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A Comparative Study of the Physio-chemical Properties in Soil Profile Under Different Forest Types

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သစ်တောမြေအမျိုးမျိုးအောက်ရှိ မြေဆီလွှာဖြတ်ပိုင်းများ၏ရူပဂုဏ်သတ္တိနှင့် ဓါတုဂုဏ်သတ္တိများကို နှိုင်းယှဉ်လေ့လာခြင်း

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စာတမ်းအကျဉ်း

ဤသုတေသနစာတမ်းသည် ယခင်လေ့လာပြီးသော မြေဆီလွှာဆိုင်ရာ သုတေသန စာတမ်းများ၊ မိုးရေချိန်၊ မိခင်ကျောက်သားနှင့် ဘူမိဗေဒကို အခြေခံ၍ မြန်မာနိုင်ငံရှိ သစ်တော (၉) မျိုးအောက်တွင် မြေဆီလွှာဖြတ်ပိုင်းများ၏ မြေဆီလွှာ ဂုဏ်သတ္တိများကို လေ့လာခဲ့ပါသည်။ အဆိုပါ သစ်တောမြေများတွင် သဲနုန်းပါဝင်မှုနှင့် မြေဆီလွှာဆိုင်ရာ ဂုဏ်သတ္တိများ ကွဲပြားခြားနားကြောင်း လေ့လာသိရှိရပါသည်။ လေ့လာတွေ့ရှိချက်အရ သစ်တောမြေများတွင် နုန်းမြေမှသဲမြေစေး အထိ ပါဝင်၍ ဖော့စဖောရပ်စ်၊ နိုက်ထရိုဂျင်ဓါတ် နှင့် ပိုတက်ဆီယမ်ဓါတ်များ ကဲ့သို့သော အပင်အတွက် လိုအပ်သည့် အာဟာရဓါတ်များ ပါဝင်မှု အမျိုးမျိုးရှိကြောင်း လေ့လာသိရှိရပါသည်။ မြေအချဉ်ငန်ဓါတ်မှာ အနည်းငယ်ချဉ်သော မြေများမှ အသင့်အတင့် ငန်သောမြေအထိ ရှိကြောင်း လေ့လာတွေ့ရှိ ရပါသည်။ ထို့ကြောင့် စိုက်ပျိုးမြေများကို ကျယ်ကျယ်ပြန့်ပြန့် အသုံးပြုမည်ဆိုပါ က အသေးစိတ် ဓါတ်ခွဲစမ်းသပ်ခြင်းများ ဆောင်ရွက်၍ နိုက်ထရိုဂျင်ဓါတ်နှင့် ဖော့စဖောရပ်စ် ကဲ့သို့သော အာဟာရ ဓါတ်များ ဖြည့်တင်းရန် လိုအပ်ပါကြောင်း လေ့လာသိရှိရပါသည်။ ဤသုတေသနသည် အမျိုးအစား မတူသော မိခင်အောက်ခံကျောက်သား၊ ရာသီဥတုနှင့် သဘာဝပေါက်ပင်များတွင် လေ့လာခြင်းဖြစ်သည့် အတွက် မြေဆီလွှာဆိုင်ရာဂုဏ်သတ္တိများ ကွဲပြားခြင်း ဖြစ်နိုင်ပါသည်။ ထို့ကြောင့် သဘာဝပေါက်ပင် များကွဲပြား၍ ကျန်အခြေအနေ တူညီသော ဒေသများတွင် မြေဆီလွှာ ဂုဏ်သတ္တိများကို ဆက်လက် နှိုင်းယှဉ်လေ့လာရန် လိုအပ် ပါကြောင်း လေ့လာ သိရှိရပါသည်။

A Comparative Study of the Physio-chemical Properties in Soil Profile under Different Forest Types

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Abstract

A study was conducted in the soils under different vegetation types of Myanmar. The aim of the present study was to assess the physio-chemical properties in soil profiles under different forest types. Nine forest types according to previous studies and rainfall and geogology map were selected for the analyzing of soil characteristics. Significant differences were found in the different forest types in respect of chemical properties and sand and silt particles, some of physical properties. The soils are loamy to sandy clay types, generally varied in soil nutrients, especially phosphorous, nitrogen and potassium and slightly acidic to slightly alkali conditions. The suggestion is made that the use of the soils for intensive planting would require specific soil test and the judicious use of inorganic chemical fertilizers, like nitrogen and phosphorous. The study revealed that the physico-chemical properties of soil in the study areas significantly vary because of the different in geology, climate and vegetation types. So further study on different forest types will be more emphasize on same conditions of geology and climate.

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1. Introduction

The soil and vegetation have a complex interrelation and they develop together over a long period of time. The growth and reproduction of forest cannot be understood without the knowledge of soil. In other hand, the vegetation influences the chemical properties of soil to a great extent. Moreover, different tree species can differ significantly in their influence on soil properties as well as soil fertility (Augusto et al. 2002). The selective absorption of nutrient elements by different tree species and their capacity to return them to the soil brings about changes in soil properties (Singh et al. 1986). And concentration of nutreients/elements in the soils is a good indicator of their availability to plants. Their presence in soil would give good information towards the knowledge of nutrient cycling and bio-chemical cycle in the soil–plant ecosystem (Pandit and Thampan 1988). So, the adequate theoretical and practical knowledge of various forest soils and the complex relationship between them is necessary to study. In Myanmar, most previous studies have tended to concentrate on surface soil characteristics with tree species while others have compared characteristics of soils under teak plantation and natural forest or under dry zone area. Little consideration has been given to the study of soil characteristics under different vegetation units, particularly within the different vegetation types with various geology units. The present study is undertaken with the aim of assessing the properties of soil with different vegetation types.

2. Objectives

- to analyze and compare some physical and chemical properties of soils under different forest types
- to provide useful knowledge of the physio-chemical properties of forest soils which may guide for future establishment of plantation

3. Literature Review

3.1 Soil profile

The soil profile comprises two or more soil layers called horizons, one below the other, each parallel to the surface of the land. These horizons range from rich, organic upper layers (humus and topsoil) to underlying rocky layers (subsoil, regolith and bedrock). Important characteristics that differentiate the various horizons are: Color, texture, structure, consistency, porosity and soil reaction. Thicknesses ranging from several feet thick to as thin as a fraction of an inch. Generally, the horizons merging with one another and which may or may not be showing sharp boundaries. Most soils have three major horizons (A, B, C) and some have an organic horizon (O).

3.1.1 O – (humus or organic)

The top, organic layer of soil, made up mostly of leaf litter and humus. The O horizon is thin in some soils, thick in others, and not present at all in others.

3.1.2 A - Horizon

The layer called topsoil; it is found below the O horizon and above the E horizon. Seeds germinate and plant roots grow in this dark-colored layer. It is made up of humus (decomposed organic matter) mixed with mineral particles. Living organisms are most abundant in this horizon, consisting of plant bacteria, fungi and small animals. Organic matter is most plentiful, particularly mulch layer. When a soil is tilled improperly or eroded by wind or water, the A Horizon may be removed away.

E Horizon

Leached of clay, minerals, and organic matter, leaving a concentration of sand and silt particles of quartz or other resistant materials – missing in some soils but often found in older soils and forest soils. This eluviation (leaching) layer is light in color; this layer is beneath the A Horizon and above the B Horizon. It is made up mostly of sand and silt, having lost most of its minerals and clay as water drips through the soil (in the process of eluviation).

3.1.3 B - Horizon

Rich in minerals that leached (moved down) from the A or E horizons and accumulated here. Lies immediately beneath the A Horizon and above the C Horizon. The B Horizon has properties of both A and C. Living organisms are fewer in number than in the A Horizon, but more abundant than in the C Horizon. Color is transitional between A and C as well. It is frequently higher in clay than either of the other. This eluviation (leaching) layer is light in color; this layer is beneath the A Horizon and above the B Horizon. It is made up mostly of sand and silt, having lost most of its minerals and clay as water drips through the soil (in the process of eluviation).

3.1.4 C - Horizon

The deposit at Earth's surface from which the soil developed. The deepest of the three. This is the material from which the mineral part of the forms. It is the parent material of soils. It may have accumulated in place by the breakdown of hard rock, or it may have been placed there by the action of water or ice. It may be unaltered by biological or other solum forming activities. It may begin at bottom of rooting zone , negligible profile development and may have cementation or weathering.

3.1.5 R – (bedrock)

A mass of rock such as granite, basalt, quartzite, limestone or sandstone that forms the parent material for some soils – if the bedrock is close enough to the surface to weather. This is not soil and is located under the C horizon.

3.2 Forest Soil types in Myanmar

There are 24 main soil types in Myanmar based on the method of FAO-UNESCO. The characteristics of these soils are determined upon (i)the physical and mineral composition of the parent material, (ii) the relief (physical features), (iii) the climate under which the soil material has been developed and, (iv) the vegetation. Among them the forest soil classification system was modified by forest department according to the basis of the distribution of the important forest resources (i.e. soils supporting some type of forest cover)(Rozanov, Boris G, 1974. Further detailed soil survey will bring more information on the particular soil characteristics required for any forest types. The different types of the individual forest soil characteristics are described as follows:-

3.2.1 Red Brown Forest Soils (Rhodic Ferralsol)

The Red Brown Forest soils are the typical soils of tropical ever green forest of Myanmar. They occur on the well drained hill slopes at the elevation from 1000 to 4000 feet above sea level. These soil also occur in the northern hilly region and on the hill slopes of Rakhine mountain range, Taninthayi and Dawna range. These soils are formed under the influence of tropical evergreen forests with the annual rainfall of about 80 to 200 inches.

Some are also found at the low uplands. The soils are well structured and have a good drainage. The soil is slightly acid with the pH value ranging from 5.5 to 6.5 . Usually these soils have medium to heavy loamy texture. The soils contain moderate amount of plant available nutrients. These soils can be regarded as forest land of good productivity, however, the soils on the lower elevation are suitable for gardens and plantation.

3.2.2 Yellow Brown Forest Soils (Xanthic Ferralsol)

The Yellow Brown Forest soils widely occur in Myanmar covering the low hills of Bago Yoma, foot hills of Taninthayi Yoma, Rakhine Yoma and sloping areas at the bottom of northern hilly region up to the approximate norht latitude of 25 degrees. They are closely connected with the Red Brown Forest soils in their distribution and usually replacing them down the slope. They mainly occur in the region of gentle slopes of low hills and foot hills at the elevation of 300 to 1500 feet above sea level. These soils are typical for the monsoon or tropical mixed deciduous forests. These soils contain more percentage of clay and humus than the Red Brown Forest soils. However, in some places of the slopes, the soils are shallow due to the presence of pisolithic lateritic layer. According to the land use classification, the great moajority of these soils are classified as good garden lands.

3.2.3 Mangrove Forest (Orthic solonchak) and Saline Swampy Meadow Gley (Gley - Gleysol)

These soils occur in very small area along the coastal line of Myanmar, especially in the region of Ayeyarwady Delta, Myeik archipelago and islands of Rakhine coast line. These are marine flat lowlands which are affected by daily tides. The lands are only suitable for prawn breeding, sea beach resorts and establishing mangrove firewood forests.

Saline Swampy Meadow Gley soils occur in Ayeyarwady Delta and along the river bands of the Gulf of Motama and the marine flat lowlands influanced by the tidal sea water which is always salty. Due to high salinity and whole year tidal sea water, the land can only be utilized for prawn breeding and mangrove firewood forests.

3.2.4 Lateritic Soils (Plinthic Ferrasol)

These soils occur mostly in the lower Myanmar in the lower slopes of the hills of Bago Yoma, Rakhine Yoma and Dawna hill range. They are found on well drained low uplands and at the foot of low hills. They usually occur at the elevation not higher than 300 feet above sea level. They are formed under the influence of the tropical forests under the conditions of wet tropical monsoon climate with 80-2000 inches of rainfall. Morphologically, they are characterized by yellow or yellow brown and reddish brown colours. The yellow and red colour of the soils are due to the presence of iron with oxidation and reduction processes. In some places the horizons of pisolithic laterite are found at the depth of 18 to 20 inches, whereas, in other places they are not found even at the depth below 4 and 5 feet. The humus content of these soils in forest area is high, but can be less in the deforested areas. The soil reaction is acidic in the upper horizon and can be more acidic at the lower horizons. The available plant nutrients are very low in these soils. These soils are suitable for cash crops and garden such as durian and mango or reforestation for soil conservation.

3.2.5 Yellow Brown Dry Forest and Indaing (Orithic cambisol)

These soils occur on low upland plains in the Dry zone area. The lands are dry and sandy so can be utilized for forests and dry cropping on uplands.

3.2.6 Red Brown Savanna Soils (Luvisol) and Light Forest Soils (Cinnamon) Nitosol

These soils are mostly found in the undulating relief of the hill slopes and low uplands. The soils are sandy and usually well drained. The soil reaction is about neutral in the top soil and neutral or slightly alkaline in the subsoil (pH ranges from 7.0 to 8.0). The soil contains a certain amount of lime and is rich in calcium and magnesium. The soils are low in other nutrients except potassium. These soils are the most important land resources of the Dry zone area. Most of the areas are ploughed and cultivated.

Thes soils mostly occur on the very gently sloping alluvial-deluvial undermountainous plains in the Dry zone area and also found on the lowest parts of the slopes in the Shan Plateau. The physical properties of these soils are very favorable and in spite of being sandy they are pervious and not heavy to work. They generally have good fertility which is connected with their position in the under mountainous plains, and there is a permanent supply of nutrients from the surrounding mountains by the surface run-off. These soils are suitable for the cultivation of Ya crops (dry cropping on uplands).

3.2.7 Red Earths and Yellow Earths (Acrisol)

The Red Earths soils are the most dominating soils of Shan Plateau and of the northern mountainous region at the elevation of more than 3000 feet above sea level. The Shan Plateau is about completely covered with these soils. They are well drained and easy to plough. The soil reaction is slightly acid to neutral with pH ranging from 6 to 7. However, the Yellow Earths soils are more acidic and have more clay percentage. Iron and alluminium contents are also very high. The humus contents of Yellow Earths are more than that of the Red Earths. The soils are deficient in nitrogen and phosphorus. The content of potassium is high in the Red Earths. The Red Earths is the typical soils for agriculture in Shan state. They are well drained, having good structure and easy to plough so they are very suitable for cultivation of seasonal and perennial crops. However, due to relief and slopes, erosion control measure are required. The Yellow Earths soils can only be utilized for gardens, flowers and forests.

3.2.8 Mountainous Yellow Brown and Red Brown soils (Histic Cambisol and Chromic Cambisol)

These soils occur on the mountainous terrain at the elevation from 4000 to 6000 feet in the Shan Plateau. The soils should be under forest. Forest conservation and soil erosion control measures are very important for these soils.

3.2.9 Chin Hills Complex (Orthic Cambisol) and Turfy Primitive and Primitive Crushed stones (Lithosol)

These soils are found on the high mountainous belt of he Chin Hills at the elevation of 4000 to 6000 feet above sea level. These soils are less structured having bedrock in the lower horizons so in the rainy season, there happens to be any dnager of landslide. These soils are only suitable for forest conservation and plantation crops.

These soils widely occur in the area of low hills and sharpest and eroded slopes of the eastern side Rakhine Yoma in Magway Region. These territories are covered with the open cover of low shrubs with spines and sparse dry grasses. The surface layer of the soils is just a mixture of crushed stones with some quantity of slightly humisified fine earth. The surface is often covered with crushed sand stone and lime concretions. These soils are totally unsuitable for cultivation. and should only be used for forests.

3.2.10 Alpic complex (Gelic Cambisol) and Northern Hills Complex (Orthic Cambisol)

These soils occur in the nothern most area of Myanmar within Putao District at the elevation of 6000 to 10,000 feet above sea level where there are the tops of the mountains covering with snow for the whole year so they should be preserved for the picturesque resources of the country.

These soils occur on the very high northern mountainous region within of Myitkyina areas. They can only be utilized for forest conservartion. Soil conservation is necessary to be undertaken for these soils.

4. Materials and Methods

4.1 Study site based on forest soil classification

This study was carried out by using a forest cover status map of Myanmar (2000, FD), soil map of Myanmar (Myanmar agriculture service), Distribution of soil based on forest type (modified after Rozanov, 1965), Burma Rock Types, Geology map of Burma (Table-1). Nine forest soil type were identified on the map photographs; vegetation types via: Evergreen forest, Moist upper mixed deciduous forest (MUMD), Dry upper mixed deciduous forest (DUMD), Lower mixed deciduous forest (LMD), Hill forest (broadleaf forest type), semi-indaing, mangrove forest, dry forest and thorn forest. Location of study area can be seen in figure 1.

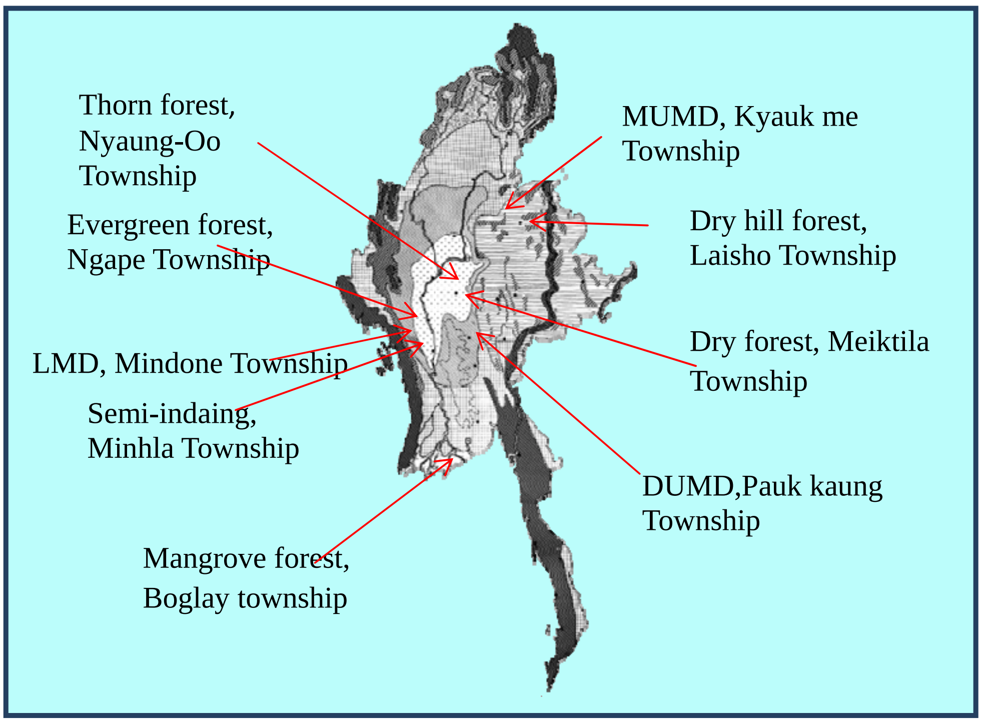


Table.1 **- Soil sample sites in relation to parent material, topography, mean annual rainfall and forest types**

No.	Forest type	Slope %	Forest type *	Terrain regions	Geology age **	Rock type ***
1	Evergreen forest	23	Tropical wet evergreen forests	Magwe Region	Eocene – flysch type units (along western ranges)	hard rock- soft sand stone, limestone, shale and conglomerate
2	MUMD	16	Tropical moist deciduous forests	Shan Highlands	Eocene a molasses type units (along central belts)	limestone and dolomite
3	LMD	10	Tropical moist deciduous forests	Magway Region	Miocene- Pliocene Irrawaddy formation and its equivalents	Soft rock- sand stone, limestone, shale and conglomerate
4	DUMD	12	Tropical dry deciduous forests	Bago Yoma	Cainozoic- Oligocene Central province	Soft rock- sand stone, limestone, shale and conglomerate
5	Semi-indaing	10	Sub tropical dry forests	Western mountains and BogaYoma	Cainozoic- Oligoncene Central province	Soft rock- sand stone, limestone, shale and conglomerate
6	Hill forest	8	Sub Tropical moist hill forest	Shan- Taninthayi Highlands	Mezosonic Uorassic cretaceous Kalaw red bed and its equivalent	Lime stone & dolomite
7	Mangrove forest	2	Salty muds of tropical mangrove forest	Ayeyawady Delta- sittaung valley	Q2Holocene- Alluvium	Bed rock continuously covered by as least 6 m of soil
8	Dry forest	3	Tropical dry savannas forest	Central Myanmar Dry zone	Cainozoic- Mocene undifferentiated Central province	hard rock- sand stone, limestone, shale and conglomerate
9	Thorn forest	4	Dry Diospyros Forest	Central Myanmar Dry zone	Cainozoic- Mocene undifferentiated Central province	hard rock- sand stone, limestone, shale and congiomerate

sources - * - ***climate- average weather of Myanmar (http;www// climatemps.com)***
*****- Geological Map Of Myanmar (2008); ***- Burma rock types***

Mean Annual Rainfall MAR are estimated from Meteorological Service isohyet maps and hence are approximate only for differing forest types. Moreover soil types in table 2 have been classified according to both Great Soil groups (FAO/ UNESO) and the Myanmar Forest Soil Classification.

The different forests soil by dominant spp at the study sites are selected by local govermment staff under forst department in appendix II.

Table.2 **- Soil classification and vegetation types in sample sites**

No	Type of forest	Soil classification		
		Myanmar	**Fao (UNESCO)**	**USDA Soil Group**
1	Evergreen	Red Brown Forest Soil	Cambisol	Inceptisol
2	MUMD	Red Brown Forest Soil	Rhodic Ferralsols	Oxisol
3	LMD	Yellow Brown Forest Soil	Xanthic Ferrasol	Oxisol
4	DUMD	Brown dry forest soil	Nitosotols	Utisol (Humic)
5	Semi-indaing	Yellow Brown dry forest soil	Xanthic Ferrasols	Oxisol
6	Hill forest	Yellow earth and Red earth	Ferric Acrisols	Inceptisol
7	Mangrove	Mangrove forest soil	Thionic Fluvisol	Entisol
8	Dry forest	Reddish Brown Dry Forest Soil	Luvisols	Alfisol
9	Thorn forest	Red brown forest soil	Vertisols	Vertisol

4.2 Soil sampling and analysis

Soil samples were collected from three points in each forest soil types, using soil auger or tool and collected in polythene bags. This study examined the variation in the physio-chemical properties of soils. Soil samples were taken at five depths 0-10, 20-30, 40-50, 60-70, 80-90cm and site features and soil-profile. Chemical analyses include pH and levels of organic carbon (C), organic matter, C-N ratio, total nitrogen (N),total phosphorus (P), extercable potassium and calcium. The physical properties included for all soils are the proportion of partical size distribution, colour, structure and bulk density. The soil tests were conducted at Forest Research Institute of Yezin. Laboratory analytical methods are given; -

List of Soil Variables Used in the Analysis

Soil Variable	Method of Determination
1. Sand , Silt and Clay (%)	Pipeting
2. Organic matter (%)	Ignection
3. Total nitrogen (%)	Kjeldahl method (Brenner 1960)
4. Av. Phosphorus (%)	Blue Method
5. Exchangeable Ca++ (%)	Atomic Absorption spectrophotometer method
6. Exchangeable K (%)	Atomic Absorption spectrophotometer method
7. PH	Determined in water 1: 2.5

Simple statistical analyses were used to compare the soil properties under the different vegetation types. The statistical mean and the analysis of variance were used to ascertain whether the differences in these soil properties were significantly different. A single-tailed Pearson correlation coefficient was calculated between various soil physical and chemical parameters using SPSS-16 software.

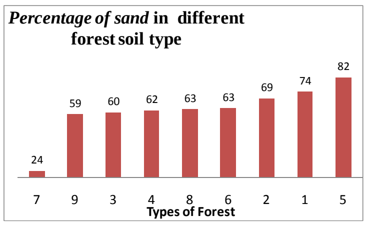
5. Results and Discussions

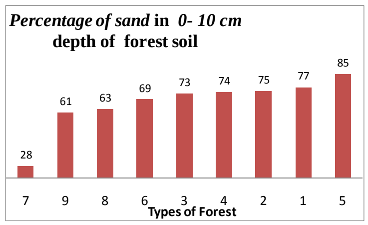
5.1. Soil physical properties of differnet soil layers with various forest types

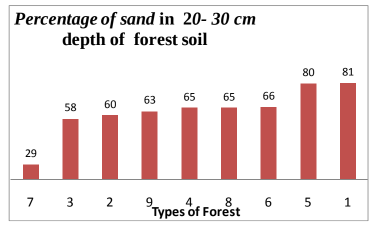
Some clear trends profile morphology under different forest types are shown in appendix III. Soils formed under evergreen forest generally has small protion of O layer and A and B horizon sequences, few firm or weak subsoil strength and good permeability. Textures are dominated by sandy loams, loamy sands in upper layers, overlying clay loam in lower layers. Subsoils typically have granular structure. In the other, subsoils of MUMD, DUMD, LMD and Hill forests soil are characterised by angular structure (see fig. 2-10) in appendix I). And semi-indaing forest sub-soil are occured in platy structure. Table 3. shows the summary of sand compostition in different forest soil types. Sand compositions of the mangrove soils are significant differences on one hand and that of semi-indaing forest on the other (see in chart). Sand and clay or silt composition of MUMD , DUMD, LMD and hill forest were not statistically different. The high proportion of sand in the soils may be attributed to the fact most of the soils in the area are developed from sandy ridges and deposits as rock types. The predominance of sand and the low proportions of silt and clay in the soils may be due to erosion and leaching and it leads to the removal and loss of minerals especially clay minerals from the soil profile. The amount of silt is small being usually under 15% for MUMD and semi-indaing forest.

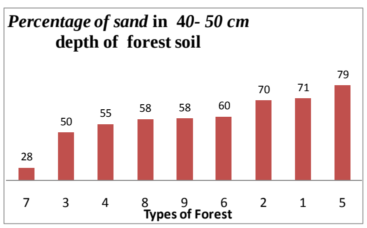
Table.3 **- Summary result of sand composition in different soil layers**

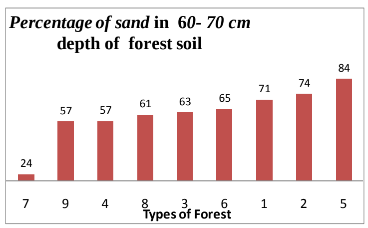
Types of forest	Label no.	0- 10 cm		20-30 cm		40-50 cm		60-70 cm		80-90 cm		Forest type	
		Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E
Evergreen	1	77 bc	7	81 c	1	71 bc	3	71 bc	1	68 bc	1	74 cd	1
MUMD	2	75 bc	3	60 bc	13	70 bc	1	74 bc	3	68 bc	2	69 cd	1
LMD	3	73 bc	3	58 b	1	50 ab	2	63 bc	2	58 b	6	60 bc	5
DUMD	4	74 bc	7	65 bc	1	55 bc	14	57 b	14	57 b	8	62 bc	4
Semi- indaing	5	85 c	1	80 c	0	79 c	2	84 c	3	84 c	2	82 e	1
Hill forest	6	69 bc	5	66 b	0	60 bc	12	65 bc	13	59 b	3	63 bc	4
Mangrove	7	28 a	4	29 a	3	28 a	4	24 a	3	11.a	4	24 a	2
Dry forest	8	63 b	12	65 bc	6	58 bc	10	61 bc	10	65 bc	14	63 bc	2
Thorn forest	9	61 b	3	63 bc	11	58 bc	3	57 b	5	56 b	6	59 b	2

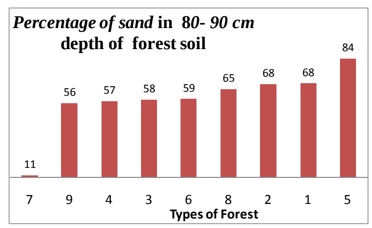












5.2 Soil chemical properties under differnet soil layers

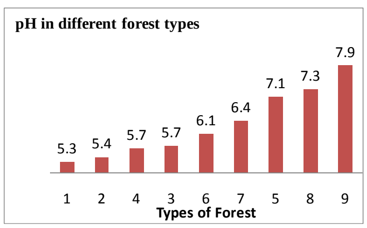
There are consistent trends in chemical properties among different soil layer in each forests soils in appendix IV . However, there are marked differences in the various forest types in appendix V. Higher different concentrations of total N, Organic C, C:N, OM and Ca and to a lesser extent in extractable K and low levels of avabile P occur in all soil types. Levels of total N are low (< 0.07 %) in surface layers under semi- indaing, hill forest and dry forest. Higher levels of total N and OM throughout the soil profiles among the forests reflect great accumulation of soil organic matter due to greater leaf litter accumulation from the predominantly broadleaved understorey and higher productivity. This higher input of organic matter is incorportated into the soil through the more active microbial decompostion and mixing by soil fauna under the forest.

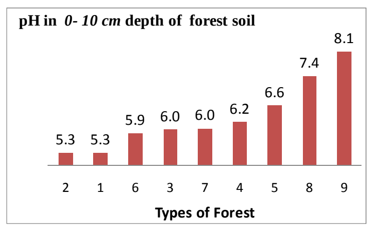
5.2.1 pH (Soil reaction)

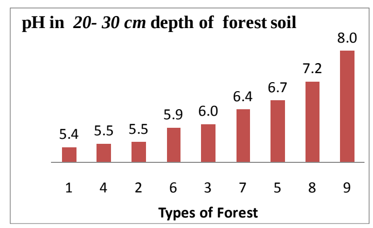
The soils are generally slightly acid to slightly base with mean values ranging from 5.2 to 8.1 (in water 1:2.5). The mean pH of dryforests is significantly higher than that of the others and therefore relatively more base. Soils in Evergreen recorded the lowest pH value of 5.2 while salty soils in dry forest had the highest value of 8.1. The relatively acidic nature of forest soil may be possibly the release of organic acids as a result of decomposition of organic compounds based on types of forest. There are no significant differences between MUMD, LMD and DUMD in table 4. pH in upper portion of forest soil is a few higher than that of lower depth among the forests in figure. The generally low level of acidity in the soils may be attributed to the sandy nature of the soils and the low clay contents of the soils.

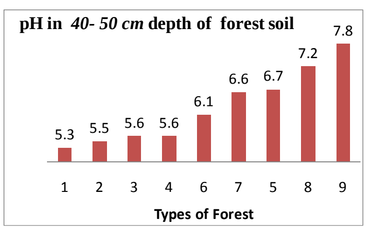
Table.4 **- Soil reaction at various depths in the different forest types**

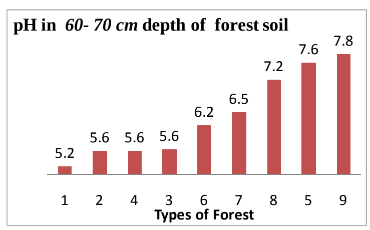
Types of forest	Label no.	0- 10 cm		20-30 cm		40-50 cm		60-70 cm		80-90 cm		Forest type	
		Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E
Evergreen	1	5.3 a	0.09	5.4 a	0.13	5.3 a	0.04	5.2 a	0.12	5.2 a	0.39	5.3 a	0.08
MUMD	2	5.3 a	0.09	5.5 a	0.46	5.5 ab	0.03	5.6 ab	0.1	5.3 a	0.17	5.4 ab	0.04
LMD	3	6.0 ab	0.07	6.0 ab	0.15	5.6 ab	0.35	5.6 ab	0.07	5.5 ab	0.34	5.7 bc	0.11
DUMD	4	6.2 ab	0.49	5.5 a	0.06	5.6 ab	0.17	5.6 ab	0.4	5.5 a	0.19	5.7 b	0.16
Semi- indaing	5	6.6 bc	0.3	6.7 cd	0.2	6.7 cd	0.29	7.6 d	0.09	7.8 e	0.09	7.1 e	0.06
Hill forest	6	5.9 ab	0.45	5.9 ab	0.15	6.1 bc	0.1	6.2 b	0.07	6.3 bc	0.1	6.1 c	0.16
Mangrove	7	6.0 ab	0.47	6.4 bc	0.31	6.6 cd	0.35	6.5 bc	0.42	6.6 cd	0.34	6.4 d	0.22
Dry forest	8	7.4 cd	0.15	7.2 d	0.06	7.2 de	0.07	7.2d	0.62	7.3 de	0.65	7.3 e	0.04
Thorn forest)	9	8.1 d	0.06	8.0 e	0.12	7.8 e	0.03	7.8 d	0.09	8.0 e	0.09	7.9 f	0.05

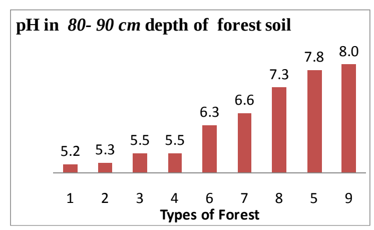










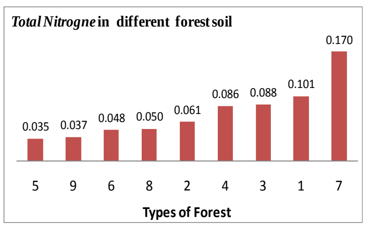


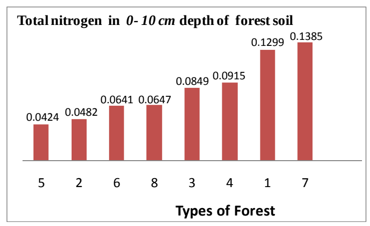
5.2.2 Nitrogen

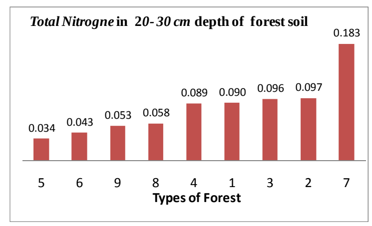
Nitrogen is an essential element for all growth processes in plants, if it is not available, the plant remains stunted and comparatively undeveloped. Soil N is supposed to be the most limiting nutrient in a majority of forest ecosystems (Fenn et al. 1998). The values of total N varied significantly in different forest types. Values of total N in the study area ranged between 0.034 and 0.18 % in table 5. Total amount of Nitrogen in Evergreen and Mangrove are higher than in others forests types. As C and N are intimately linked and primary source of C and N is found in the soil as an organic matter, in the form of plants and animal's debris (Aber and Melillo 1991), total N showed a significantly positive relationship with organic C or organic matter in this study. The values of total N in the upper layer is higher as compared to lower layers (in figure) , according to present of N ,in the form of nitrates in the soil , it is very mobile and get moved freely with moisture (Gupta and Sharma 2008). This can be attributed to higher water holding capacity and the presence of heavy litter and humus contents of the these layers. Therefore the high amount of organic matter in the forest types may also be the reason for richness of N as compared to lower layers.

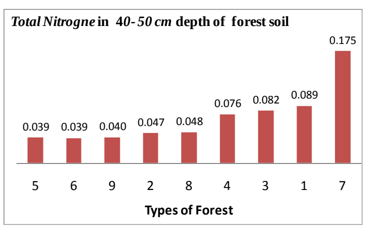
Table.5 **- Amount of nitrogen at various depths in the different forest types**

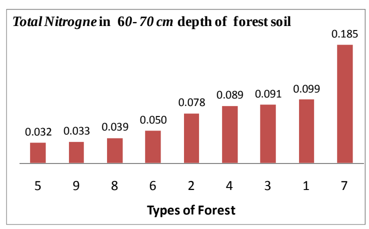
Types of forest	Label no.	0- 10 cm		20-30 cm		40-50 cm		60-70 cm		80-90 cm		Forest type	
		Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E
Evergreen	1	0.1299 de	0.004	0.0895 b	0.007	0.0891 b	0.006	0.0988 c	0.0015	0.0978 b	0.002	0.101 e	0.003
MUMD	2	0.0482 abc	0.014	0.0973 b	0.004	0.0468 a	0.011	0.0777 bc	0.004	0.0338 a	0.009	0.0608 c	0.007
LMD	3	0.0849 bc	0.004	0.0961 b	0.005	0.0815 b	0.009	0.0915 c	0.001	0.0859 b	0.003	0.088 de	0.002
DUMD	4	0.0915 cd	0.01	0.0891 b	0.002	0.0761 b	0.008	0.0891 a	0.017	0.0827 b	0.011	0.0857 d	0.005
Semi- indaing	5	0.0424 ab	0.024	0.0336 a	0.007	0.0393 a	0.003	0.0315 a	0.01	0.0279 a	0.004	0.0349 a	0.007
Hill forest	6	0.0641 ab c	0.001	0.043 a	0.002	0.039 a	0.002	0.0502 bc	0.003	0.0461 a	0.009	0.0483 abc	0.003
Mangrove	7	0.1385 e	0.009	0.1828 c	0.009	0.1752 c	0.006	0.1849 d	0.003	0.1694 c	0.003	0.1702 f	0.003
Dry forest	8	0.0647 abc	0.029	0.0577 a	0.018	0.0483 a	0.008	0.039 a	0.016	0.0407 a	0.009	0.0501 bc	0.006
Thorn forest	9	0.0333 a	0.002	0.0533 a	0.003	0.0403 a	0.004	0.0333 a	0.009	0.0267 a	0.005	0.0374 ab	0.006

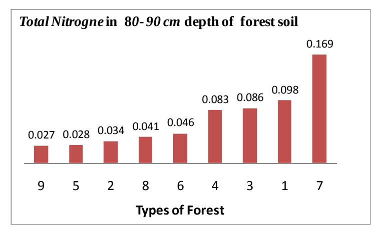












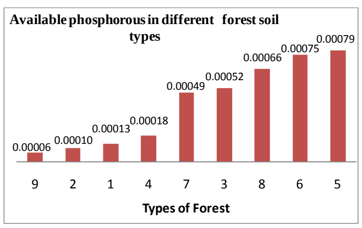
5.2.3 Phosphorus

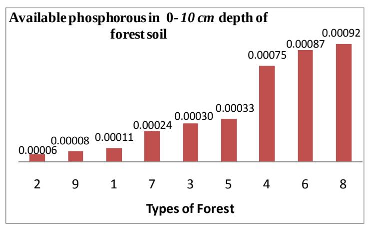
Available P is inevitable for the vital growth processes in plants. It is observed that P is found in all terrestrial systems in the form of organic and inorganic matter, while organic P forms are the major available source of phosphorus. Soil organic matter has the inorganic form of P transformed into insoluble form in many soils. The rates of weathering also control phosphorus availability to plants. Phosphorus in turn controls the input levels of plant residues (Brown et al. 1994).

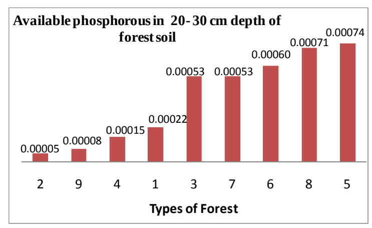
To identify the vegetation type of the area, the amount of P indicates the character of soil to allow specific plants to grow at a particular site. However, values of available P ,between 0.00004 in mangrove and 0.0011 % in different forest type, in the study area can not easily to assess for this point. Available P with lower amount was non- significant among forest types and also layers and no correlated with other nutrients in this study site (in table 6). In hill forest, dry forest and semi-indaing forest soil available P is higher than other forests.

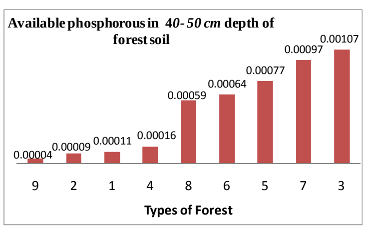
Table.6 - Phosphorous content at various depths in the different forest types

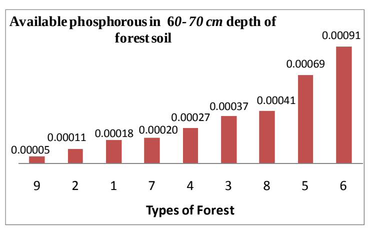
Types of forest	Label no.	0- 10 cm		20-30 cm		40-50 cm		60-70 cm		80-90 cm		Forest type	
		Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E
Evergreen	1	0.00011 a	0.00012	0.00022 a	0.00063	0.00011 a	0.00054	0.00018 a	0.00013	0.00007 a	0.00002	0.00013 a	0.00012
MUMD	2	0.00006 a	0.00008	0.00005 a	0.00019	0.00009 a	0.00008	0.00011 a	0.0001	0.00013 a	0.00059	0.00010 a	0.00003
LMD	3	0.00030 a	0.00049	0.00053 a	0.00007	0.00107 a	0.00001	0.00037 a	0.00006	0.00033a	0.00004	0.00052 a	0.00013
DUMD	4	0.00075 a	0.00068	0.00015 a	0.00012	0.00016 a	0.00067	0.00027 a	0.00016	0.00008 a	0.00007	0.00018 a	0.00023
Semi- indaing	5	0.00033 a	0.00007	0.00074 a	0.00001	0.00077 a	0.00055	0.00069 a	0.00009	0.00085 a	0.00018	0.00079 a	0.00001
Hill forest	6	0.00087 a	0.00012	0.00060 a	0.00051	0.00064 a	0.00057	0.00091 a	0.00002	0.00086 a	0.00002	0.00075 a	0.00008
Mangrove	7	0.00024 a	0.00012	0.00053 a	0.00022	0.00097 a	0.00024	0.00020 a	0.00047	0.00040 a	0.00006	0.00049 a	0.00004
Dry forest	8	0.00092 a	0.00001	0.00071 a	0.00024	0.00059 a	0.00004	0.00041 a	0.00089	0.00065 a	0.00084	0.00066 a	0.00026
Thorn forest)	9	0.00008 a	0.00002	0.00008 a	0.00002	0.00004 a	0.00001	0.00005 a	0.00016	0.00007 a	0.00011	0.00006 a	0.00005

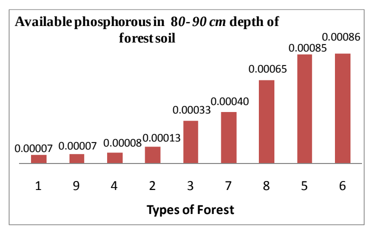












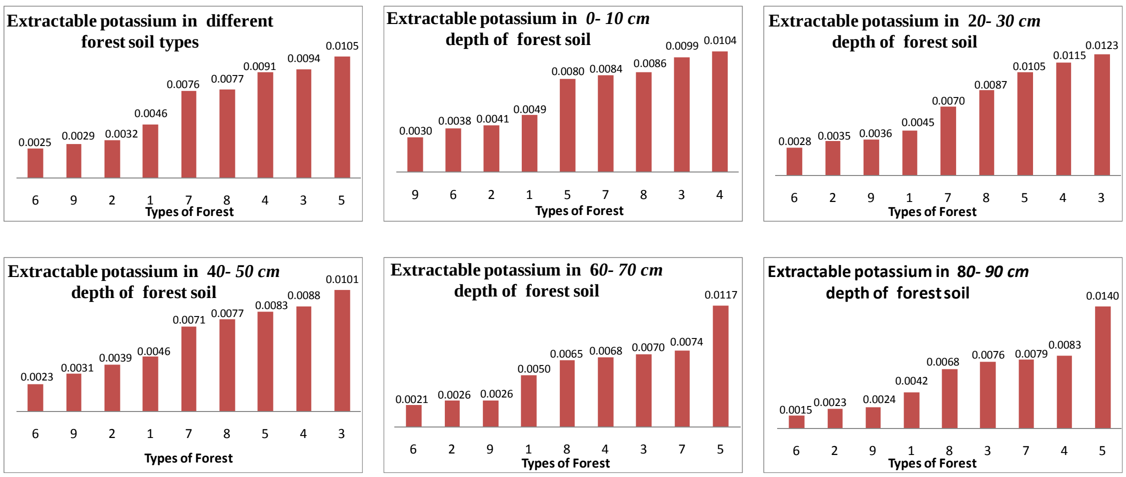
5.2.4 Potassium

The mineral potassium (exchangeable K) is found in soluble form in all parts of plants, and is responsible for the carbohydrate and protein formations. Potassium performs very vital processes like regulating transpiration and respiration, influencing enzyme action, and synthesis of carbohydrates and proteins.

Table.7 - Potassium content at various depths in the different forest types

Types of forest	Label no.	0- 10 cm		20-30 cm		40-50 cm		60-70 cm		80-90 cm		Forest type	
		Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E
Evergreen	1	0.0049 a	0.0038	0.0045 ab	0.0053	0.0039 ab	0.0012	0.005 ab	0.0056	0.0042 a	0.0059	0.0046ca	0.002
MUMD	2	0.0041 a	0.002	0.0035 ab	0.0009	0.0101 b	0.0005	0.0026 a	0.0009	0.0023a	0.0007	0.0032 a	0.0008
LMD	3	0.0099 a	0.0012	0.0123 c	0.0008	0.0046 ab	0.0054	0.007 ab	0.0031	0.0076 ab	0.0006	0.0094 bc	0.0004
DUMD	4	0.0104 a	0.0007	0.0115 c	0.0011	0.0088 ab	0.0011	0.0068 ab	0.0008	0.0083ab	0.0004	0.0091 bc	0.0011
Semi- indaing	5	0.008 a	0.001	0.0105 bc	0.002	0.0083 ab	0.0018	0.0117 b	0.0003	0.0140 b	0.0001	0.0105 c	0.0002
Hill forest	6	0.0038 a	0.0009	0.0028 a	0.0008	0.0023 a	0.0012	0.0021 a	0.0009	0.0015a	0.0002	0.0025 a	0.0004
Mangrove	7	0.0084 a	0.0012	0.007 abc	0.0006	0.0071 ab	0.0004	0.0074 ab	0.0003	0.0079ab	0.0036	0.0076 b	0.0003
Dry forest	8	0.0086 a	0.0044	0.0087 abc	0.0007	0.0077 ab	0.0007	0.0065 ab	0.0004	0.0068 ab	0.0003	0.0077 b	0.0008
Thorn forest	9	0.003a	0.0009	0.0036 ab	0.002	0.0031 a	0.0011	0.0026 a	0.0007	0.0024 a	0.001	0.0029 a	0.0003

Exchangable K showed a significant among forests and a non correlation with soil pH, organic matter and calcium in these studies in tabel 7. Usually, potassium in these study area are found in moderately amount with large variation. Exchangeable K in soil largely depends on the composition of parent rock material at different altitudes and sites in various parts of the soil. The decrease of K is caused by leaching and drainage.

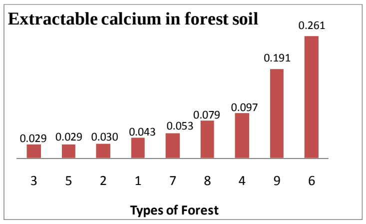


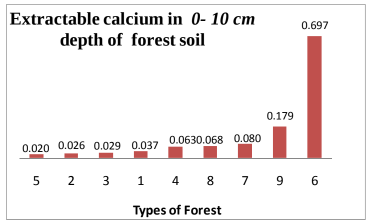
5.2.5 Calcium

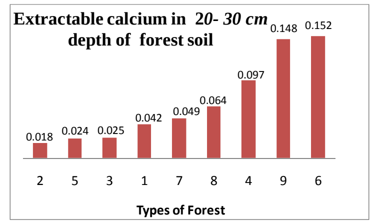
The content of exchangeable calcium was significant difference among the layers but also vegetation types. Overall the least calcium was in Mangrove forest soil. Increase in calcium under vegetation was 0.027 to .221 % in table 8. Lower increase was in surface layer as compared to higher ones. The lower values in forest type can be found in high rainfall region then leaching of the bases from the soils resulting in low pH and coarse textrer. Howerer, the higher value of calcium in hill forest soil due to presence of limestone parent material.

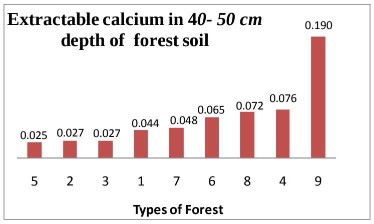
Table.8 **- Calcium content at various depths in the different forest types**

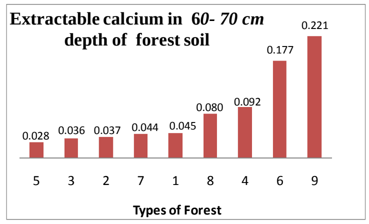
Types of forest	**Label no.**	**0- 10 cm**		**20-30 cm**		**40-50 cm**		**60-70 cm**		**80-90 cm**		**Forest type**	
		Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E
Evergreen	1	0.037 a	0.004	0.042 ab	0.008	0.044 a	0.009	0.045 a	0.009	0.045 ab	0.01	0.043 a	0.003
MUMD	2	0.026 a	0.001	0.018 a	0.005	0.027 a	0.005	0.037 a	0.011	0.041 ab	0.008	0.03 a	0.003
LMD	3	0.029 a	0.004	0.025 a	0.002	0.027 a	0.006	0.036 a	0.004	0.026 a	0.007	0.029 a	0.002
DUMD	4	0.063 a	0.003	0.097 bc	0.018	0.076 a	0.008	0.092 ab	0.009	0.158 cd	0.022	0.097 ab	0.01
Semi- indaing	5	0.02 a	0.003	0.024 a	0.005	0.025 a	0.006	0.028	0.004	0.048 ab	0.016	0.029 a	0.004
Hill forest	6	0.697 b	0.479	0.152 c	0.03	0.065 a	0.027	0.177 bc	0.079	0.217 d	0.052	0.261 c	0.102
Mangrove	7	0.08 a	0.035	0.049 ab	0.036	0.048 a	0.037	0.044 a	0.033	0.046 ab	0.034	0.053 a	0.014
Dry forest	8	0.068 a	0.006	0.064 ab	0.003	0.072 a	0.007	0.08 a	0.001	0.112 bc	0.017	0.079 a	0.006
Thorn forest	9	0.179 a	0.035	0.148 c	0.033	0.19 b	0.035	0.221 c	0.006	0.219 c	0.006	0.191 bc	0.012

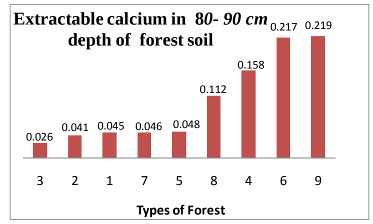










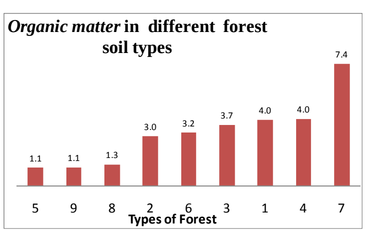


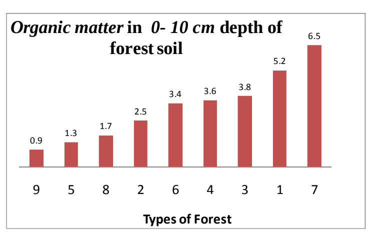
5.2.6 Soil Organic Matter (SOM) and Organic Carbon

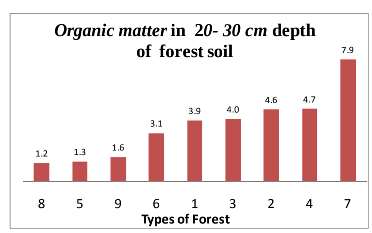
SOM in the form of surface residues can also influence water retention directly by reducing evaporation rates and increasing the infiltration of water. Its impact on soil biology is even more enormous. Most soil organisms are heterotrophic and gain their energy from the decomposing SOM. The quality and quantity of SOM therefore determine the production potential of the soil. The values of organic matter in the study area ranged between 0.8 % in dry forests and 7.9 % in mainly mangrove forest type in table 9.

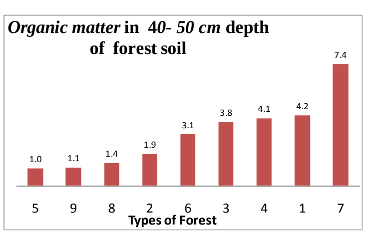
Table.9 **- Organic matter at various depths in the different forest types**

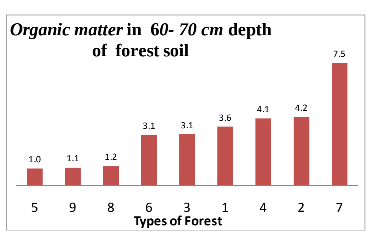
Types of forest	**Label no.**	**0- 10 cm**		**20-30 cm**		**40-50 cm**		**60-70 cm**		**80-90 cm**		**Forest type**	
		Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E
Evergreen	1	5.2de	0.4	3.9 c	0	4.2 c	0.4	3.6 b	1.3	3.0 c	0.3	4 c	0.1
MUMD	2	3.8cd	1.6	4.6 c	0.1	1.9 ab	0.9	4.2 b	0	1.8 b	0.3	3 b	0.4
LMD	3	2.5 abc	0.5	4 c	1.3	3.8 c	0.7	3.1 b	0.1	3.7 d	0.1	3.7 bc	0.4
DUMD	4	1.3 a	0.1	1.3 ab	0.3	1a	0.2	1.3 a	0.3	0.8 a	0.2	1.1 a	0.3
Semi- indaing	5	3.6bcd	0.1	4.7 c	0.1	4.1c	0.1	4.1 b	0.1	3.7 d	0.1	4 c	0.1
Hill forest	6	6.5 e	0.1	3.1 bc	0.6	3.1 bc	0.2	3.1 b	0.2	3.4 cd	0.2	3.2 b	0.1
Mangrove	7	3.4 bcd	0.1	7.9 d	0.4	7.4 d	0.1	7.5 c	0.1	7.6 d	0.1	7.4 c	0.1
Dry forest	8	1.7 ab	0.6	1.2 ab	0.3	1.4 a	0.6	1.2 a	0.7	1.0 a	0.2	1.3 a	0.3
Thorn forest	9	0.9a	0.5	1.6 a	1	1.1a	0.1	1.1 a	0.2	0.9 a	0	1.1a	0.2

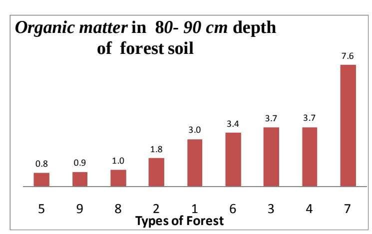












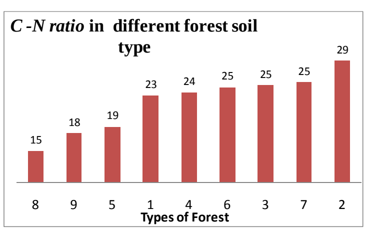
Organic matter was also comparatively higher in mixed broad-leaved forest types as well as mangrove. Generally, the increase in upper layers with increasing altitude is due to the addition of leaf litter annually and slow decomposition rates of organic residues with low temperature. Organic matter showed a positive correlation with total N and negative with exchangable Ca and soil pH. Generally the soil is rich in SOM contents, it is definitely rich in total N contents also.

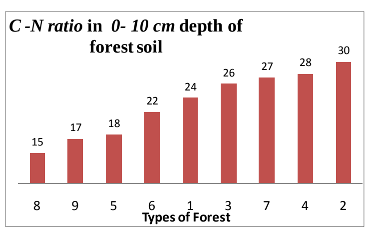
5.2.7 C:N Ratio

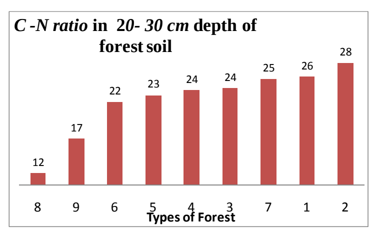
The carbon : nitrogen ratio indicates the availability of carbon and nitrogen (C/N) in the soil (Miller 2001). When fresh organic material undergoes decomposition in soil, the rate of decomposition and the amount of humus formed are related to the C:N ratio of the residue. When the rate of decomposition increases as the C:N ratio narrows in the soil. The vegetation influences the C:N ratio and the C:N ratio determines the stand composition (Fisher and Binkley 2000). Values of the C:N ratio in the study area ranged between 12 and 32 according to mature forest and undisturb forest types. The C:N ratio was found to be significantly and negatively correlated with total N in table 10. C and N may be affected by stand age, species composition, and soil properties.

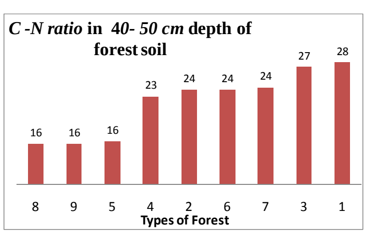
Table.10 **- C: N ratio at various depths in the different forest types**

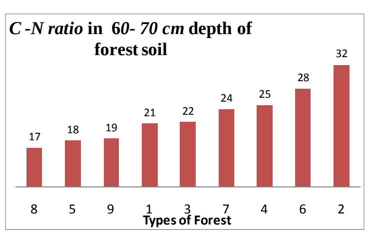
Types of forest	Label no.	0- 10 cm		20-30 cm		40-50 cm		60-70 cm		80-90 cm		Forest types	
		Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E	Mean	S E
Evergreen	1	24 bc	2	26 c	1	28 b	1	21 ab	1	18 a	4	23c	1
MUMD	2	30 c	3	28 c	1	24 b	1	32 c	1	30 d	1	29 d	1
LMD	3	26 c	2	24bc	3	27 b	2	22 ab	1	26 cd	3	25 c	1
DUMD	4	28c	3	24 bc	1	23 ab	2	25 abc	2	20 ab	4	24 c	1
Semi- indaing	5	18 ab	3	23 bc	2	16 a	1	18 a	1	17 a	1	19 b	2
Hill forest	6	22 abc	2	22 bc	3	24 ab	5	28 bc	1	28 d	1	25 c	1
Mangrove	7	27 c	3	25c	4	24ab	4	24 abc	2	26 cd	2	25 c	1
Dry forest	8	15a	3	12:00 AM	2	16 a	2	17 a	3	15 a	1	15 a	1
Thorn forest	9	17ab	0	17 ab	3	16 a	1	19 a	6	19 ab	1	18 b	1

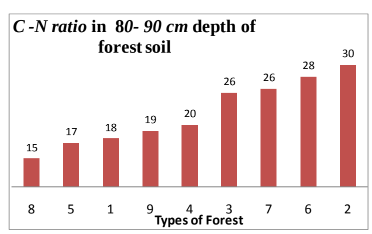












6. Conclusion and Recommendations

Red brown forest soil is found in evergreen forest. The soil is shallow on the slopes. Evergreen forest soil are generally well-structured and range in texture from sandy clay loams to loamy sand, with a slightly acid soil reaction and are moderately supplied with nitrogen. The soil in MUMD occurs on well-drained slopes and usually indicates a good quality of soil and DUMD- stiff soil and LMD- alluvial and sully clayey and are found on deep, porous soils and well drain slopes. The commonly associated soil in semi-indaing forest is sandy to gravely clay soil with platy structure. Red and yellow earth soil in Hill forest has developed on limestone. They are generally deep and lower portion is compact. They have a moderate supply of nutrients expect in potassium and phosphorous. Dry and thorn forest occur in yellow brown and red brown forest soils. The soils are poor in nitrogen and phosphorous, but possess adequate amounts of potassium. They are neutral to alkaline in reaction and their textures range from sandy loam to silty clay loam. The soils from mangrove areas has good structure and fine texture, slightly acid and had high organic matter content and high level of nutrients concentration. All nutrient contents is almost the same concentration with different depth.

The comparison of soils under forests shows marked differences in profile morphology and chemical properties which have important implications for forest management. Soils under forest generally have texture contrast profiles characterised by sandy top soils. Texture contrast soils have limited potential for plantation development mainly because of low nutrient status, and some are susceptible to summer moisture deficits in young stage. The soils were generally found to be lower amount in exchangeable bases. Moreover, no significant differences were found among the soils with respect to available phosphorus. The low level of exchangeable bases in the soils may be attributed to develope on base-deficient sandy ridges and deposits which results in low rate of fixed nutrients. Howerer, there were significant differences in the pH, nitrogen and organic matter contents.

The gradational soils under dry forest, MUMD and hill forests also have low nutrient status, especially phosphorous and nitrogen and / or potassium. Therefore the use of the soils for intensive planting would require specific soil test and the judicious use of inorganic chemical fertilizers, like nitrogen and phosphorous if not regional species in the area. The study revealed that the physio-chemical properties of soil in the study areas significantly vary because of the different in geology, climate and vegetation types. So further study on different forest types will be more emphasized on same conditions of geology and climate.

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Appendix I

Fig 2. Soil profile under Evergreen forest

Fig 3. Soil profile under moist upper mixed deciduous forest

Fig 4. Soil profile under Lower mixed deciduous forest

Fig 5. Soil profile under Dry upper mixed deciduous forest

Fig 6 . Soil profile under Semi-indaing forest

Fig 7. Soil profile under hill forest

Fig 8. Soil profile under Mangrove forest

Fig 9. Soil profile under dry forest

Fig 10. Soil profile under Thorn forest

Appendix II

Vegetation types in sample sites

No.	Type of forest	Location	Dominant species
1	Evergreen forest (Chintagong semi-evergreen)	Reserved forest Goke Gyi , Ngape township	Didu (*Salmalia insignis*), Letpan (*Salmalia malabarica*), Taung peinne (*Artocarpus chaplasha*), Thinga (*Hopea odorata*), Sagawa (*Michelia champaca*), Myauk ngyo (*Homalium tomentosum*), Bonmeza (*Albizzia chinensis*), Thit phyu (*Elaeocarpus floribundus)*
2	Moist upper mixed deciduous forest (MUMD)	Reserved forest, Kyauk me township	Thinwin (*Millettia pendula*), Tinwa (*Cephalostachyum pergracile),* Nabe (*Odina wodier),* Yindaik (*Dalbergia cultrata*), Ingyin(*Pentacme siamensis*), Pyinkado (*Xylia dolabriformis)*
3	Low mixed deciduous forest (LMD)	Protected forest , Shwechaung village, Mindone township	Thabye (*Eugenia spp.),* Baing (*Tetrameles nudiflora)* , Thinga (*Hopea odorata),* Sagawa *(Michelia champaca),* Gyo (*Schleichera oleosa),* Zinbyun (*Dillenia pentagyna),* Nagye (*Pterospermum semisagittalum),* Taw-thayet (*Mangifera caloneura),* Ma-U-Lettanshe (*Anthocephalus morindaefolius),* Kyathaung wa (*Bambusa polymorpha),* Tinwa (*Cephalostachyum pergracile)*
4	Dry upper mixed deciduous forest (DUMD)	Reserved forest, Pauk kaung township	Teak (*Tectona grandis),* Pyinkado (*Xylia dolabriformis),* Panga (*Terminalia chebula),* Knaw (*Asina cordifolia),* thitya (*Shorea oblongifolia),* myinwa (*Dendrocalamus strictus),* Yon (*Anogeissus acuminata),* Myaukchaw (*Homalium tomentosum*), Kyetyo (*Vitex peduncularis*), In (*Diperocarpus tuberculatus*)
5	Deciduous Dipterocarp or indaing forests (Semi-indaing)	Reserved forest , Minhla township	In (*Dipterocarpus Tuberculateus),* Ingyin (*Pentacme siamensis*), Thitya (*Shorea oblongifolia*), Teak (*Tectona grandis*), Thitsi (*Melanorrhoea usitata*), Kabaung (*Strychnos nux-balanda)*
6	Hill forest	Lwengue reserved forest, Laisho township	Laukkya (*Schima wallichii),* Chinbyit (*Bauhinia malabarica*), Taukkyan(*Terminalia crenulata),* Zinbyun (*Dillenia pentagyna),* Kyun-nalin(*Premna pyramidata),* Phankha (*Terminalia chebula),* Ma-U-Lettanshe(*Anthocephalus morindaefolius),* Yemane(*Gmelina arborea),* Kadut(*Ficus hispida)*
7	Mangrove forest	Kadonkani Reserved forest, Boglay township	kanazo(Heritiera fomes) , tayaw (Excoecaria agallocha), myinka (Cynometra ramiflora), pankthakar (Dysoxylum proeceium), byue U talone (Bruguiera gymnorhiza), yekhayar (Aegiceras corniculutum), madama(Ceriops decandra), yamana (Intsia bijuga), byuechehtaunk (Rhizophora mucronata), kyana (Xylocarpus granatum)
8	Dry forest	Reserved Forest, Meiktila Township	Kokko (*Albissia lebbek),* Nabe (*Lannea coromendelica),* Bonmeza (*Albizzia chinensis),* Magyi *(Tamarindus indica),* Thanat (*Cordia dichotoma)*
9	Thorn forest	Protected Forest, Nyaung-Oo Township	Than (*Terminalia okiveri),* Dahat (*Tectona hamiltoniana),* Cutch-sha (*Acacia catechu),* tanaung (*Acacia leucophloea)*

Appendix III

Soils in relation to horizon sequence, texture profile, soil colour and Bulky density

Forest type	Soil profile	Depth/ thickness (cm)	Horizon feature	Bulk density
1. Evegreen	O1	0-10	Dark greyish brown (10 YR 4/2) loam, moderate medium granular, very common roots, clear smooth boundary	1
	O2	10-20	Brownwish black (7.5YR 3/2) sandy clay loam, moderate common fine granular structure, non – sticky and non-plastic, few fine fragments of hard rock, very fine roots, gradual smooth boundary,	
	A2	20-40	Dark reddish brown (5YR 2/4) sandy clay, structure and rock fragments as above, very fine roots and medium roots, corse roots, diffuse smooth boundary	
	B2	40-90	Brown (7.6 YR 4/6) sandy clay, moderate common fine granular structure but on the lower portion strong medium platy structure, rock as above, few fine roots and medium roots	
2. MUMD	A1	0-30 1	Brownwish black (7.5 YR3/2) Sandy clay loam, moderate fine and very fine subangular blocky, sticky, slightly plastic, driable, slightly hard, very few medium root, many vey fine roots, few yellow spot gravelly stone, common fine distinct brownish yellow, mottling, diffuse boundary	1.2
	B1	30-90	Brown (7.5 YR4/4) clay loam to clay, weak fine and medium subangular blocky, sticky and plastic, yellow brown and red brown mottles, common very fine root,	
3. LMD	A	5-10	Small protion layer of organic matter, Browish black (10 YR 3/2) sand loam, moderate to strong fine to medium subangular blocky, slightly stickly and slightly plastic, very fine roots and medium roots gradual smooth boundry	1.2
	B	10-70	Brown (7.5 YR 4/6) sandy loam, weak fine subangular blocky structure, slightly sticky and slightly plastic,Very few fine and medium root, clear smooth boundary	
	B 3	70 -90	Yellowish brown (10 YR 5/8) clay loam, moderate very fine and fine angular bolcky, medium distinct yellowish red mottles, very sticky and very plastic, few fine root	
4. DUMD	A1	0-30	Brownwish black (7.5 YR3/2) sandy clay loam, moderate fine and very fine subangular blocky, sticky and slightly plastic, many coarse, medium and fine roots, very few, small, soft irregular yellow nodules, clear wave boundary	1.2
	A2	30-50	Reddish brown (5 YR 4/4), sandy clay loam, moderate and fine subangular blocky, common mixing of red and yellow brick stone, few red gravelly clay with coating of yellow mineral, clear slightly wave boundary, common fine and medium roots	
	A3	50-60	Bright brown (7.5 YR 5/8) clay loam, moderate fine subnagular blocky, sticky and plastic, common mixing of red and yellow brick stone, few red gravelly clay with coating of yellow mineral, black stone with coating of yellow mineral, common common fine & medium root,	
	B	60-90	Bright brown (7.5 YR 5/8) clay loam to clay, weak fine and medium subangular blocky, sticky and plastic, small, soft, irregular red & yellow nodules, very few fine root	
5.Semi-Indaing	O2	0-10	Dark brown (7.5YR 3/2) sandy loam, single grain, non sticky and non-plastic, gradual boundary	1.3
	A3	10-50	Brown (10YR 4/3) sandy clay loam, moderate very fine subangular blocky, sticky, non plastic, few decomposed rock fragments and common very fine root, few fine and medim roots, gradual boundary	
	B1	10-80	Yellowish brown (10 YR 10/8) sandy clay loamy moderate fine sbuangular blocky, sticky and slightly plastic, common subangular rock fragments, common very fine roots, medium roots and corse roots, fine distinct brownish yellow mottels, diffuse boundary	
	B2	80-90	Yellowish brown (10 YR 4/4) clay loamy, platy structure	

Forest type	Soil profile	Depth/ thickness (cm)	Horizon feature	Bulk density
6. Hill forest	A1-	0-10	Reddish brown (5 YR 4/5) clay loam, weak fine subangular blocky structure, sticky and plastic, gradual smoth boundary, common very fine roots	1.3
	A3/ B	10-30	Yellowish red (5 YR 4/6) clay loam, moderate subangular blocky, sticky and plastic, common fine distinct brownish yellow mottle, few very fine roots, gradual regular boundary,	
	B	30-90	Yellowish red (5 YR 4/7) clay loam, strong subangular blocky, abundant small red and yellow mottles, sandy clay loam, few fine root and medium root	
7. Mangrove forest	A2	0-20 cm	Uniform colour light grey (10 YR3/3), silty clay with many fine and medium yellowish red clay mottles, granular, sticky and plastic, many very fine and medium roots. Gradually smooth bounday	0.9
	A3	20-30	Dark yellowish brown (7.5YR5/4) slity clay, many fine and medium, red and grey clay mottles, graunlar, sticky and plastic, common very fine roots , clear smooth boundary	
	B	30-90	Yellowish brown (10 YR 5/4) clay loam to sandy clay, moderate granular, common medium to coarse distinct light yellowish brown mottles, common fine root	
8. Dry forest	B	0-28	Olive brown (2.5 Y 4/4) and yellowish brown (2.5 Y 5/4), sandy loam, weakly developed medium granular structure, some grass roots and diffuse boundary	1.4
	B1	28-32	Yellowish brown and bright yellowish brown (2.5 Y 6/6) dry, sand, weakly developed medium granular structure, some grass roots and diffuse boundary	
	B2	32-60	Yellowish brown (2.5 Y 5/4) moist and olive brown (2.5 Y 4/4) dry, sandy loam, some roots mostly fibrous, few mottling, trace of hard pan between 42-60cm within the horizon	
	B3	60 –90	Yellowish brown (2.5 Y 5/4) moist and olivebrown (2.5 Y 4/4) dry, sandy loam, weakly developed medium granular structure.	
9. Thron forest	B	0-20	Brown (7.5 YR 4/6) moist and brown (7.5 YR 4/6) dry, loamy sand, weakly developedmedium granular structure, loose , very gravelly.	1.4
	B1	20-40	Dull reddish brown (5 YR 4/4) moist and brown(7.5 YR 4/6) dry, loamy sand, weakly developed medium granular structure, loose, very gravelly.	
	B2	40-80	Brown (7.5 YR 4/4) moist and brown (7.5 YR 4/4)dry, loamy sand, weakly developed mediumgranular structure, loose, verygravelly	
	B3	80-90	Olive brown (2.5 Y 4/4) moist and brown (10 YR4/6) dry, loamy sand, weakly developed medium granular structure, very gravelly	

Appendix IV

Comparison of chemical properies of soils in different forest types

Types of Forest	Depth (cm)	pH	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Calcium (%)	Organic matter (%)	OC (%)	CN	Sand (%)	Silt (%)	Clay (%)
Evergreen	0-10	5.3 a	0.13 b	0.00011 a	0.0049 a	0.045 a	5.2 c	3 c	24 abc	77 a	12.0 a	6.0 a
	20-30	5.4 a	0.090 a	0.00005 a	0.0045 a	0.042 a	3.9 b	2.3 b	26 bc	81 a	9.0 a	8.0 a
	40-50	5.3 a	0.089 a	0.00009 a	0.0046 a	0.042 a	4.2 b	2.5 b	28 c	71 a	13.0 a	15 a
	60-70	5.2 a	0.099 ab	0.00011 a	0.005 a	0.046 a	3.6 ab	2.1 ab	21 ab	71 a	10.0 a	15 a
	80-90	5.2 a	0.098 ab	0.00013 a	0.0042 a	0.038 a	3.0 a	1.7 a	18 a	68 a	12.0 a	14.0 a
MUMD	0-10	6.0 a	0.085 a	0.0003 a	0.0099 ab	0.027 a	3.8 a	1.8 a	22 a	73 a	7.0 a	19 a
	20-30	6.0 a	0.096 a	0.00053 a	0.0123 b	0.031 a	4 a	2.1 a	24 a	58 a	7.0 a	33 a
	40-50	5.6 a	0.082 a	0.00107 a	0.0101 ab	0.031 a	3.8 a	2.2 a	26 a	50 a	7.0 a	42 a
	60-70	5.6 a	0.091 a	0.00037 a	0.007 a	0.03 a	3.1 a	2.3 a	26 a	63 a	7.0 a	30 a
	80-90	5.5 a	0.086 a	0.00033 a	0.0076 ab	0.025 a	3.7 a	2.3 a	27 a	59 a	9.0 a	32 a
LMD	0-10	5.3a	0.048 a	0.00006 a	0.0041a	0.038 a	2.5 a	1.4 a	30 a	75 a	12 a	13 ab
	20-30	5.5a	0.097 b	0.000217 a	0.0035 a	0.032 a	4.6 b	2.7 b	28 ab	60 a	23 a	8 a
	40-50	5.5a	0.046 a	0.000107 a	0.0039 a	0.036 a	1.9 a	1.1 a	24 a	70 a	10 a	21 bc
	60-70	5.6a	0.077 b	0.00018 a	0.0026 a	0.024 a	4.2 b	2.4 b	32 a	74 a	12 a	11 a
	80-90	5.3 a	0.033 a	0.000067a	0.0023 a	0.021 a	1.8 a	1.0 a	30 a	68 a	9 a	22 c
DUMD	0-10	6.2 a	0.091 a	0.00033 a	0.0104 a	0.029 a	3.6 a	2.1 a	20 a	74 a	16.0 a	11 a
	20-30	5.5 a	0.089 a	0.00053 a	0.0115 a	0.025 a	4.7 a	2.7 a	23 a	65 a	17.0 a	17 a
	40-50	5.6 a	0.076 a	0.00097 a	0.0088 a	0.026 a	4.1 a	2.4 a	24 a	55 a	20.0 a	24 a
	60-70	5.6 a	0.089 a	0.0002 a	0.0068 a	0.021 a	4.1 a	2.4 a	25 a	57 a	18.0 a	25 a
	80-90	5.5 a	0.083 a	0.0004 a	0.0083 a	0.045 a	3.7a	2.2 a	28 a	58 a	18.0 a	24 a
Sem-indagin	0-10	6.6 a	0.042 a	0.00075 a	0.008 a	0.074 a	1.3 b	0.8 b	18 a	85 b	6.0 ab	7.0 a
	20-30	6.7 a	0.034 a	0.0006 a	0.0105 a	0.096 a	1.3 b	0.7 b	23 a	80 ab	5.0 a	14 b
	40-50	6.7 a	0.039 a	0.00064 a	0.0083 a	0.077 a	1 ab	0.6 ab	16 a	79 a	8 b	13 b
	60-70	7.6 a	0.032 a	0.00091 a	0.0117 a	0.108 a	1 ab	0.6 ab	18 a	84 ab	7ab	9 ab
	80-90	7.8 a	0.028 a	0.00086 a	0.0140 a	0.129 a	0.8 a	0.5 a	17 a	84 ab	6 ab	10 ab
Hill forest	0-10	5.9 a	0.092 c	0.00024 a	0.0038 b	2.091 b	3.4 a	2.0 a	22 a	69 b	15.0 a	15 a
	20-30	5.9 a	0.082 bc	0.00015 a	0.0028 ab	0.455 a	3.1 a	1.8 a	22 a	66 ab	14.0 a	18 ab
	40-50	6.1 ab	0.075 ab	0.00016 a	0.0023 ab	0.194 a	3.1 a	1.8 a	24 a	58 a	13.0 a	26 b
	60-70	6.2 ab	0.065 a	0.00027 a	0.0021 ab	0.53 a	3.1 a	1.8 a	28 a	65 ab	13.0 a	22 ab
	80-90	6.3 b	0.07ab	0.00008 a	0.0015 a	0.65 a	3.4 a	1.9 a	28 a	57 a	16.0 a	25 b
Mangrove	0-10	6.0 a	0.138 a	0.00087 a	0.0084 a	0.08 a	6.5 a	3.8 a	24 a	28 a	33.0 a	36 a
	20-30	6.4 a	0.183 a	0.00074 a	0.007 a	0.049 a	7.9 a	4.2a	24 a	29 a	32.0 a	41 a
	40-50	6.6 a	0.175 a	0.00077 a	0.0071 a	0.049 a	7.4 a	4.4 a	25 a	28 a	43.0 a	28 a
	60-70	6.5 a	0.185 a	0.00069 a	0.0074 a	0.044 a	7.5 a	4.4 a	26 a	24 a	43.0 a	33 a
	80-90	6.6 a	0.169 a	0.00085 a	0.0079 a	0.045 a	7.6 a	4.6 a	27 a	11.0 a	40.0 a	45 a
Dry forest	0-10	7.4 a	0.065 c	0.00092 a	0.0086 a	0.092 a	1.7 a	1.0 a	15.0 a	63 a	7 ab	25 ab
	20-30	7.2 a	0.058 bc	0.00071 a	0.0087 a	0.068 a	1.2 a	0.7 a	12.0 a	65 a	8 ab	22 a
	40-50	7.2 a	0.048 ab	0.00059 a	0.0077 a	0.069 a	1.4 a	0.8 a	16.0 a	58 a	8 b	24 ab
	60-70	7.2 a	0.039 a	0.00041 a	0.0065 a	0.073 a	1.2 a	0.7 a	17.0 a	61 a	8 b	26 b
	80-90	7.3 a	0.041 a	0.00065 a	0.0068 a	0.096 a	1.0 a	0.6 a	15.0 a	65 a	5.0 a	26 b
Thorn forest	0-10	8.1 b	0.033 ab	0.00008 a	0.0030 a	0.179 a	0.9 a	0.5 a	17.0 a	61 a	11.0 a	30 a
	20-30	8.0 ab	0.053 b	0.00008 a	0.0036 a	0.148 a	1.6 b	0.9 b	17.0 a	63 a	9.0 a	27 a
	40-50	7.8 a	0.04 ab	0.00004 a	0.0031 a	0.19 a	1.1 ab	0.6 ab	16.0 a	60 a	10.0 a	29 a
	60-70	7.8 ab	0.033 ab	0.00005 a	0.0026 a	0.221 a	1.1 ab	0.6 ab	19.0 a	57 a	10.0 a	32 a

	80-90	8 ab	0.027 a	0.00007 a	0.0024 a	0.219 a	0.9 a	0.5 a	19.0 a	56 a	11.0 a	30 a

Appendix V

Physical and chemical properties of soil in different forest soil profiles samples

Forest type	Sample no.	Depth	PH	Total N%	Ava.P%	K %	Ca %	O.M %	OC %	C/N	Sand %	Silt%	Clay%	Remarks
Evergreen	Profile I	0-10	5.2	0.1190	0.00003	0.0034	0.033	4.52	2.6	22	77	12	6	Loamy-Sand
		20-30	5.3	0.0935	0.00005	0.0027	0.026	3.88	2.3	24	83	10	5	Loamy-Sand
		40-50	5.3	0.0863	0.00002	0.0028	0.031	4.41	2.6	30	68	12	24	Sandy Clay Loam
		60-70	5.3	0.0835	0.00030	0.0036	0.030	3.23	1.9	22	75	12	10	Sandy-Loam
		80-90	5.4	0.1050	0.00035	0.0033	0.025	3.00	1.7	17	60	14	28	Sandy Clay Loam
	Profile II	0-10	5.3	0.0956	0.00027	0.0049	0.045	4.84	2.8	29	76	13	6	Loamy-Sand
		20-30	5.4	0.0840	0.00008	0.0053	0.049	4.42	2.6	31	79	12	7	Loamy-Sand
		40-50	5.3	0.0970	0.00024	0.0065	0.060	4.30	2.5	26	70	14	13	Sandy-Loam
		60-70	5.3	0.1160	0.00002	0.0066	0.061	3.80	2.2	19	60	10	26	Sandy Clay Loam
		80-90	5.4	0.0949	0.00002	0.0055	0.051	2.90	1.7	18	80	12	5	Loamy-Sand
	Profile III	0-10	5.5	0.1750	0.00002	0.0065	0.034	6.19	3.6	21	78	12	5	Loamy-Sand
		20-30	5.5	0.0910	0.00002	0.0056	0.052	3.50	2.0	22	80	4	12	Loamy-Sand
		40-50	5.4	0.0840	0.00001	0.0044	0.041	3.99	2.3	28	75	13	7	Loamy-Sand
		60-70	5	0.0970	0.00001	0.0048	0.044	3.77	2.2	23	77	8	9	Loamy-Sand
		80-90	4.9	0.0935	0.00001	0.0037	0.060	3.00	1.7	19	65	9	8	Loamy-Sand
MUMD	Profile I	0-10	5.45	0.0469	0.00007	0.0040	0.026	2.40	1.4	30	76	6	15	Sandy-Loam
		20-30	5.4	0.0900	0.00002	0.0050	0.024	4.00	2.3	26	55	36	8	Sandy-Loam
		40-50	5.42	0.0466	0.00012	0.0028	0.037	2.24	1.3	28	77	1	19	Sandy Clay Loam
		60-70	5.5	0.0720	0.00001	0.0040	0.037	3.82	2.2	31	68	11	17	Sandy-Loam
		80-90	4.5	0.0415	0.00006	0.0026	0.046	2.02	1.2	28	72	4	19	Sandy Clay Loam
	Profile II	0-10	5.28	0.0456	0.00008	0.0056	0.028	2.38	1.4	30	62	30	12	Sandy Loam
		20-30	5.8	0.1110	0.00060	0.0030	0.009	5.00	2.9	26	66	17	13	Sandy Loam
		40-50	5.57	0.0527	0.00008	0.0062	0.020	1.96	1.1	22	64	18	20	Sandy Loam
		60-70	5.8	0.0980	0.00050	0.0010	0.057	4.80	2.8	28	80	12	5	Loamy Sand
		80-90	5.65	0.0360	0.00011	0.0022	0.052	1.99	1.2	32	72	9	20	Sandy Loam

Forest type	Sample no.	Depth	PH	Total N%	Ava.P%	K %	Ca %	O.M %	OC %	C/N	Sand %	Silt%	Clay%	Remarks
MUMD	Profile III	0-10	5.25	0.0522	0.00003	0.0026	0.024	2.67	1.5	30	86	1	13	Loamy Sand
		20-30	5.4	0.0910	0.00003	0.0024	0.022	4.91	2.8	31	60	15	4	Sandy-Loam
		40-50	5.47	0.0411	0.00012	0.0026	0.024	1.55	0.9	22	68	12	24	Sandy Clay Loam
		60-70	5.4	0.0630	0.00003	0.0027	0.018	4.01	2.3	37	75	12	10	Sandy-Loam
		80-90	5.67	0.0240	0.00003	0.0020	0.025	1.27	0.7	31	60	14	28	Sandy Clay Loam
LMD	Profile I	0-10	5.1	0.0938	0.00010	0.0102	0.021	4.90	2.8	30	70	5	24	Sandy-Loam
		20-30	5.2	0.0812	0.00030	0.0091	0.028	4.00	2.3	29	65	6	27	Loamy-Sand
		40-50	5.2	0.0863	0.00030	0.0083	0.023	3.90	2.3	26	35	6	58	Loamy-Sand
		60-70	5.1	0.0658	0.00050	0.0079	0.032	2.90	1.7	26	60	5	32	Loamy-Sand
		80-90	5.3	0.0714	0.00040	0.0069	0.020	3.80	2.2	31	59	8	32	Sandy-Loam
	Profile II	0-10	6.6	0.0574	0.00030	0.0132	0.031	2.85	1.7	29	78	8	14	Sandy Clay-Loam
		20-30	6.1	0.0756	0.00070	0.0118	0.021	2.37	1.4	18	76	6	16	Loamy-Sand
		40-50	6.3	0.0602	0.00210	0.0097	0.020	2.86	1.7	28	77	6	14	Sandy-Loam
		60-70	6.4	0.1218	0.00010	0.0056	0.032	2.08	1.2	10	88	4	10	Sandy Clay-Loam
		80-90	6.2	0.1036	0.00040	0.0096	0.019	3.26	1.9	18	73	8	18	Sandy-Loam
	Profile III	0-10	6.2	0.1036	0.00050	0.0064	0.035	3.64	2.1	20	71	8	18	Sandy-Loam
		20-30	6.8	0.1316	0.00060	0.0161	0.027	5.76	3.3	25	34	8	56	Sandy Clay-Loam
		40-50	5.3	0.0980	0.00080	0.0124	0.039	4.78	2.8	28	37	10	53	Sandy-Loam
		60-70	5.3	0.0868	0.00050	0.0075	0.043	4.40	2.6	29	40	13	47	Clay
		80-90	5.1	0.0826	0.00020	0.0064	0.040	3.98	2.3	28	44	10	45	Clay loam
DUMD	Profile I	0-10	7	0.0994	0.0001	0.0179	0.026	4.32	2.5	30	87	4	8	Loamy-Sand
		20-30	5.1	0.0938	0.0001	0.0102	0.024	4.9	2.8	24	75	5	16	Sandy-Loam
		40-50	5.2	0.0812	0.0003	0.0091	0.037	4	2.3	24	69	7	22	Sandy-Clay-Loam
		60-70	5.2	0.063	0.0003	0.0083	0.037	3.9	2.3	24	70	8	20	Sandy-Clay-Loam
		80-90	5.1	0.0658	0.0005	0.0079	0.046	3.9	2.3	26	70	10	18	Sandy-Loam

Forest type	Sample no.	Depth	PH	Total N%	Ava.P%	K %	Ca %	O.M %	OC %	C/N	Sand %	Silt%	Clay%	Remarks
DUMD	Profile II	0-10	5.3	0.0714	0.0004	0.0069	0.028	3.8	2.2	24	70	20	12	Sandy-Loam
		20-30	6.1	0.0756	0.0007	0.0118	0.009	2.37	1.4	18	67	21	11	Sandy-Loam
		40-50	6.3	0.0602	0.0021	0.0097	0.020	2.86	1.7	14	64	23	11	Sandy-Loam
		60-70	6.4	0.1218	0.0001	0.0056	0.057	2.08	1.2	21	71	19	9	Sandy-Loam
		80-90	6.2	0.1036	0.0004	0.0096	0.052	3.26	1.9	17	74	19	8	Sandy-Loam
	Profile III	0-10	6.2	0.1036	0.0005	0.0064	0.024	2.64	1.5	30	65	25	13	Sandy-Loam
		20-30	5.3	0.098	0.0008	0.0124	0.022	6.78	3.9	29	53	25	24	Sandy-Clay-Loam
		40-50	5.3	0.0868	0.0005	0.0075	0.024	5.4	3.1	31	32	31	40	Clay
		60-70	5.1	0.0826	0.0002	0.0064	0.018	6.4	3.7	29	31	26	46	Clay
		80-90	5.3	0.0786	0.0003	0.0075	0.025	4	2.3	18	31	26	46	Clay
Semi-indaing	Profile I	0-10	6.99	0.0412	0.00172	0.0067	0.058	1.49	0.9	21	81	5	9	Loamy-Sand
		20-30	6.93	0.0412	0.00162	0.0141	0.130	1.40	0.8	20	81	4	17	Sandy- Loam
		40-50	6.55	0.0578	0.00175	0.0063	0.062	1.13	0.7	11	80	8	14	Sandy- Loam
		60-70	7.94	0.0314	0.00270	0.0094	0.087	1.17	0.7	22	85	8	9	Loamy- Sand
		80-90	8.57	0.0296	0.00254	0.0209	0.193	1.08	0.6	21	82	6	11	Loamy- Sand
	Profile II	0-10	6.02	0.0426	0.00018	0.0100	0.068	1.15	0.7	16	83	7	8	Sandy- Loam
		20-30	6.28	0.0233	0.00006	0.0074	0.092	1.23	0.7	31	80	4	15	Sandy- Loam
		40-50	6.3	0.0305	0.00004	0.0119	0.074	1.20	0.7	23	79	7	13	Sandy- Loam
		60-70	6.44	0.0296	0.00003	0.0080	0.110	0.93	0.5	18	82	6	10	Loamy- Sand
		80-90	6.51	0.0318	0.00003	0.0126	0.116	0.87	0.5	16	82	6	11	Loamy- Sand
	Profile III	0-10	6.86	0.0435	0.00034	0.0074	0.063	1.28	0.7	17	92	6	5	Sand
		20-30	6.82	0.0363	0.00012	0.0099	0.069	1.15	0.7	18	80	7	9	Loamy- Sand
		40-50	7.26	0.0296	0.00014	0.0068	0.091	0.76	0.4	15	78	8	12	Loamy- Sand
		60-70	8.51	0.0336	0.00001	0.0178	0.079	0.89	0.5	15	84	6	9	Loamy- Sand
		80-90	8.36	0.0222	0.00001	0.0085	0.164	0.59	0.3	15	88	6	7	Loamy- Sand

Forest type	Sample no.	Depth	PH	Total N%	Ava.P%	K %	Ca %	O.M %	OC %	C/N	Sand %	Silt%	Clay%	Remarks
Hill forest	Profile I	0-10	5.8	0.0630	0.00010	0.0033	0.168	3.30	1.9	20	60	15	24	Sandy-Clay-Loam
		20-30	5.9	0.0320	0.00001	0.0043	0.143	3.12	1.8	22	64	11	23	Sandy-Clay-Loam
		40-50	6	0.0210	0.00007	0.0022	0.118	2.71	1.6	22	53	15	30	Sandy-Clay-Loam
		60-70	6.1	0.0570	0.00005	0.0032	0.20	2.88	1.7	29	63	13	23	Sandy-Clay-Loam
		80-90	6.2	0.0380	0.00004	0.0011	0.23	3.01	1.7	21	64	14	21	Sandy-Clay-Loam
	Profile II	0-10	6	0.071	0.00030	0.0032	0.27	3.39	2.0	20	74	16	6	Sandy-Loam
		20-30	6.2	0.0580	0.00020	0.0022	0.105	3.07	1.8	21	74	17	9	Sandy-Loam
		40-50	6.3	0.0480	0.00020	0.0049	0.029	3.33	1.9	25	66	16	15	Sandy-Loam
		60-70	6.3	0.0369	0.00059	0.0026	0.30	3.21	1.9	27	63	18	14	Sandy-Loam
		80-90	6.5	0.0475	0.00004	0.0031	0.12	3.91	2.3	30	59	18	20	Sandy-Clay-Loam
	Profile III	0-10	5.8	0.0584	0.00032	0.0026	1.653	3.55	2.1	25	84	3	14	Sandy-Loam
		20-30	5.7	0.0378	0.00025	0.0034	0.207	3.16	1.8	23	71	11	16	Sandy-Loam
		40-50	6	0.0475	0.00020	0.0030	0.047	3.27	1.9	25	78	5	19	Sandy-Loam
		60-70	6.1	0.0568	0.00018	0.0050	0.03	3.18	1.8	27	78	3	19	Sandy-Loam
		80-90	6.2	0.0530	0.00016	0.0020	0.30	3.15	1.8	34	65	4	23	Sandy-Clay-Loam
Mangrove	Profile I	0-10	5.1	0.0826	0.00020	0.0064	0.115	3.40	2.0	24	44	10	45	clay
		20-30	6.7	0.1817	0.00001	0.0017	0.014	9.10	5.3	29	40	2	55	clay
		40-50	6.8	0.1640	0.00019	0.0017	0.011	6.10	3.5	22	40	39	18	Clay loam
		60-70	6.6	0.1796	0.00025	0.0018	0.010	7.90	4.6	26	41	39	20	Loam
		80-90	7.0	0.1510	0.00028	0.0017	0.010	7.20	4.2	28	22	45	35	Clay Loam
	Profile II	0-10	6.7	0.1534	0.00018	0.0019	0.011	8.90	5.2	34	34	50	17	Silt Loam
		20-30	6.2	0.1794	0.00022	0.0017	0.012	7.30	4.2	24	41	53	12	Silt Loam
		40-50	6.8	0.1913	0.00001	0.0017	0.011	9.20	5.3	28	36	50	11	Silt Loam
		60-70	6.4	0.1874	0.00020	0.0018	0.012	7.30	4.2	23	25	52	22	Silt Loam
		80-90	6.5	0.1783	0.00024	0.0023	0.014	8.20	4.8	27	5	36	51	clay

Forest type	Sample no.	Depth	PH	Total N%	Ava.P %	K %	Ca %	O.M %	OC %	C/N	Sand %	Silt%	Clay%	Remarks
Mangrove	Profile III	0-10	6.2	0.1794	0.00224	0.0168	0.115	7.30	4.2	24	5	40	45	silty clay
		20-30	6.4	0.1874	0.00199	0.0176	0.122	7.30	4.2	23	7	40	55	silty clay
		40-50	6.3	0.1704	0.00211	0.0179	0.121	6.80	3.9	23	7	41	55	silty clay
		60-70	6.4	0.1877	0.00162	0.0186	0.109	7.40	4.3	23	6	39	57	Clay
		80-90	6.4	0.1788	0.00204	0.0198	0.113	7.47	4.3	24	6	39	48	Clay
Dry Forest	Profile I	0-10	7.4	0.0600	0.00109	0.011	0.067	2.10	1.2	20	67	7	24	Clay loam
		20-30	7.1	0.0490	0.00026	0.01	0.058	0.90	0.5	11	65	8	21	Clay loam
		40-50	7.1	0.0430	0.0004	0.0062	0.079	1.09	0.6	15	55	8	26	Clay loam
		60-70	7.2	0.0370	0.00057	0.0066	0.081	1.17	0.7	18	64	8	26	Clay loam
		80-90	7.5	0.0360	0.001	0.0075	0.130	1.07	0.6	17	66	7	25	Clay loam
	Profile II	0-10	7.2	0.0610	0.0007	0.0069	0.080	0.97	0.6	9	65	8	23	Clay loam
		20-30	7.2	0.0620	0.0011	0.0095	0.067	1.41	0.8	13	65	8	22	Clay loam
		40-50	7.3	0.0410	0.0003	0.007	0.059	0.89	0.5	13	56	9	25	Clay loam
		60-70	7.1	0.0420	0.00039	0.0059	0.079	1.11	0.6	15	64	8	26	Clay loam
		80-90	7.3	0.0440	0.00059	0.0069	0.078	1.09	0.6	14	66	7	25	Clay loam
	Profile III	0-10	7.7	0.0730	0.00097	0.008	0.058	2.00	1.2	16	58	7	28	Clay loam
		20-30	7.3	0.0620	0.00078	0.0065	0.068	1.19	0.7	11	65	8	23	Clay loam
		40-50	7.3	0.0610	0.00107	0.0098	0.079	2.10	1.2	20	64	8	22	Clay loam
		60-70	7.4	0.0380	0.00026	0.0069	0.080	1.21	0.7	18	56	9	25	Clay loam
		80-90	7.2	0.0420	0.00037	0.0061	0.129	0.92	0.5	13	63	1	27	Clay loam
Thorn forest	Profile I	0-10	8.2	0.0500	0.00006	0.0045	0.067	0.99	0.6	11	65	7	30	Clay loam
		20-30	7.8	0.0700	0.00007	0.0041	0.058	2.30	1.3	19	62	12	27	Clay
		40-50	7.7	0.0400	0.00004	0.0030	0.079	1.10	0.6	16	60	7	31	Clay
		60-70	7.8	0.0300	0.00002	0.0024	0.081	0.91	0.5	18	57	10	32	Clay
		80-90	8	0.0300	0.00011	0.0024	0.130	0.93	0.5	18	52	14	33	Clay

Forest type	Sample no.	Depth	PH	Total N%	Ava.P %	K %	Ca %	O.M %	OC %	C/N	Sand %	Silt%	Clay%	Remarks
Thorn forest	Profile II	0-10	8.1	0.0200	0.00009	0.0022	0.110	0.76	0.4	22	65	11	26	Clay
		20-30	8.2	0.0500	0.00008	0.0047	0.120	1.41	0.8	16	63	6	29	Clay loam
		40-50	7.8	0.0300	0.00006	0.0040	0.221	0.95	0.6	18	63	12	27	Clay
		60-70	7.7	0.0400	0.00005	0.0031	0.229	1.20	0.7	17	62	7	33	Clay
		80-90	7.8	0.0300	0.00003	0.0024	0.214	1.10	0.6	21	56	9	31	Clay
	Profile III	0-10	8	0.0300	0.00009	0.0024	0.213	1.00	0.6	19	53	14	33	Clay
		20-30	8.1	0.0400	0.00009	0.0021	0.110	1.00	0.6	15	64	10	26	Clay
		40-50	7.8	0.0510	0.00002	0.0023	0.120	1.20	0.7	14	56	10	29	Clay
		60-70	8	0.0300	0.00008	0.0022	0.223	1.10	0.6	21	52	13	32	Clay
		80-90	8.1	0.0200	0.00007	0.0024	0.231	0.67	0.4	19	60	11	26	Clay