25 – 32.

Stroh, P.A., Mountford, J.O., Araya, Y.N. and Hughes, F.M. 2013. Quantifying soil hydrology to explain the development of vegetation at an ex-arable wetland restoration site. *Wetlands, 33*(2): 311-320.

Su, X.L., Zeng, B. and Huang, W.J. 2012. Effects of the Three Gorges Dam on preupland and preriparian drawdown zones vegetation in the upper watershed of the Yangtze River, P. R. China. *Ecol. Eng.* , 44:123–127.

Subbaih, B.V. and Asija, G.L. 1956. A rapid method for the estimation of available nitrogen in soil. *Curr. Sci.*, 25: 259-260.

Suma, M., George, A.V., Rekha, V.B., and Leenamma, J. 2011. An assessment of soil properties under different land use types of the Kallada River Basin, Kerala, India. *Environ. Res. Eng. Manag.* , 1: 5-13.

Suzuki, C., Kunito, T., Aono, T., Liu, C.-T., and Oyaizu, H. 2005. Microbial indices of soil fertility. *J. Appl. Microbiol.* , 98: 1062–1074.

Takai, Y., Koyama, T. and Kamura, T.1963.Microbial metabolism in reduction process of paddy soils (Part 3). Effect of iron and organic matter on the reduction process (2). *Soil Sci. Plant Nutr.*, 9 :207–211.

Tao, D.L., Singh, N.J., and Goswami, C. 2018. Spatial Variability of Soil Organic Carbon and Available Nutrients under Different Topography and Land Uses in Meghalaya, India. *IJPSS*, 21: 1-16. https://doi.org/10.9734/IJPSS/2018/39615.

Tesfai, M. 2001. Soil and Water Management in Spate Irrigation Systems in Eritrea. Wageningen University. Promotor: 212p. ISBN 90-5808-388-8. 36.

Thien, S.J. 1979. A flow diagram for teaching texture-by-feel analysis. *J. Agron. Educ.*, *8*(1):54-55.

Thompson, K. and Grime, J.P. 1979. Seasonal variation in the seed banks of herbaceous species in ten contrasting habitats. *J. Ecol.* , 67: 893–921.

Tripathi, S. K., Vanlalfakawma, D. C., and Lalnunmawia, F. 2017. Shifting cultivation on steep slopes of Mizoram, India: Impact of policy reforms. In: Cairns, M. (ed.), *Shifting Cultivation Policies: Balancing Environmental and Social Sustainability*. CABI Publishing, London: 395- 413.

Tsheboeng., Gaolathe .,Bonyongo., Mpaphi.,Murray-Hudson., andMike. 2014. Flood variation and soil nutrient content in floodplain vegetation communities in the Okavango Delta. *South Afr J. Sci.*, 110: 1-5. 10.1590/sajs.2014/20130168.

Valipour, M. 2014. Drainage, waterlogging, and salinity. *Arch Agron. Soil Sci.*_, 60(12): 1625-1640.

Van der Werf, G.R., Morton, D. C., De Fries, R. S., Olivier, J. G. J., Kasibhatla, P. S., Jackson, R. B., Collatz, G. J., and Randerson, J. T. 2009. CO2 Emissions from Forest Loss. *Nature Geosci*., 2: 737-738. http://doi.org/10.1038/ngeo671.

Vepraskas, M.J. and Faulkner, S.P. 2001. Redox chemistry of hydric soils. In: Richardson, J.L., Vepraskas, M.J. (eds.), *Wetland Soils: Genesis, Hydrology, Landscapes and Classification.* Lewis Publishers, Boca Raton, Florida, 126p.

Visser, E.J.W. and Voesenek, L.A.C.J. 2004. Acclimation to soil flooding – sensing and signal– transduction. *Plant & Soil*. 254:197–214.

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci.*, 37(1): 29-38.

Wang, B., and An, S.I. 2001: Why the properties of El Nino changed during the late 1970s. *Geophys. Res. Lett.* , 28: 3709–3712.

Wapongnungsang, M. C. and Tripathi, S. K. 2018. Changes in soil fertility and rice productivity in three consecutive years cropping under different fallow phases following Shifting cultivation. *IJPSS*, 25 (6):1-10. https://doi.org/10.9734/IJPSS/2018/46087.

Watanabe, F.S. and Olsen, S.R. 1965. Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soil. *Soil Sci. Soc. Am. J.* , 29(6): 677-678.

Wei, J. B., Xiao, D. N., Zeng, H., and Fu, Y. K. 2007. Spatial variability of soil properties in relation to land use and topography in a typical small watershed of the black soil region, northeast, China. *Environ.Geol.* , doi:10.1007/s00254-007-0773-z

Williams, C.H. and Steinbergs, A. 1959. Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Aust. J. Agric. Res.*, *10*(3): 340-352.

Yong, M.S., Jae, D.S., Geon, Y.J., Doo, H.K., and Moo, E. P. 2011. Effect of flooding and soil salinity on the growth of yam (*Dioscorea batatas*) transplanted by seedling of aerial bulblet in saemangeum reclaimed tidal land. *Korean J. Soil Sci. Fertil.*, 44(1): 8- 14.

Young, E. O. and Ross, D. S. 2001. Phosphate release from seasonally flooded soils: a laboratory microcosm study. *J. Environ. Qual.* , 30: 91–101.

Zhang, Z.B., Peng, X., Wang, L.L., Zhao, Q.G., and Lin, H. 2013.Temporal changes in shrinkage behavior of two paddy soils under alternative flooding and drying cycles and its consequence on percolation. *Geoderma*, 192:12-20.

SOIL AND VEGETATION CHARACTERISTICS IN THE POST FLOOD SCENARIO IN SELECTED TREE BASED LAND USE SYSTEMS IN THRISSUR, KERALA

by

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ABSTRACT OF THE THESIS

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ABSTRACT

The unprecedented and intense nonstop rainfall for days together occurred in Kerala during August 2018 affected all the aspects of human lives including socio economic conditions, transportation, infrastructure, agriculture, and livelihood. Flooding lead to food crop shortages due to the loss of entire crop harvest and degradation of soil quality. The present study is aimed at identifying the impacts of Kerala flood 2018 on soil physico – chemical and biological properties, vegetation and soil seed banks along the 'Kurumali' river basin of Thrissur district of Kerala in five major land use systems prevalent in the area viz; forest, rubber, nutmeg and coconut plantations and open land. For this purpose, all five land use systems in flood affected and the same five land use systems in the adjacent area where flood has not been affected were selected. Soil samples were collected up to one meter soil depth (0-20 cm, 21- 40 cm, 41- 60 cm,61- 80 cm and 81- 100cm) for soil analysis after seven months of flood . Soil physical properties like soil bulk density, soil porosity and soil texture; and chemical properties like soil pH, EC, available N, P, K; secondary nutrients like Ca, Mg and Sulphur and micronutrients like Fe, Cu, Mn, Zn and Boron were analysed. The biological properties assessed were total microbial count (Bacteria, Fungi and Actinomycetes), dehydrogenase activity and microbial biomass carbon. Soil seed bank data were generated in two seasons (Pre- monsoon and post- monsoon of 2019) from the top soil of all the five land use system studied. In vegetation analysis diversity indices, abundance and dominance of species were worked out.

The bulk density and porosity had a little effect due to flood in all land use systems while soil texture had changed from sandy clay loam to clay loam structure in forest flood affected system. In coconut, it is changed from loamy texture to sandy clay loam and in open, the change was from loamy sand to silty clay loam in the surface soil ie. 0- 20 cm depth. The pH had a significant increase after flood in forest and open land use system (0.31 and 0.26, respectively). The rubber and coconut flood

affected systems had a significant decrease (0.16 and 1.34, respectively) in pH from flood non affected condition. The EC had a significant decrease after flood in rubber, coconut and open land use system (0.9dS m^{-1}, 0.8 dS m^{-1} and 0.37 dS m^{-1} , respectively). The organic carbon content in forest, rubber and nutmeg flood affected land use system had showed a significant increase (0.2 %, O.8 % and 0.4 % , respectively) from flood non affected condition; whereas coconut and open flood affected land use system had showed a significant decrease in organic carbon (1.3 % and 0.7 % , respectively) from flood non affected condition. The forest flood affected had showed a significant increase (84kg ha^{-1}) in available N from flood non affected condition. Rubber, nutmeg and open flood affected system had showed a significant decrease (201.6 kg ha^{-1}, 35.7 kg ha^{-1} and 207.9 kg ha^{-1} , respectively) in available N from flood non affected condition. The effect of flood on available P also showed similar trend of OC at the soil depth of 0-20 cm. The forest, coconut and open flood affected land use system had a significant decrease (196.6 kg ha^{-1} 421.5 kg $ha^{-1}$and 125.8 kg ha^{-1} , respectively) in available K from flood non affected system. While rubber and nutmeg flood affected system showed a significant increase (299.4 kg $ha^{-1}$and 292.0 kg ha^{-1}respectively) in available K. The nutmeg plantation had a significant increase (9193 mg kg^{-1}) while coconut plantation had significant decrease (1840.6 mg kg^{-1}) in calcium content of soil after flood. Similarly the nutmeg plantation had a significant increase (174.1 mg kg^{-1}) whereas coconut plantation had a significant decrease (131.4 mg kg^{-1}) in magnesium content of soil after flood. The rubber plantation had a significant decrease (7.744mg kg^{-1}) after flood in sulphur content of the soil. The forest had a significant increase (4.49 mg kg^{-1}) in ‘Fe’ content after flood while open land use system had a significant decrease (5.43 mg kg^{-1}) at the depth of 0- 20 cm. The forest, rubber and nutmeg had showed a significant increase (39.14 mg kg^{-1}, 21.78 mg $kg^{-1}$and 55.71 mg kg^{-1}respectively) after flood in manganese content of soil at the depth of 0-20 cm. While coconut and open land use system had a significant decrease (60.22 mg $kg^{-1}$and 19.39 mg/kg, respectively) in manganese content after flood. The rubber and nutmeg had a significant increase (40.46 mg kg^{-1} and 7.29 mg kg^{-1} , respectively) in copper content of soil after flood at the depth of 0-20 cm. Open land use system was also recorded with a significant increase (9.39 mg kg^{-1}) in copper content of soil after flood at the depth 0- 20 cm. Forest, rubber and nutmeg plantation had a significant increase (1.07 mg kg^{-1}, 2.13 mg kg^{-1} and 17.32 mg kg^{-1} , respectively) in zinc content after flood at the depth of 0-20 while, coconut and open land use system had a significant decrease (6.44 mg kg^{-1} and 1.56 mg kg^{-1} , respectively).

Total microbial count (Bacteria, Fungi and Actinomycetes) had no significant difference after flood in any of the land use systems. With respect to the dehydrogenase activity, the entire four tree based land use systems remained without any appreciable change. The forest, rubber and nutmeg land use systems also had an increase (9.67μg g^{-1}, 64.48 μg g^{-1} and 25.89 μg g^{-1} respectively) in microbial biomass carbon after flood. While coconut and open land use system had a decrease (90.98 μg $g^{-1}$and 121.44 μg g^{-1}, respectively) in MBC after flood. Soil seed bank had no effect due to flood. The present study reveals that among the five land use systems, Forest land use system showed a comparatively neutral effect in some and a distinctive positive effect in most of the soil physico - chemical and biological properties after seven months of flood. The results implicated that the forest land use system was the least affected or reselient with respect to soil properties due to flood impact. The seed bank generated not showed any noticeable difference after flood. The flood has no serious effect on higher vegetation.