Comparative Study of soil nutrients and carbon pool under Sal growing in Assam and Doon Valley

Thesis · October 2019
DOI: 10.13140/RG.2.2.25583.38561

1 author:

Chandrima Debi
Forest Research Institute Dehradun

Comparative Study of soil nutrients and carbon pool under Sal growing in Assam and Doon Valley

DISSERTATION

Under The Guidance of **Dr. M.K. Gupta** Scientist E, Forest **Soil & Land Reclamation Division, FRI** Dehradun.

Submitted By Chandrima Debi
M.Sc. Forestry (2011-2013)
4th Semester F.R.I University

Submitted for the partial fulfillment of the requirement of the award of Master of Science degree in M.Sc Forestry Course (4th semester).

Comparative Study of soil nutrients and carbon pool under Sal growing in Assam and Doon Valley

DISSERTATION REPORT

Submitted by,

CHANDRIMA DEBI

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Forestry

4th SEMESTER (2011-2013)

Under the guidance of

Dr. M.K. GUPTA

Scientist-E,

FOREST SOIL AND LAND RECLAMATION DIVISION,

FOREST RESEARCH INSTITUTE, DEHRADUN

Forest Research Institute (Deemed) University

FOREST RESEARCH INSTITUTE, DEHRADUN

INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION

Dr. Ramesh K. Aima , IFS
Dean (Academic)

Phone : 0135-2752682 (O)
Fax : 0135-2752682
EPABX : 0135-2224452(O)
E-mail : aimark@icfre.org

FOREST RESEARCH INSTITUTE (DEEMED) UNIVERSITY

(INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION)

P.O.: I.P.E. KAULAGARH ROAD, DEHRADUN-24819

CERTIFICATE

This is to certify that the Dissertation work entitled **"Comparative Study of soil nutrients and carbon pool under Sal growing in Assam and Doon Valley"** is a bonafide work carried out by Ms.Chandrima Debi**,** student of M.Sc. Forestry course (2011-2013) of Forest Research Institute (Deemed University), Dehradun and submitted in partial fulfillment of the requirement for M.Sc. Forestry course degree programme.

The work has been carried out under the supervision of **Dr. M.K. Gupta,** Scientist- E, Forest Soil and Land Reclamation Division, Forest Research Institute, Dehradun.

Date: **Dr. Ramesh Kumar Aima,**
IFS
Place: Dehradun **Dean (Academic)**
FRI University

Dr. M. K. Gupta
Scientist-E
Forest Soil and Land
Reclamation Division
Forest Research Institute
Dehradun, India.

Phone : 0135 – 2224470

E-mail : guptamk@icfre.org

FOREST RESEARCH INSTITUTE UNIVERSITY
(INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION)
(An autonomous body of Ministry of Environment & Forest, Govt. of India)
POST: I. P. E. KAULAGARH ROAD, DEHRADUN-248195

CERTIFICATE

This is to certify that **Ms. Chandrima Debi**, student of M.Sc. Forestry (2011-2013)-4th Semester, has worked for her Dissertation on the topic **"*Comparative Study of soil nutrients and carbon pool under Sal growing in Assam and Doon Valley*"** under my guidance and submitted to Forest Research Institute University for partial fulfilment of M.Sc. Forestry 2011-2013 degree programme.

She bears a good moral character and is sincere and hardworking. I wish her success in all endeavours.

PLACE: FRI (DEHRADUN)

DATE………..

Dr. M. K. Gupta
Scientist-E
Forest Soil and Land
Reclamation Division
Forest Research Institute
Dehradun

DECLARATION

I, hereby declare that the Dissertation entitled "***Comparative Study of soil nutrients and carbon pool under Sal growing in Assam and Doon Valley***" submitted to Forest Research Institute University, Dehradun for partial fulfilment of the requirement of the award of the degree of Master of Science in M.Sc. Forestry course is a record work carried out by me.

Place: Chandrima Debi

Date: M.Sc. Forestry (4thSemester)

ACKNOWLEDGEMENT

I owe my sincere gratitude and regards to my guide Dr. M. K. Gupta, Scientist E, Forest Soil and Land Reclamation Division, Indian Council of Forestry Research and Education (ICFRE), Forest Research Institute, Dehradun, for his cordial guidance and constant supervision during the entire course of the preparation of the dissertation.

I express my heartfelt thanks to Dr. R. K. Aima, Dean, Forest Research Institute University, Dehradun for his cooperation during the preparation of this dissertation. I also thank my Course- coordinator, Dr. S. Dhawan for allowing me to work under soil science division.

I thank Shri Ashok Kr. DevChoudhury, ACF, Western Range Dharamtul, Ditrict Morigaon, Mrs. Alka Bhargava, CCF REWP, Jalukbari Forest School Assam, Shri Bhaskar Deka, ACF. Shri. S. Rahman, ACF, Beltola Forest Division, Assam, for their guidance and the collection of field data.

I also thank Mr. Antrix Soni (TA) Soil Science and land Reclamation Division, to help me complete my practical work on time for the dissertation.

I thank my mother for her constant encouragement and inspiration for successful completion of dissertation. I would also thank my friends Ankur Gupta, Anjali Barua, Naren Das for their help in the collection of samples and moral support. Above all I would like to thank Almighty for helping me to complete my work in time.

Contents

Introduction

Soil is a natural resource and cannot be assumed high quality permanent sources of sustainable nutrition for plants. Soil are very important and should be given due priority. Soil is medium of plant growth; therefore, proper care should be taken. Tree cover has its own effects on soil physical and chemical properties. Litter plays a vital role in enrichment of the soil. Forest soils are natural body having depth and surface area. It exists as a continuous cover on the land surface. The climate of a place affects the forest soils in many different ways. It has led to the development of a variety of soils in India. Soil is the product of natural destructive and synthetic forces. The physical and chemical weathering of rocks and minerals forms unconsolidated debris regolith. Its upper part is bio-chemically weathered. The soils found in the different parts of the country are a function of several factors- climatic, biotic, geomorphic etc.

The word soil is derived from a Latin word solum, meaning ground. Soil is the upper thin layer of earth's surface derives from the weathering of rocks and minerals. The term soil is a complex mixture of eroded rocks, minerals, nutrients, decaying organic matter, water, air and billions of living organisms, most of them microscopic decomposers. Although, soil is a potentially renewable resource, it is produced very slowly by the weathering of rocks, deposits of sediment by erosion and decomposition of organic matter in dead organism (Miller, 1999).

The nature and properties of soil cycling between the soils and trees are the important dimensions to determine the site quality. The vegetation influences the physico-chemical properties of the soil to a great extent. It improves the soil structure, infiltration rate and WHC, hydraulic conductivity and aeration (Ilorkar and Totey, 2001; Kumar *et al*., 2004). Soil testing is an important component of site quality / fertility assessment. Soil fertility is mainly governed by the pH, organic carbon, available nutrients and clay contents in the soil; therefore, estimation of these attributes is very important and their status can indicate wholesome fertility of soil in use. Overexploitation of soil is a major cause of the decline in the soil fertility. Soil cannot perform fully unless its physical, chemical and biological conditions are well balanced and processes are well coordinated. Trees play unique role in increasing soil fertility through soil conservation and recycling of nutrients also. Soil supports trees and nourishes them through nutrient supply. It is not sufficient that a soil should contain the elements necessary to support plant life: it is equally necessary that these elements should be in condition suitable for absorption by the roots of plants, that is, they should be in solution. Soil nutrient changes in different land uses at different stages of development can indicate relative sustainability of system. Nitrogen and phosphorus, to a great extent, originate from soil organic fraction and potassium from inorganic fraction. Significant changes in physical and chemical attributes of the soil occur as a result of tree planting, at or near the surface and are related to the supply of organic matter from the leaf litter (Page, 1968). The accumulation of soil organic matter under trees is the most commonly reported effect of trees on soils (Odum, 1960). Moisture and temperature play critical roles in exchanges between total and available nutrient pools, and uptake by plants. Nutrients may be weathered from the soil parent rock and tree root exudates may also influence weathering (Rosoman, 1994). The soil changes slowly through time and its formation takes millions of years. A general relationship between parent material, soil and vegetation has been very important for natural woodland ecosystem.

The organic matter is the most capable and potent substance to bring about physical, chemical and biological soil amelioration. Its decomposition and re-synthesis releases strong acids to bring down the soil reaction and it improvement of porosity, field capacity, bulk density and consequently the movement of air and water in the soil. Changes in forest type, productivity, decay rates and disturbances can effectively modify the carbon contents of forest soils. SOC can be made a central consideration in land management strategy more so for forest areas as it is an important component of climate change.

There is growing international concern over the increase of carbon in the form of CO_2 in the atmosphere over the past few decades. Forests constitute both a sink and a source of atmospheric CO_2. Managing forests in order to retain and increased their stored carbon will help reduce the rate of increase of CO_2 and stabilize atmospheric concentrations. Another crucial component could be the expansion of the area and /or biomass and soil carbon density of plantations on both forest and non-forest lands, thereby increasing storage of carbon in durable wood products.

Sal is moderate to slow growing tree, and can attain heights of 30 to 35 m and a trunk diameter of up to 2-2.5 m. The leaves are 10–25 cm long and 5–15 cm broad. In wetter areas, it is evergreen; in drier areas, it is dry-season deciduous, shedding most of the leaves in between February to April, leafing out again in April and May.

The present work deals with the comparative study of soil nutrients and carbon pool under Sal growing in Assam and Doon valley. After the collection of the soil samples, a number of analysis and tests are performed to compare the nutrient status as well as the physical properties of the soil samples of Sal growing in two different geographical sites *i.e.* Assam and Dehradun. A general understanding of soil testing helps us to know how the results can be interpreted and to appreciate the accuracy of analytical results. A soil test determines the soil's nutrient supplying capacity by mixing soil for only a few minutes with a strong extracting solution (often an acid or a combination of acids). The soil reacts with the extracting solution, releasing some of the nutrients. The solution is filtered and assayed for the concentration of each nutrient. The nutrient concentration is then related to field calibration research that indicates the yield level reached with varying soil nutrient concentrations. This method works very well for some nutrients, but is less accurate for others, for example those nutrients supplied largely from organic matter (OM) decomposition such as nitrogen. This is primarily due to the difficulty of estimating or predicting the rate at which OM will decompose and release these nutrients in plant-available forms.

Comparative study of the soils under sal forest under different geographical locations helps us to establish interrelationship between various factors responsible for the formation of soil type under particular vegetation.

1. SOIL PARAMETERS

1.1. Nitrogen:

Nitrogen is an essential building block of amino and nucleic acids, essential to life on Earth. It is the constituent of amino acids, proteins, some coenzymes, nucleotides, ATP nucleic acids, vitamins, hormones, cytochromes, chlorophyll. The major functions are cell division, growth, metabolic activities and photosynthesis. First and foremost among the nutrient elements is nitrogen. Curiously, although this element constitutes nearly 79% of the atmosphere and all creatures exposed to the air live in a veritable ocean of it. Elemental nitrogen in the atmosphere cannot be used directly by either plants or animals, and must be converted to a reduced (or 'fixed') state in order to be useful for higher plants and animals. Nitrogen is obtained as NO_3^- , NH_4^+ and rarely as NO_2^-. It is required more in meristematic tissue of plants. Nitrogen cycle is the turnover of N through mineralization performed by microorganisms and soil fauna and immobilization carried out by microorganisms. Gains in soil N occur by microbial fixation of molecular N_2 and by addition of ammonia (NH_3), nitrate (NO_3^-), and nitrite(NO_2^-) in rainwater; losses occur through crop removal, leaching and volatilization. Biological N_2 fixation converts N_2 to combined forms (NH_3 and organic N); this process is performed by bacteria and cyanobacteria or by plant-bacterial associations with these organisms. Organic forms of N, in turn, are converted to NH_3 and NO_2^- by mineralization. The conversion to organic N to NH_3 is termed ammonification; the oxidation of NH_3 to NO_3^- is termed as nitrification. Utilization of NH_3 and NO_3^- by plants and soil organisms constitutes assimilation and immobilization, respectively. Nitrogen is ultimately returned to the atmosphere as molecular N_2 by biological denitrification, thereby completing the cycle.

Deficiency of it results in chlorosis starting from older leaves, stunted growth due to decrease protein synthesis, smaller cell and slow divisions, premature leaf fall, lateral leaf bud and tillering suppressed, low yield.

1.2. Phosphorus:

Phosphorus is a key element in all known forms of life. It is obtained from soil as $H_2PO_4^{2-}$ and PO_4^{2-}. Inorganic phosphorus in the form of the phosphate PO_4^{3-} plays a major role in biological molecules such as DNA and RNA where it forms part of the structural framework of these molecules. Living cells also use phosphate to transport cellular energy in the form of adenosine triphosphate (ATP). Phospholipids are the main structural components of all cellular membranes. It is required in meristematic tissue, developing fruits and seeds. It is withdrawn from older tissues. It is the constituents of nucleotides, ATP, phospholipids, NAD^+, $NADP^+$ and some other coenzymes. Its major functions are energy transfer, cell division and phosphorylation reactions. The P cycle in soil is a dynamic system involving soil, plants and microorganisms. Major processes include uptake of soil P by plants, recycling trough return of plant and animal residues, biological turnover through mineralization-immobilization, fixation reactions at clay and oxide surfaces, and solubilization and formation if minerals phosphates through chemical reactions and activities of microorganisms. In natural systems, essentially all of the P utilized by plants is returned to the soil in plant and animal residues; under cultivation, some P is removed in the harvest and only part is returned. Most losses of soil P arise through erosion; smaller losses occur as a result of leaching.

Deficiency results in stunted growth, leaves dull green or with anthocynins, chlorosis with necrosis first in older leaves or premature abscission, delayed flowering, poor vascular tissue.

1.3. Potassium:

Soil parent materials contain potassium (K) mainly in feldspars and micas. As these minerals weather, and the K ions released become either exchangeable or exist as adsorbed or as soluble in the solution (Foth and Ellis, 1997). Potassium is the third most important essential element next to N and P that limit plant productivity. Its behaviour in the soil is influenced primarily by soil cation exchange properties and mineral weathering rather than by microbiological processes. Unlike N and P, K causes no off-site environmental problems when it leaves the soil system. It is not toxic and does not cause eutrophication in aquatic systems (Brady and Weil, 2002). Wakene (2001) reported that the variation in the distribution of K depends on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed. The greater the proportion of clay mineral high in K, the greater will be the potential potassium availability in soils (Tisdale *et al.,* 1995). Soil K is mostly a mineral form and the daily K needs of plants are little affected by organic associated K, except for exchangeable K adsorbed on OM. Mesfin (1996) described low presence of exchangeable K under acidic soils while Alemayehu (1990) observed low K under intensive cultivation. Normally, losses of K by leaching appear to be more serious on soils with low activity clays than soils with high- activity clays, and K from fertilizer application move deeply (Foth and Ellis, 1997).

Potassium in nature occurs only as ionic salt and is taken up in the same form. Its high requirement is in leaves meristems, bud and root tips. It is cofactor of several enzymes and plays a detrimental role in maintaining osmotic potential. Its major functions are maintenance of cell turgidity, opening and closing of stomata, balancing of other ions, increases hardiness, essential for photosynthesis, respiration synthesis of various types and membrane permeability. Deficiency results in mottled chlorosis initially in older leaves, marginal yellowing or scorch and curling, premature death and loss of apical dominance. In the soil itself, potassium appears in three forms:(1) in the soil solution;(2) as the exchangeable ion K^+ adsorbed to, or released from, the surfaces of clay particles; and (3) in organic matter. Some layered-aluminosilicate clay minerals may have the capacity to adsorb potassium not only on their outer surfaces but also inside the layered crystal lattices, thereby causing the immobilization of potassium ion.

1.4. Soil carbon:

Uncultivated soils have higher in soil OM (both on surface and in soil) than those soils cultivated years (Miller and Gardiner, 2001). In the forest, there is a continuous growth of plants and additions to the three pools of OM: standing crop, forest floor and soil. In the grassland ecosystems, much more of the OM is in the soil and much less occurs in the standing plants and grassland floor. Although approximately 50% of the total OM in the forest ecosystems may be in the soil, over 95% may be in the soil where grasses are the dominant vegetation (Foth, 1990).

Soil carbon improves the physical properties of soil. It increases the cation exchange capacity (CEC) and water-holding capacity of soil and it contributes to the structural stability of clay soils by helping to bind particles into aggregates. Soil organic matter, of which carbon is a major part, holds a great proportion of nutrients, cations and trace elements that are of importance to plant growth. It prevents nutrient leaching and is integral to the organic acids that make minerals available to plants. It also buffers soil from strong changes in pH. It is widely accepted that the carbon content of soil is a major factor in its overall health.

The increasing concentration of carbon dioxide (CO_2) and other greenhouse gases (GHGs) in the atmosphere is now widely recognized as the leading cause of global warming (IPCC, 2007). In order to reduce the GHGs in the atmosphere, two key activities are relevant reduce the anthropogenic emissions of CO_2 and create or promote carbon (C) sinks in the biosphere. Storing carbon (C) in biosphere is one of the strategies accepted by the United Nations for mitigating high atmospheric concentrations of carbon dioxide and other greenhouse gases that cause global warming. Forest soils are one of the major carbon sinks on earth, because of their high organic matter content (Dey, 2005). Soil organic carbon, being the largest terrestrial carbon pool holds a very significant role in global terrestrial ecosystem carbon balance. Soil investigations picked up especially after the International conference on Soils and the Green House Effect held in Netherlands in 1989. The Intergovernmental Panel for Climate Change identified creation and strengthening of carbon sinks in the soil as clear option for increasing removal of CO_2 from the atmosphere. Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere. Climatic conditions, natural vegetation, soil texture, and drainage all affect the amount and length of time carbon is stored. Soil organic carbon is sensitive to impact of anthropogenic activities. The conversion of natural vegetation to various land uses results in rapid decline in soil organic matter (Post and Kwon, 2000).

1.5. Texture

The term soil texture refers to the relative percentage of coarse and fine soil particles. It is a basic property of soil and is not readily subject to change. Soil includes two ecologically important fractions. A Coarse fraction and a fine fraction. The coarse fraction, larger than 0.05 mm, in diameter, include stones, gravels and sand; the fine fraction, smaller than 0.05mm, in diameter, is comprised of silt and clay. The coarse fraction represents the skeleton of soil; its function is largely limited to the physical support of plants and it has a minor part in plant nutrition. The fine soil is made up of silt and clay particles smaller than 0.05 mm in diameter; it determines mainly the water holding capacity of the soil, soil aeration, and supply of available nutrients. Clay content has retention capacity for nutrients and water. Clay soils resist wind and water erosion better than silty and sandy soils, because the particles are more tightly joined to each other. In medium textured soils, clay is often translocated downward through the soil profile and accumulates in the subsoil. The fine fraction is the active portion; it is the carrier of life in the soil, it is soil protoplasm. ''It directly influences soil-water relationship, aeration and root penetration through its relationship with interparticle pore space. It is a basic property and not readily subject to change.

The soils are classified into twelve textural classes. The more common textural classes listed in order of their increasing fineness are:

Sand	Sandy Clay Loam
Loamy sand	Clay Loam
Sandy Loams	Silty Clay Loam
Loam	Sandy Clay
Silt Loam	Silty Clay
Silt	Clay

On the basis of proportion, soils are classified into different textural group

Textural group	Relative proportion of different sized material
Sandy Loam	85%Loam+15% clay or Silt or both.
Loamy Sand	70% Sand +30% Clay or Silt or both.
Loam soil	50% Sand +50% clay or Silt or both.
Silt	90% Silt + 10% Sand

The limits in the range of each textural name have been established upon significant differences in the physical properties of each textural class.

1.6 Soil pH

One of the most discussed soil properties due to its effect on physical and chemical properties of soil, plant nutrition and microbial activity. Soil may be acidic, neutral or alkaline. Soil may be acidic in high rainfall areas and due to the kind of parent material. Alkali soils are formed due to sodium. Source of H^+ ions like Aluminium in strongly acidic soils, Hydrogen and aluminium in moderately acidic soil. Source of OH^- ions like Calcium, Magnesium, Potassium and Sodium. Several factors affect pH measurement. Primary among these is the salt concentration of a soil (a salt is any molecule that, when placed in water, separates into positively and negatively charged components or ions). The salt concentration of a soil may vary with the season or with fertilizer application, and is generally greater immediately following fertilizer application than before. The result may be an apparent pH drop up to one-half a pH unit.

Management of soil pH

- Liming in acidic soil
- Gypsum application in alkali soils.

Table showing soil categories according to pH

Soil pH	Categories
Below 5.5	Acid
5.5 - 6.5	Slightly acid
6.5 - 7.5	Neutral
7.5 - 8.5	Tending to become alkali
Above 8.5	Alkali

Maintenance of soil fertility is an important aspect of forestry. Plant material and animal wastes available on the ground, decompose and release nutrients to the soil solution. These nutrients may undergo further transformations in organic and inorganic forms which may be enabled by soil micro-organisms. Nutrients are continuously removed from the soil by trees, leaching and erosion etc. Soils which can supply all the essential nutrients to the plants are called fertile soils. Therefore, soil fertility is an aspect of soil–plant relationship *viz.* plant growth with reference to nutrients available in the soil. Soil Quality cannot be measured directly however; it can be inferred by measuring soil physiochemical and biological properties that serve as quality indicator. Among soil chemical properties pH, organic carbon and available plant nutrients *viz.* nitrogen, phosphorus and potassium are important to know the inherent capacity of the soil to supply nutrients to plant growth. Estimation of soil chemical property of a particular site may provide vital information about soil's nutrient bearing capacity and also useful in selection of suitable species on the particular location. Soil quality helps to assess changes in dynamic soil properties caused by external factors. It identifies problem areas and assesses differences between management systems and is valuable to measure the sustainability of land and soil management systems at present and in the future. Maintenance and improvement of soil quality is a prime concern.

Vegetation impacts soils in numerous ways. It can prevent erosion from rain or surface runoff. It shades soils, keeping them cooler and slowing evaporation of soil moisture. Or it can cause soils to dry out by transpiration. Plants can form new chemicals that break down or build up soil particles. Vegetation depends on climate, land form topography, and biological factors. Soil factors such as soil density, depth, chemistry, pH, temperature and moisture greatly affect the type of plants that can grow in a given location. Dead plants and dropped leaves and stems of plants fall to the surface of the soil and decompose. There, organisms feed on them and mix the organic material with the upper soil layers; these organic compounds become part of the soil formation process, ultimately shaping the type of soil formed

Objective

To study and compare the soil nutrients and carbon pool under Sal forest growing in Assam and Doon valley.

2. Literature Review

Forest soils influence the composition of the forest stand and ground cover, rate of tree growth, vigour of natural reproduction and other silviculturally important factors (Bhatnagar 1965). For instance, growth of Shorea robusta (sal) in tropical forests is highly influenced by nitrogen, phosphorus, potassium, carbon, organic matter and soil pH (Bhatnagar 1965). Physiochemical characteristics of forest soils vary in space and time due to variations in topography, climate, physical weathering processes, vegetation cover, microbial activities, and several other biotic and abiotic variables. Vegetation plays an important role in soil formation (Chapman and Reiss 1992). For example, plant tissues (from aboveground litter and belowground root detritus) are the main source of soil organic matter (OM), which influences physiochemical characteristics of soil such as pH, water holding capacity (WHC), texture and nutrient availability (Johnston 1986). Nutrient supply varies widely among ecosystems (Binkley and Vitousek 1989), resulting in differences in plant community structure and production (Ruess and Innis 1977, Chapin et al. 1986). Organic matter supplies energy and cell building constituents for most microorganisms (Allison 1973) and is a critical factor in soil fertility (Brady 1984).

Soil is a complex system made up of mineral matter, organic matter, and soil water and soil air. Therefore, it contains not only solid and liquid phases but also gaseous phases.

Any part of the earth's surface that supports vegetation bears a covering of soil. Soil is thus defined as "any part of earth's crust in which plants root." But this is a limited definition of soil. As we know, soil is actually formed as a result of long term process of complex interactions leading to the production of mineral matter in close association with interstitial organic matter living as well as dead. In soil formation, modification of parent mineral matter takes fairly a long time. Such a modification is actually the result of interactions between climatic, topographic and biological effects. Soil is thus not merely a group of mineral particles. It has also a biological system of living organic as well as some other components. It is thus referred to call it a soil complex, which have five categories of components given by Dokuchayev (1889), mineral matter , soil organic matter or humus soil water (soil solution),soil atmosphere, biological system A perusal of the above shows that the soil is not merely mineral matter, but a complex of several other types of components. Thus, biologically soil may be said "the weathered superficial layer of the earth's crust in which the living organisms grow and al so release the products of their activities, death and decay." According to Dokuchayev

(1889), a famous pedologist, "soil is a result of the actions and reciprocal influences of parent rocks, climate, topography, plants, animals and age of the land. Soil is a natural body, differentiated into horizons of mineral and organic constituents, usually unconsolidated, of variable depth, which differs from the parent material below in morphology, physical properties and constitution, chemical properties and composition and biological characteristics. Thus soil is also a seat of biological interactions and root activity. So it is important for the growth of vegetation. It is the storage of plant nutrients, air and water. A soil has a certain distinctive physical, chemical and biological qualities which permit it to support plants growth and which set it off from the infertile substratum, which may consist of over burden or solid bedrock lying beneath. Soil is one of the most important natural resources and study about soil chemistry is not only interesting but also a challenging subject. It is a heart of terrestrial ecological system, so understanding of the soil system is the key to the success and environmental harmony of any human use of the land. Soil chemical analysis is made to assess the available amounts of major nutrients, nitrogen phosphorus potassium and to assess a few other determinations which is correlated to soil fertility, such as soil texture, soil reaction (pH) and salinity.

The term soil fertility refers to the quality of soil which sustains plants and helps them to grow well. It is a very significant quality of soil. It depends on many things such as soil texture, soil pH, nutrients, organic matter, water holding capacity, microorganism, structure, microclimate, irrigation facility, land fragmentations, soil erosion, agricultural system and practices, diseases and insects, consumption of nutrients by crops, conversion of nutrients into inconsumable by plants and gases, leaching of nutrients (Sigdel, 2009).

There are six agro-climatic zones in the State, namely (name of the Zone Name of the Districts under the zone):

1. North Bank Plain Zone: Lakhimpur, Dhemaji, Sonitpur, Darrang
2. Upper Brahmaputra Valley: Sibsagar, Jorhat, Golaghat, Dibrugrah, Tinsukia
3. Central Brahmaputra Valley: Nagaon and Morigaon
4. Lower Brahmaputra Valley: Kamrup, Barpeta, Bongaigaon, Nalbari, Goalpara, Dhubri and Kokrajhar
5. Barak Valley: Cachar, Karimganj and Hailakandi
6. Hill Zone: Karbi Anglong.

Shorea robusta, economically one of the most important species was introduced in large scale in foothill regions of north-eastern Himalaya s since 1920. Though the species offers a good promise in the tract but the intimate knowledge about the nature and properties of the soils supporting the species at the foothill regions of North-Eastern Himalayas ad will eventually help in characterising the soils suitable for the species. Since *Shorea robusta* possess a deep root system and can draw the mineral elements from greater soil volume, the deep soil with even coarser texture having low concentration of the nutrient element are often able to meet the demand of the species (Banerjee *et al.,* 1989).

As timber Sal emerged as an important commodity, the government attempted to manage sal forests for commercial timber production in order to increase revenue. Eventually, the governments saw sal forests more as a timber source rather than for other forest products. But the sal forests, to the contrary, extend to the most heavily populated zones and local people access sal forests for different uses, irrespective of whether they are designated as protective (Kumar *et al.*, 1994; Lehmkuhl, 1994; Bhat and Rawat, 1995; Aryal *et al.*, 1999) or productive forests (Nair, 1945; FRIB, 1947; Mathauda, 1958; Verma and Sharma, 1978; Rana *et al.*, 1988; Maithani *et al.*, 1989; Patnaik and Patnaik, 1991; Rajan, 1995; Tewari, 1995; Gupta *et al.*, 1996; Ganeshaiah *et al.*, 1998; Melkania and Ramnarayan, 1998; Gautam and Devkota, 1999; Pokharel *et al.*, 1999; Pokharel, 2000). It is evident that sal forests have the potential to yield other forest products, too. A sal tree in addition to timber and fuelwood, produces fodder (Panday, 1982; Gautam, 1990; Pandey and Yadama, 1990; Mathema, 1991; Upadhyay, 1992; Thacker and Gautam, 1994; Fox, 1995; Shakya and Bhattarai, 1995; Edwards, 1996; Gautam and Devkota, 1999); leaves for plates (Rajan, 1995; Gautam and Devkota, 1999); seed for oil (Verma and Sharma, 1978; Sharma, 1981); feed (Rai and Shukla, 1977; Sinha and Nath, 1982), resin or latex from heartwood (FRIB, 1947) and tannin and gum from bark (Narayanamurti and Das, 1951; Karnik and Sharma, 1968). Besides, associates of sal are known to produce edible fruits, fodder and compost, fibres, leaves for umbrellas, medicinal plants, thatch, grass, brooms and many other products depending on the species composition (Stainton, 1972; Jolly, 1976; Panday, 1982; Amatya, 1990; Gautam, 1990; Gilmour and Fisher, 1991; Mathema, 1991; Chettri and Pandey, 1992; Upadhyay, 1992; Schmidt *et al.*, 1993; Bhatnagar and Hardaha, 1994; Chandra, 1994; Jackson, 1994; Tamrakar, 1994; Thacker and Gautam, 1994; APROSC, 1995; Fox, 1995; Shakya and Bhattarai, 1995; Tewari, 1995; Edwards, 1996; Sah, 1996; Dwivedi, 1997; Melkania and Ramnarayan, 1998; Poudyal, 2000; Webb and Sah, 2003). Moreover, there are interesting facts of traditional practices of lopping, browsing and litter collection in sal forests of Nepal and elsewhere (Dinerstein, 1979; Agrawal *et al.*, 1986; Prasad and Pandey, 1987a;

Chopra and Chatterjee, 1990; Pandey and Yadama, 1990; Mukhopadhyay, 1991; Upadhyay, 1992; Saxena *et al.*, 1993; Sundriyal *et al.*, 1994; Bahuguna and Hilaluddin, 1995; Bhat and Rawat, 1995; Nepal and Weber, 1995; Banerjee and Mishra, 1996; Rao and Singh, 1996; Melkania and Ramnarayan, 1998).

3. Methodology

For the comparative study of the soil growing under the sal forest, soil samples were collected from two geographically distinct locations i.e Assam and Doon valley for the determination of the nutrient status and carbon pool.

3.1. Study Area

a) Assam:

3.1.1 Location:

Assam State is bounded by the States of Nagaland, Manipur, Mizoram and Tripura in the south ; Bhutan and the State of Arunachal Pradesh in the north and northeast ; Myanmar in the east ; Meghalaya in the southwest and Bengal in the west. It has a geographical area of 78,438 km, making up 2.39% of the total area of the country. It is situated between 89°42’ and 96°02’ east longitude and 24°7’ and 28°00’ north latitude.

Sal Forest Assam (Kholahat Reserve Forest, Western Range Dharamtul)

Morigaon district is situated between 26.15 ^{0} North and 26.5 ^{0} North latitude and between 92^{0} East longitude. Morigaon Town, the district headquarter is situated at a distance of 78Km from Dispur, the state capital of Assam, India. The district covers an area of 1450.02 Sq.Km and is bounded by the Brahmaputra on the North, Karbi Anglong district on the South, Nagaon District on the East and Kamrup District on the West. The greater part of the district is an alluvial plain, criss-crossed with numerous rivulets and water ways and dotted with wetlands and marshes. The river Brahmaputra flows along with the northern boundary of the district, while Killing, Kollong and Kopili rivers flow through the southern part of the district. The river Killing meets Kopili at the Matiparbat where from Kopili moves westward. Kollong joins Kapili at the Jagi Dui Khuti Mukh and from here they jointly flow into the Brahmaputra. There are three Reserved Forest constituted under Assam Forest Regulation Act, 1891 namely Sunaikuchi, Kholahat, and Bura Mayong and wildlife Sanctuary Pabitara, famous for the Indian one horned Rhinoceros.

The soil samples were collected from Kholahat Reserve Forest, Western Range Dharamtul, under Nagaon Forest Division, District Morigaon. Six soil samples were collected from this site from depth of 0- 30 cm and 30- 60 cm respectively soil. The reserve is situated between the geographical limits of East longitude 92^0 and 93^0 30' North Longitude 25^0 30' and 26^0 30'. The total area of the Kholahat RF is 6164 ha.

3.1.2 Configuration of the ground:

Most of the Reserves are situated on the outlying stretches of the Karbi-Anglong Hills and Meghalaya Hills and often contain steep slopes such as are found in Kholahat RF. The slopes are comparatively moderate and terrain is more or less undulating.

3.1.3. Geology, Rock and Soil:

The southern slopes of the Khasi hills are said to be of the gneissic origin. Nearly whole of the north Karbi- Anglong hills are composed of massive gneiss or foliated granite. The gneiss is composed mostly of quartz feldspar with magnetic hornblende and mica. There is great quantity of ferruginous sandstone passing locally into sandy haematite and conglomerate. In the hilly areas the soil found in the forest is generally clayey loam which is good and suitable for forest growth. The soil is mainly derived by the weathering and decomposition of mostly gneiss and sandstones. On exposure, the soil on the ridges and slopes looses fertility very quickly due to washing away of the fine material and with it the organic and mineral matter.

In the plains the soil is of alluvial origin. The differences in the soil are mainly due to the rocks in the sources of the rivers being geographically different and also due to the rates of flow and rise and subsidence of flood water which determine the size of particles being deposited. Broadly speaking there is more sand and silt in the Brahmaputra alluvium. The soil is mostly composed of sandy to silty loam and is slightly acidic in reaction. Generally the old alluvium is very deep, brownish to yellowish brown in colour with the texture of fine loams to coarse loams and is slightly to moderately acidic.

The area represents a part of the foreland depression between the Himalayas in the north and the Shillong plateau in the south with the following stratigraphic succession;

Age	Formation	Lithology
Quaternary	Younger & older Alluvium	Fine to course sand, gravel pebble embedded in sand
Archean	Shillong Group	Gneiss intruded by acidic granite & basic intrusive

The unconsolidated alluvium of Quaternary age comprise of younger and older alluvium consisting of sand of various textures with minor amount of silt and clay and is found in the area between kolong and Brahmaputra, while the older alluvium is found in the channels of kolong and Kopili river and to the south. The Archean group of rocks comprise of biotite- hornblende gneiss granulites, schist intruded by granites & pegmatite exhibit NE-SW trend with moderate dip towards NW. As per CGWB records, the granite basement is encountered at a depth of 95m at Jagiroad, 239 m at Dharamtul and 254 m at Rajagaon towards Brahmaputra, i.e., the slope of the basin dips from south to north

3.1.4. Climate

The climate of Assam is dominated by the subtropical monsoon. The annual rainfall ranges from 1800 mm in the central Kamrup district to 3000 mm in the Barak Valley. Three quarter of the rains fall during the monsoon between June and September. The plains are flooded and the Brahmaputra becomes an inner sea. Autumn and winter are dry seasons and during spring, storms linked to cyclones in the Bengal Gulf occur occasionally. The climate is characterised by the excessive moisture of air and rise of temperature is checked by frequent showers and thunderstorms. The change of season is therefore not marked by extreme contrast of temperature and humidity.

The annual rainfall on an average varies from 1350.77 mm to 2271.26 mm. The coldest month of the year is December and January when the minimum temperature varies from 7.20C to 11.1 0C. From March to the middle of November the temperature is fairly high, July and August being the hottest months, when the maximum temperature on average rises to 33.050C. There is no frost. Fogs occur frequently during November to February in the early morning.

3.1.5. Vegetation

Major Forest Types with list of major species: In the "Revised Survey of Forest Types in India", Champion and Seth categorized as many as fifty one different forest types/ sub types for north-east region. However, broadly speaking the forests in Assam can be described into the following types/ sub-types.

1. Tropical Wet Evergreen Forests
2. Tropical Semi-Evergreen Forests
3. Tropical Moist Deciduous Forests
4. Sub-tropical Broadleaf Hill Forests
5. Sub-tropical Pine Forests
6. Grassland and Savannahs
7. Littoral and Swamp Forests

1. Tropical Wet Evergreen Forests are found in the districts of Golaghat, Jorhat, Sibsagar, Tinsukia, and Dibrugarh and in a narrow stretch in Lakhimpur and Dhemaji districts along foot hills. These forests also occur in the southern part of the State at lower elevations in Borail Range, and in Loharbund, Sonai, Longai and Dholia Reserve Forests in Cachar and Karimganj districts.

2. Tropical Semi Evergreen Forests have mostly medium sized trees with few large trees. Shrubs, lianas, climbers, orchids and ferns grow copiously. At the fringe bamboos and canes occupy the space. Species association and frequency of their occurrence vary from forest to forest.

3. Moist Deciduous Forests can further be described as Sal Forests and Mixed Deciduous Forests. Sal Forests occupy considerable forest area in the Central and Lower parts of the

State in the Districts of Nagaon, Morigaon, Kamrup, parts of Nalbari and Barpeta, Darrang, Dhubri, Kokrajhar and Goalpara. In these forests, Sal grows in association with *Lagerstroemia* species (Jarul, Ajar), *Schima Wallichii* (Ghugra), *Stereospermum personatum* (Paruli), *Adina cordifolia* (Haldu), *Artocarpus* species (Sam), *Ficus* species (Bor, Dimoru, Dhupbor, Bot, Athabor, tengabor, Lotadioru, Khongaldimoru), *Bischofia javanica* (Uriam), *Gmelina arborea* (Gomari), *Michelia champaca* (Teeta champa), *Terminalia* species (Hilikha, Bhomora, Bahera), *Toona ciliate* (Poma), etc. Moist Deciduous Mixed Forests occur at the foot of hills in Lakhimpur, Dhemaji, Karbi-Anglong and N. C. Hills districts. Trees are mostly deciduous with sprinkling of few evergreen and semi-evergreen species. Important plant species growing in these forests include *Adina cordifolia* (Haldu), *Albizia* species (Siris, Kolasiris, Koroi, and Sau), *Alstonia scholaris* (Satiana), and *Artocarpus chaplasa* (Sam)

4. Sub-tropical Broad Leaf Hills forests and Sub-tropical Pine forests occur in the districts of Karbi-Anglong and N. C. Hills. Species commonly occurring are *Alseodaphne petiolaris* (Ban-hanwalu), *Antidesma bunius, Betula alnoides, Cleidon speciflorum* etc. Higher up pure stands of *Pinus kesiya* (Khasi-pine) are found, particularly in the Hamren sub-division in Karbi-Anglong district.

5. Grass land and Savannahs are grass dominated biomes and form the major part of vegetation in Kaziranga National Park, Orang N.P., Dibru-Saikhowa N.P., Pobitora, Sonai-Rupai, Laokhowa, Barnadi, Burachapori Wildlife Sanctuaries and some part in Manas National Park. Grasslands support important wildlife population in Assam. Important grasses are *Apluda mutica, Phragmatis karka, Sclerostachya fusca, Saccharum species.*

6. Littoral and Swamp forests have almost lost their identity because of biotic pressure on land. Presently sedges and grasses form the largest component of vegetation. Important species include *Ageratum conyzoides, Alocasia* species, *Alpinia* species, and *Amaranthus* species.

b) Doon Valley:

3.2. The Doon valley is located in the Siwalik Himalayas, lying between latitudes 29° 55’ and 30 °30’ N and longitudes 77° 35’and 78 °24’E. It is about 20 km wide and 80 km long saucer-shaped valley with a geographical area of 2100 km ^{2}. The valley is longitudinal, intermontane, syncli-nally depressed bouldery (Thakur and Pandey 2004; Kumar *et al.,* 2007) filled with coarse clastic fan – Doon gravel of late Pleistocene and Holocene (Puri, 1950).

The valley is uniformly oriented in the NW–SE direction, with the Lesser Himalayas in the northeast and the Siwalik ranges in the south-west. The two major hydrologic basins of the valley are the Ganga in the southeast with the Song and Suswa as its main tributaries and the Yamuna in the northwest with the river Asan as its main tributary.

The soils of the Doon Siwalik were developed on the deep alluvial deposits with parent material derived from the Doon alluvium. It consists of accumulated beds of clays, boulders, pebbles and sand with the admixture of water-borne small to big size stones in the subsoil in varying proportions (Singhal *et al.,* 1982; Yadav *et al.,* 1973). This alluvium was deposited by the multilateral, multi-braided channel system. All the study sites investigated in the present study were heavily forested with the northern tropical moist deciduous forest having an admixture of a variety of species in the four-tier structure (top canopy, middle strata, and understory shrub and herb strata) with S. robusta as the predominant species.

3.2.1. Location: The New Forest State, placed in the valley of Dehradun is situated between 30° 19' 55" and 30° 21' 16" North latitude and 77° 58' 40" and 78° 1' East longitude. The average length of the main block is about 3.22 km and the average width is about 1.61 km. The area lies in the valley of Yamuna, and is drained in the East by river Tons, which is a tributary of the Asan and joins the Yamuna near Rampur Mandi. The campus was created in 1927 on village land, which was then surrounded by natural forest of Sal.

3.2.2 Configuration of the ground: The general elevation of the ground is about 2,200 feet. The land is more or less levelled with gentle slope. The ground slopes gently southwards with a sufficient fall which ensures good natural drainage. The exceptions of the slopes overlooking the eastern Tons, which are cut up by water channels, are steep with a northern aspect.

3.2.3 Geology, rock and soil: It comprises mainly of conglomerates and the middle Siwalik sand rocks. The conglomerates consist of hard rock pebbles, quartzite or fine gravelled semi crystalline sandstones in a highly calcareous matrix. The soil is generally medium silty to clay loams, overlying boulder deposits at good depth. It is often shallow and stony. The soils and subsoil is porous and extremely well drained.

Sal Forest Dehradun.

3.2.4 Climate

3.2.4. a. Rainfall

The monsoon generally breaks at the end of June and the rains continue until about the middle of September, the heaviest fall normally occurs in July and August. Occasional showers may occur in September and October after which there is little rainfall. Scanty rainfall occurs in January and February after which there is very little rainfall and occasional thunderstorms until the break of monsoon.

3.2.4. b. Temperature: The mean annual temperature of the area as recorded at Forest Research Institute Observatory is 19.41^0 C with mean minimum and maximum temperature of $29.2\ ^0$ C and 10.5^0C respectively. The hottest month are May- June and the coldest being December – January.

3.2.5. Soil supporting *Shorea robusta (Sal)*:

A patch of *Shorea robusta* occurs near the Pine plantation at 30°20'19.2" N and 78°0'41.8" E coordinates at an elevation of 691m, in the Champion Block. The overwood is Shorea robusta and the middle wood is mainly comprised of *Mallotus philipinensis* and *Ailenthus excelsa.*

Good regeneration of Sal was noticed. The slope is gentle and concave. There is very slight erosion due to tree cover, bushes and the gentle slope. The surface is slight crusting and the drainage is medium. Three soil samples were collected from the site and were named as SS_1, SS_2, and SS3 with respective depths from 0 to 30 cm to 30 to 60 cm respectively.

3.3. Soil Sampling and Analysis

Soil testing is comprised of four steps:

- Collection of a representative soil sample
- Laboratory analyses of the soil sample
- Interpretation of analytical results
- Management recommendations based on interpreted analytical results

Individual analyses included in a 'standard' or 'routine' soil test varies from laboratory to laboratory, but generally include soil pH, and available phosphorus (P) and potassium (K). They sometimes also include available calcium (Ca) and magnesium (Mg), salinity, and often include an analysis of organic matter content and soil texture. Most laboratories offer nitrogen (N), sulphur (S), and micronutrient. The methods used to test soils vary depending on chemical properties of the soil. For example, tests used for measuring soil Phosphorus, nitrogen etc.

3.3.1. SOIL PARAMETERS ESTIMATION

Soil samples were collected from three different locations on the natural sites from the different depths 0-30 cm and 30-60 cm. A pit of 30 cm wide, 60 cm deep and 50 cm in length was dug out. Soil from 0 to 30 cm and 30 to 60 cm depth, from three sides of the pit, scraped with the help of Kurpee. This soil mixed thoroughly and removed gravels. Keep in a polythene bag and tightly closed with thread with proper labelling. After carefully removing fine roots and organic materials the air dried samples were sieved through a 2 mm mesh screen and used for chemical analysis. Twelve soil samples i.e. Six from Kholahat RF and Six from New Forest Area, FRI Dehradun were collected for the analysis.

3.3.1. a. pH

Soil pH is a measure of the acidity or alkalinity of a soil. The term pH applies to solutions, so the analysis must be conducted on a soil/water mixture. The soil sample is mixed with water, allowed to equilibrate for at least an hour, and then the pH measured. Several factors affect pH measurement. Primary among these is the salt concentration of a soil (a salt is any molecule that, when placed in water, separates into positively and negatively charged components or ions). The salt concentration of a soil may vary with the season or with fertilizer application, and is generally greater immediately following fertilizer application than before. The result may be an apparent pH drop up to one-half a pH unit.

The pH was estimated in soil: distilled water (1:2.5) suspension using a digital pH Meter (Jackson, 1967). Available nitrogen was determined by alkaline potassium permanganate method (Subbiah & Asija, 1956). Available P and Ex. K were determined by the Olsen sodium bicarbonate extraction (Olsen & Dean, 1965) and sodium acetate extraction, respectively and determined by Spectrophotometric method as described by Jackson (1967).

When samples are collected frequently or at various times of the year it may be noted that pH values tend to increase and decrease, seemingly at random. This can lead to questions regarding the reliability of soil pH measurements, but the fluctuations may be due to changes in soil salt levels and do not usually present a serious problem in the use of the analysis.

3.3.1. b Available Nitrogen (N)

A major portion of soil nitrogen is contained in the soil organic matter. Plant availability of organic N is dependent on OM breakdown, which is difficult to estimate. Therefore analyses of "total N", a sum of all forms of soil nitrogen, including organic nitrogen, are not routinely conducted. Instead, N in the nitrate form (NO_3-N) is assayed. Nitrate is directly available to plants, so this test provides an indication of short term Nitrogen availability. However, NO_3-N can be quickly lost from soil, either leached past the rooting zone, or lost to the atmosphere in gaseous forms.

Nitrate analyses can provide an accurate determination of the nitrogen available to plants at the time of soil sampling, although this may not provide reliable information concerning nitrogen availability later in the growing season.

Estimation of Nitrogen content in the given sample by Kjeldahl method:

The reagents used to estimate nitrogen are as follows

1. N/10 NaOH – It is prepared by dissolving 100 cc. of 1N NaOH in 100 ml of distilled water.

2. N/50 H_2SO_4 – It is prepared by dissolving 100cc. of 1N H_2SO_4 in 1000 ml of distilled water.
3. Indicator – Methyl Red- It is prepared by dissolving 1gm of solid methyl red in 250 ml absolute alcohol and 250 ml distilled water.
4. $KMNO_4$
5. Distilled water
6. Conical flasks
7. Titration apparatus

Procedure

1. 5 gm of soil sample was taken in the Kjeldahl flask
2. 50 ml of $KMNO_4$ was measured by the measuring cylinder and was added to Kjeldahl flask.
3. 200 ml of distilled water was added to it.
4. The sample in the flask was connected to the distillation unit.
5. The sample was left for digestion for 1 1/2 hours.
6. 10 ml of N/50 H_2SO_4 and 4 to 5 drops of methyl red was taken in a separate flask.
7. Then, this flask was put on the other side of the Kjeldahl apparatus and the end of the delivery tube was dipped in the conical flask.
8. The distillate was collected and then titrated with N/10 NaOH solution till the pink colour disappears.

Formula used

$$\textbf{\% of Nitrogen} = \frac{\textbf{Difference between readings x 1.4 x N}}{\textbf{Weight of sample (gm) x 10}}$$

Where, Difference = Titration Reading – Blank Reading

N = Normality of H_2SO_4, *i.e.* 1/50

3.3.1. c Available Phosphorus (P)

Most soil Phosphorus is tightly bound to soil particles or contained in relatively insoluble complexes. The phosphorus -containing complexes in alkaline soils are very different than those in neutral or acidic soils. The amount of phosphorus removed during soil extraction is very much dependent on the nature of phosphorus complexes and on the specific extractant used, so it is critical that P extractants be matched to soil properties. To analyse the Phosphorus content in the soil sample Blue Colour Method or Bray Method was used.

In most natural ecosystems, such as forests and grasslands, phosphorus uptake by plants is constrained by both the low total quantity of the element in the soil and by very low solubility of the scarce quantity that is present (Brady and Weil, 2002). It is the most commonly plant growth-limiting nutrient in the tropical soils next to water and Nitrogen (Mesfin, 1996). Erosion tends to transport predominantly the clay and organic matter fractions of the soil, which are relatively rich in phosphorus fractions.

Flame Photometer

Estimation of Phosphorus % in the given soil sample by the help of Blue Colour Method or Bray Method

Apparatus used: (1) 250 ml conical flask

(2) 50 ml conical flask

Reagents Used: (1) $NaHCO_3$ (Sodium bicarbonate)

(2) Ammonium Molybedate

(3) Tin chloride (SnCl2)

(4) Activated Charcoal

Method to prepare the reagents:

(1) $NaHCO_3$ (Sodium bicarbonate)

- Take 84.01 gm for preparing 2 litres of solution i.e. 42 gm for 1 litre.
- Dissolve it in 1 litre of volumetric flask.
- Make up the solution with distilled water.

(2) Ammonium Molybedate 250 ml

- Take 3.5 gm of Ammonium Molybedate
- Add 100 ml concentrated HCl.
- To the solution add 100 ml Distilled Water.
- Make upto 250 ml in 250 ml conical flask.

(3) Colouring agent Tin Chloride ($SnCl_2$)

- Take 0.625 gm of Tin chloride
- To it add 5 ml conc. HCl
- Add 250 ml Distilled water to the given solution.

Procedure

1. Take 5 gm soil in 250 ml conical flask.
2. Add 50 ml $NaHCO_3$ to the soil sample.
3. To it add 1 teaspoonful of activated charcoal.
4. Keep the mixture for shaking for half an hour approximately.
5. With the help of the filter paper filter the mixture.
6. After filtration take 10 ml of the filtrate in the 50 ml volumetric flask by the help of the pipette.
7. Now add 2 ml Ammonium Molybedate to the solution.
8. Make up the volume upto 50 ml.
9. After that add 2 to 4 drops of colouring agent i.e. $SnCl_2$.

10. Take the reading by the help of the Spectrophotometer.

3.3.1. d. Ex. Potassium (K)

Soil parent materials contain potassium (K) mainly in feldspars and micas. As these minerals weather, and the potassium ions released become either exchangeable or exist as adsorbed or as soluble in the solution (Foth and Ellis, 1997). Potassium is the third most important essential element next to nitrogen and phosphorus that limit plant productivity. Its behaviour in the soil is influenced primarily by soil cation exchange properties and mineral weathering rather than by microbiological processes. Unlike N and P, K causes no off-site environmental problems when it leaves the soil system. It is not toxic and does not cause eutrophication in aquatic systems (Brady and Weil, 2002) Wakene (2001) reported that the variation in the distribution of potassium depends on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed. The greater the proportion of clay mineral high in potassium, the greater will be the potential potassium availability in soils (Tisdale *et al.,* 1995). Soil potassium is mostly a mineral form and the daily K needs of plants are little affected by organic associated potassium, except for exchangeable potassium adsorbed on organic matter. Mesfin (1996) described low presence of exchangeable potassium under acidic soils while Alemayehu (1990) observed low potassium under intensive cultivation. Normally, losses of potassium by leaching appear to be more serious on soils with low activity clays than soils with high-activity clays, and K from fertilizer application move deeply (Foth and Ellis, 1997).

Exchangeable potassium: The exchangeable potassium was extracted with neutral normal ammonium acetate from a known quantity of soil. The extractant was fed to flame photometer for measuring potassium contents (Page *et al,* 1982).

Estimation of Potassium content in the soil sample

Apparatus required: (1) 250 ml conical flask

(2) 10 ml volumetric flask

Chemicals Required: Ammonium acetate (CH_3COONH_4)

Procedure

1. Take 5 gm of soil sample in the conical flask.

2. Add 50 ml of Ammonium acetate to the soil sample.
3. Leave the mixture for shaking for half an hour.
4. With the help of the filter paper filter the mixture.
5. Collect the filtrate in 10 ml of the filtrate in 100 ml volumetric flask.
6. Make up the volume till 100 ml with distilled water.
7. Take the galvo reading by the help of Flame Photometer.

Formula Used for the estimation of potassium % in the soil sample is as follows:

% K = X (ppm) x 0.010

3.3.1. e. Organic Carbon (OC)

The total amount of organic carbon in the soil can be considered as a measure of stored organic matter. In a sense, stored organic matter is a mean organic matter store or standing stock of organic matter because it reflects the net product or balance between ongoing accumulation and decomposition processes and it is thus greatly influenced by crop management and productivity. Over the past few years, various attempts have been made to obtain both global and regional inventories of soil organic matter storage based on soil map units. Generally, sample generic soil horizons based on the effects of land use types and/or management practices provide a useful estimate of total soil carbon storage (Carter *et al*., 1997).

In the laboratory, samples were air dried and after drying the samples, grind it and sieve it through 100 mesh sieve. This sieved sample used for soil organic carbon estimation. Soil organic carbon was estimated by standard **Walkley & Black (1934) method**. Amount of coarse fragments were estimated in each sample collected from different forests and deducted from the soil weight to get an accurate soil weight per ha basis and soil organic carbon estimation.

Organic carbon estimatio

Estimation of soil organic carbon by Walkley & Black method

Apparatus required: (1) 500 ml conical flask

(2) Measuring cylinder

(3) Pipette

Reagents Used: (1) $K_2Cr_2O_7$ (Potassium dichromate)

(2) FAS (Ferrous ammonium sulphate)

(3) Diphenyl amine

(4) Conc. H_2SO_4

(5) Orthophosphoric acid

Methods to prepare the reagents

1) $K_2Cr_2O_7$ (Potassium dichromate)
   - Take 98.07 gm of $K_2Cr_2O_7$ in 2 litre conical flask
   - Add 1000 ml distilled water to it.

- Make the solution for 2 litres.

2) FAS (Ferrous ammonium sulphate)
   - Take 392.14 gm FAS in a conical flask.
   - Add 50 ml conc. H_2SO_4
   - Make paste with 1 litre distilled water.
   - Now make up the solution for 2 litres.
3) Diphenyl amine
   - Take 2.5 gm of diphenyl amine in conical flask.
   - Add 400 ml of conc. H_2SO_4.
   - Make up the solution upto 500 ml with distilled water.

Procedure

1. Take 1 gm soil in 500 ml conical flask.
2. Add 10 ml $K_2Cr_2O_7$ by the help of pipette.
3. Add 20 ml conc. H_2SO_4 by the help of measuring cylinder.
4. Leave the mixture for half an hour.
5. Now add 200 ml distilled water.
6. Again add 10 ml Orthophosphoric acid.
7. Add 2 to 5 drops of Diphenyl amine which is an indicator.
8. Now titrate the mixture with FAS.
9. Endpoint is obtained when dull green colour is obtained.

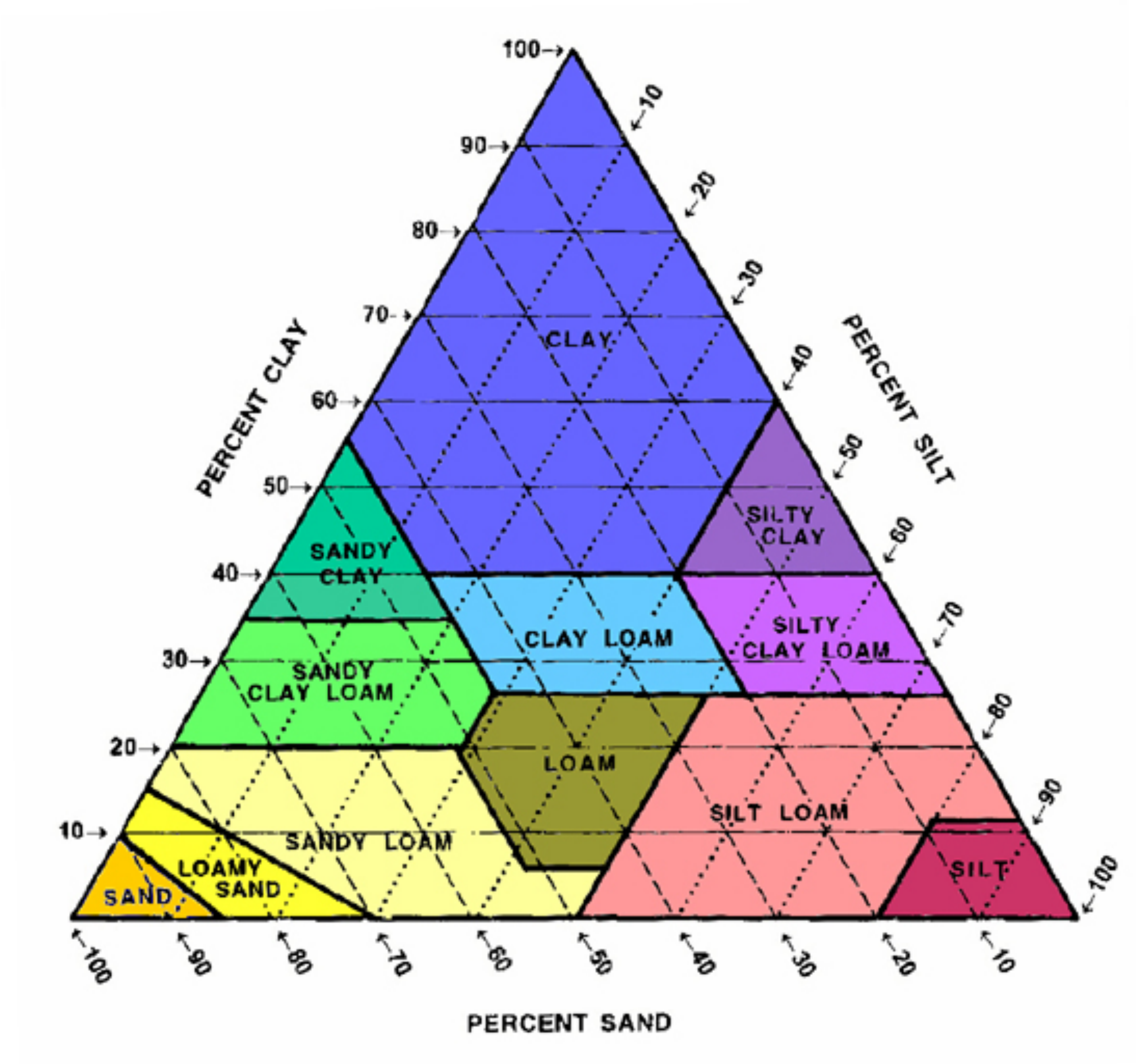
Formula used

% C= (Blank Reading – Reading) x 0.2

% Organic matter = % Organic carbon x 1.724

3.3.1.f Texture Estimation

The texture of a soil horizon is an almost permanent character, as texture does not change over a very long period of time. The texture of the soil is one of the fundamental considerations in soil classification. Textural analysis also indicates the weathering stage to some extent. The textural class name is suggestive of many properties that have bearing on its management and productivity. Sandy soils are of open character, possess good drainage and aeration, and are usually loose and friable and easy to handle in tillage operations. Clayey and silty soils, owing to their large surface area possess high adsorptive and retention capacities for moisture, gases and nutrients. They usually have fine pores, are moderate to poor in aeration and drainage, and are relatively difficult to handle for cultivation purposes.



Soil characteristics under Sal Forest of Assam (Kholahat Reserve Forest, Nagaon) and Uttarakhand (New Forest State, FRI, Dehradun)

pH: Soil pH under the Sal forest of both Assam and Uttarakhand are slightly acidic. The pH of the Assam varies between 5.3 to 5.8 whereas, the pH of Uttarakhand soil varies between 5.3 to 6.1 (Table 1).

Table 1: Estimation of pH, soil organic carbon, organic matter, nitrogen, potassium, phosphorus and soil texture of the soil under Sal forest of Assam and Uttarakhand

Site	Site	Site	Site	Site	Site	Site	Site	Av. P	Sand	Silt	Clay	Texture
	(cm)		(%)	(t/ha)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
Sal Assam	0 -30	5.7	1.16	46.4	2.00	0.02408	0.034	0.0006	76.00	13.00	11.00	Loam
Sal Assam	0 -30	5.6	0.72	28.8	1.24	0.02688	0.017	0.0014	71.00	22.00	7.00	Loamy Sand
Sal Assam	0 -30	5.8	0.66	26.4	1.14	0.04312	0.013	0.0017	73.00	20.00	7.00	Loamy Sand
	Mean	5.70	0.85	33.87	1.46	0.0314	0.021	0.0012	73.33	18.33	8.33	
Sal Assam	30 - 60	5.3	0.76	30.4	1.31	0.02576	0.011	0.0022	69.00	23.00	8.00	Loamy Sand
Sal Assam	30 - 60	5.5	0.82	32.8	1.41	0.02688	0.02	0.0006	66.00	27.00	7.00	Silty Loam
Sal Assam	30 - 60	5.7	0.78	31.2	1.34	0.02856	0.017	0.0013	74.00	19.00	7.00	Loamy Sand
	Mean	5.50	0.79	31.47	1.36	0.0271	0.0160	0.0014	69.67	23.00	7.33	
Sal Uttarakhand	0 -30	5.7	1.12	44.8	1.93	0.02464	0.014	0.0004	69.00	23.00	8.00	Loamy Sand
Sal Uttarakhand	0 -30	5.3	0.68	27.2	1.17	0.02576	0.026	0.0017	73.00	20.00	7.00	Loamy Sand
Sal Uttarakhand	0 -30	6.1	0.8	32	1.38	0.04592	0.007	0.0022	69.00	22.00	9.00	Loamy Sand
	Mean	5.70	0.87	34.67	1.49	0.0321	0.0157	0.0014	70.33	21.67	8.00	
Sal Uttarakhand	30 - 60	5.5	0.72	28.8	1.24	0.0224	0.02	0.0017	66.00	26.00	8.00	Silty Loam
Sal Uttarakhand	30 - 60	5.3	0.62	24.8	1.07	0.02352	0.015	0.0013	70.00	21.00	9.00	Loamy Sand
Sal Uttarakhand	30 - 60	6	0.96	38.4	1.66	0.03472	0.006	0.0007	74.00	18.00	8.00	Loamy Sand
	Mean	5.60	0.77	30.67	1.32	0.0269	0.0137	0.0012	70.00	21.67	8.33	

Soil organic carbon and Organic matter

The soil of Assam has organic carbon ranging from 0.66 to 1.16 and the soil organic matter ranging between 1.034 to 1.999 whereas, the organic carbon in the Uttarakhand soil varies from 0.72 to 1.12 and soil organic matter varies between 1.068 to 1.93. There is very little difference between soil organic carbon and soil organic matter percentage in the soil of Assam and Uttarakhand.

Available Nitrogen, Phosphorus and Potassium

Available nitrogen in the soil of Assam ranges between 0.02408 to 0.0431 with highest concentration in the third sample. The soil of Uttarakhand has nitrogen varying from 0.0224 to 0.0459. The phosphorus concentration between the soil of Assam and Uttarakhand is also non significant. The Potassium concentration in the soil shows that the soil of Assam has higher Potassium concentration as compared to the Uttarakhand soil.

Soil Texture

The soil texture analysis shows that the soil of both Assam and Uttarakhand has loamy sand texture

Site	**Depth**	**pH**	**Org. C**	**SOC Stock**	**Org. M**	**Av. N**	**Ex. K**	**Av. P**	**Sand**	**Silt**	**Clay**
	(cm)		**(%)**	**(t/ha)**	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**
Sal Assam	0 -30	5.70	0.85	33.87	1.46	0.0314	0.0213	0.0012	73.33	18.33	8.33
Sal Assam	30 -60	5.50	0.79	31.47	1.36	0.0271	0.0160	0.0014	69.67	23.00	7.33
	Mean	**5.60**	**0.82**	**32.67**	**1.41**	**0.0292**	**0.0187**	**0.0013**	**71.50**	**20.67**	**7.83**
Sal Uttarakhand	0 -30	5.70	0.87	34.67	1.49	0.0321	0.0157	0.0014	70.33	21.67	8.00
Sal Uttarakhand	30 -60	5.60	0.77	30.67	1.32	0.0269	0.0137	0.0012	70.00	21.67	8.33
	Mean	**5.65**	**0.82**	**32.67**	**1.41**	**0.0295**	**0.0147**	**0.0013**	**70.17**	**21.67**	**8.17**

Results of one - way ANOVA indicates that ex. potassium between the soil of Assam and Uttarakhand were significantly different whereas organic carbon, organic matter, ex. Nitrogen and Phosphorus have no significant difference.

The study of the climate of Assam and Uttarakhand were made by comparing the climatological data of the two states which is represented in the following tables.

Table 3: Meteorological Data of Forest Research Institute. Monthly average data (2012 – 2013).

Month	Temperature (0 0 C)			Vapour Pressure (mm of Hg)		Relative Humidity (%)		Rainfall	Evaporation	Bright Sunshine	Mean Wind Velocity
	Max	**Min**	**Mean**	**0719**	**1419**	**0719**	**1419**	**mm**	**(mm)**	**Hr /day**	**Km/ hr**
Jan	18.6	3.5	10.5	6.4	7	99	49	27.7	1.2	5.1	2.2
Feb	22.6	5.5	13.8	7.2	7.3	96	37	13.1	2.1	6.1	2.7
Mar	28.2	8.9	18.2	8.9	8.8	89	31	25.8	3.8	8	3.1
Apr	31.8	13.4	22.5	12.1	10.9	76	32	34.8	5.1	8.5	3.6
May	36.9	16.5	25.9	12.4	9.9	56	22	0.3	7.2	8.7	3.8
June	38.6	21.4	29.2	16.6	13.9	60	30	41.7	7.7	7	4.2
July	30.9	23.2	26.5	22.2	22.9	93	77	659.5	3.4	2.8	2.6
August	29.6	22.5	25.4	21.7	22.7	97	80	976.8	2	2.7	2.3
Sept	30.4	20.8	25	19.7	22.6	93	70	301.3	2.9	6.3	2.5
Oct	29.4	12.8	21.2	12.1	13.4	91	46	2.9	2.8	8.8	2
Nov	25.5	7.7	16.3	8.4	10.3	98	46	22.7	1.6	7.3	1.4
Dec	21.8	4.4	12.7	6.7	8.3	99	47	17.2	1.1	6.2	1.6
Jan-13	19.8	2.5	10.6	5.8	7.1	99	43	99.3	1.3	6.7	1.9
Feb-13	21	7.7	14	8.2	9.4	97	56	182.5	1.8	6	2.5
Total	**385.1**	**170.8**	**271.8**	**168.4**	**174.5**	**1243**	**666**	**2405.6**	**44**	**90.2**	**36.4**
Av.	**27.50**	**12.2**	**19.41**	**12.02**	**12.46**	**88.78**	**47.57**		**3.14**	**6.44**	**2.6**

Table 4: Rainfall in Morigaon and Nagaon district of Assam during the period from January 2012 to January 2013. ***(Source: IMD, RMC, LGBI Airport, Borjhar, Assam.)***

Month		Morigaon	Nagaon
January	Actual	23.9	9.5
	Normal	18.7	12.0
	% Dep	28%	-21%
	Pattern	Excessive	Deficient
February	Actual	0.0	0.0
	Normal	24.4	22.5
	% Dep	-100%	-100%
	Pattern	No rain	No rain
March	Actual	14.8	12.4
	Normal	51.6	48.1
	% Dep	-71%	-74%
	Pattern	Scanty	Scanty
April	Actual	182.3	107.5
	Normal	116.8	128.9
	% Dep	56%	-17%
	Pattern	Excessive	Normal
May	Actual	106.6	80.7
	Normal	169.1	171.3
	% Dep	-37%	-53%
	Pattern	Deficient	Deficient
June	Actual	256.4	184.6
	Normal	310.1	285.9
	% Dep	-17%	-35%
	Pattern	Normal	Deficient
July	Actual	284.4	232.5
	Normal	374.8	326.3
	% Dep	-24%	-29%
	Pattern	Deficient	Deficient
August	Actual	241.2	190.5
	Normal	309.2	294.1
	% Dep	-22%	-35%
	Pattern	Deficient	Deficient
September	Actual	250.8	280.6
	Normal	221.4	218.6
	% Dep	13%	28%
	Pattern	Normal	Excessive
October	Actual	56.4	141.4
	Normal	119.3	120.0
	% Dep	-53%	18%
	Pattern	Deficient	Normal
November	Actual	0.0	5.2
	Normal	19.9	21.6
	% Dep	-100%	-76%
	Pattern	No rain	Scanty
December	Actual	0	0
	Normal	8.2	10.8
	% Dep	-100%	-100%
	Pattern	No rain	No rain
January	Actual	0.0	0.0
	Normal	18.7	12.0
	% Dep	-100%	-100%
	Pattern	No rain	No rain

The study of the meteorological data of FRI shows that the monsoon generally breaks at the end of June and the rains continue until about the middle of September, the heaviest fall normally occurs in July and August. Occasional showers may occur in September and October after which there is little rainfall. Scanty rainfall occurs in January and February after which there is very little rainfall and occasional thunderstorms until the break of monsoon. The mean annual temperature of the area as recorded at Forest Research Institute Observatory is 19.41^{0} C with mean minimum and maximum temperature of $29.2\ ^{0}$ C and 10.5^{0}C respectively. The hottest month are May- June and the coldest being December – January.

In Assam the monsoon lasts from April to July or the onset at times is delayed by a month with early completion, while floods create havoc usually from June to September. The average annual rainfall is about 1530.9 mm (annual average Rainfall 2006 – 2010; IMD) and temperature in winter varies from a maximum of 24.8 ° Celsius to a minimum of 11.2 ° Celsius while summer temperature varies from a maximum of 32.9 ° Celsius to a minimum of 25.5 ° Celsius. The annual average maximum temperature is 30.4 ° Celsius and the minimum is 19 .8 ° Celsius and the cold period is from December to February.

Conclusion

Forest is a very important land use not only to increase soil carbon store, but also as a good tool for increasing carbon sink. Deforestation results in increased air movement and facilitates oxidation of organic matter thus emitting CO_2. In a homogenous climatic region the productive capacity of a site is directly related to the characteristics of the soil and land. Therefore, the nature of the vegetation always has some bearing on the nature of the soil and vice versa.

The overall assessment of the soils under Sal forest of Assam and Uttarakhand shows that the soils have similar chemical and physical characteristics except for Potassium concentration, which is slightly higher in the Assam soil as compared to the Uttarakhand soil. Differences in available nitrogen and phosphorus was statistically non significant between the soil samples of Assam and Uttarakhand. In general, it can be concluded the soils under Sal in both the area have more or less similar properties, hence soils are mainly governed by the vegetation as the climatic conditions and topography of both the area was nearly same. Soils normally enriched by the litter produced by the vegetation which undergo many transformations and later on released the nutrients. Both the sites were covered with the same vegetation *i.e.* Sal therefore, soil nutrient concentration was similar.

References:

Assam Forest at a glance. Published by Assam forest Department (2011-2012).

Banerjee S.K, S Nath, Balvinder Singh, P.K Das and S.K Gangopadhyay, September (1989). Soil characteristics under Sal (*Shorea robusta*) in Tarai region of The North-Eastern Himalayas,..626-633

Bhattacharya, T., Pal, D.K., Mondal, C. and Velayutham, M. 2000. Organic carbon stock in Indian soils and their geographic distribution. *Current Science*, 79 (5):655-660.

Bohn, H.L.1976. Estimate of organic carbon in world soils II Soil Sci. Soc. Am. J., 40 pp. 468–470.

Bolin, B., Degens, E.T., Duvigneaud, P., Kempe, S., 1979. The global biogeochemical carboncycle. In: Bolin, B., Degens, E.T., Kempe, S., Ketner, P. (Eds.), SCOPE 13. Wiley, Chichester, UK, pp. 1–56.

Brady, N.C. 1996. *The Nature and Properties of Soils*. Tenth edition, Prentice Hall of India Pvt. Ltd. New Delhi.

Clark, J. D. and Johnson A. H., 2011. Carbon and nitrogen accumulation in post-agricultural forest soils of western New England. *Soil Science Society of America Journal.* 75 (4): 1530-1542.

Das, A. K., Khumbongmayum, A. D., Nath P. C. and Hina N. K. 2010. Phytosociological studies in a subtropical forest on the Rono Hills, of the Papum Pare District of Arunachal Pradesh. *Indian Journal of Forestry*. 33 (1): 33-40.

Dey, S.K. 2005. A preliminary estimation of carbon stock sequestered through rubber (*Hevea brasiliensis*) plantation in north eastern regions of India. *Indian Forester*, 131 (11): 1429-1435.

Eswaran H, Reich P. F., Kimble J. M., Beinroth F. H., Pad-manabhan E. and Moncharoen P., 1999. Global Climate Change and Pedogenic Carbonates (Ed.) by: Lal R, et al. Lewis Publishers, Fl, USA, 15-25.

Gupta, M.K. and Negi, S.S. 2012. Carbon sequestration through Soil Organic Carbon pool under different forests covers in Chamoli District of Uttrakhand. *Indian Forester*, 138 (3): 207-211.

Gupta, M.K. and Sharma, S.D. 2011. Soil Organic Carbon in different land uses and land covers in Bageshwar District of Uttrakhand. *Annals of forestry* 19 (2): 237-244.

Gupta, M.K. 2011. Status of sequestered organic carbon in the soils under different land covers in Nainital district of Uttarakhand. *Indian Journal of Forestry*. 34 (4): 391-396.

Gua, L.B. and Gifford, R.M. 2002. Soil Carbon stocks and land use change: a meta analysis. *Global Change Biology* 8 (4): 345 – 360
Hydrogeology Assessment for Mayong & Bhurbandha block, Morigaon dist. Assam, INDIA
Hydrogeology Assessment for Mayong & Bhurbandha block, Morigaon dist. Assam R C S D Project Report N o 09 , 2011 GRS&GIS

Huston, M.A. 1994. Biological diversity: the coexistation of species in changing landscape. Cambridge University press, Cambridge.
Hutchings M.J. 1983. Plant diversity in four chalk grassland sites with different aspects. *Vegetation* 53:179-189.
IPCC (2003). Good Practice Guidance for Land Use, Land Use Change and Forestry. Published by the Institute for Global Environmental Strategies (IGES) for the IPCC. Publishers Institute for Global Environmental Strategies, Japan.
IPCC 2007. Mitigation of Climate Change: working Group III Contribution to the: Fourth Assessment Report. Report of the Intergovernmental Panel on Climate Change Summary for the Policy Makers. Intergovernmental Panel on climate Change, Geneva.

Isichei, A.O. and Moughalu, J.I. 1992. The effects of tree canopy cover on soil fertility in a Nigerian savanna. *J. Trop. Ecol.,* 8 (3): 329-338.

Jackson, M.L. 1967. *Soil Chemical Analysis*. Prentice Hall India, New Delhi

Jha. M.N., Gupta, M.K. and Raina, A.K. 2001. Carbon sequestration: Forest soil and land use management. *Ann. For*. 9 (2): 249 – 256

Jha, M.N., Gupta, M.K., Saxena, A. and Kumar, R. 2003. Soil organic carbon store in different forests in India. *Indian Forester*, 129 (6):714-724.

Kumar Ashok, Tripathi, B. and Singh, G. 2012. Tree and shrub diversity in degraded hills of Bar-conglomerate formation of Pali district of Rajasthan. *Indian Forester*.138 (2): 107-112.

Kumar Mahesh, Kumar Praveen, and Bohra, P.C. 2009. Effect of land use systems on soil properties and relationship between soil organic carbon and available nutrients in typical arid soils of Rajasthan. *Annals of Arid Zone*, 48 (1): 25-28.

Kumar, J. I. N., Patel Kanti, Kumar N.R. and Kumar R.B. 2010. An assessment of carbon stock for various land use system in Aravalli Mountains, Western India. *Mitigation and Adaptation Strategies for Global Change*, 15 (8): 811-824.
Lacelle,B., Waltman, S., Bliss N. and Orozco C.F. 2001. Methods used to create the North American soil organic carbon, digital data base. 485-494pp.

Lal, R, Hassan, H.M., Dumanski, j., 1999.Desertification control to sequester C and mitigate the greenhouse effect. In: N. Rosenberg, R.C. Izaurralde and E.L. Malone (editors).Carbon sequestration in soils: Science, monitoring and beyond. Battelle Press, Columbus, USA, pp. 83 – 149.

Lal, R., Kimble, J.M., Levines, E. and Whiteman, C. 1995. World soil and greenhouse effect. SSSA Special Publication Number Madison, *WI*, 57:51-65.

Lal, R. 2004. Soil carbon sequestration in India. *Climatic Change*. 65 (3): 277-296.

Makundi, Willy R. and Jayant A., Sathaye. 2004. GHG mitigation potential and cost in tropical forestry- relative role for agro forestry. Environment, Development and Sustainability, 6:235-260.

McGuire, A. D., Melillo, J.M., Kicklighter D.W., Joyce L.A. 1995. Equilibrium response Of soil carbon to climate change: empirical and process based estimates. J Biogeography. 22, pp. 785–796.

Misra R. 1968. *Ecology Work Book*. Oxford and IBH Pub. Co. New Delhi pp. 244.

Nayak, A. K., Purohit, R. P. and Thapliyal R. K. 1991. Phytosociological analysis of some temperate forests of Chamoli (Garhwal). Recent Researches in Ecology, Environment and Pollution. 6: 85-111.

Odum, O.P. (1960). Organic production and turnover in old field succession. *Ecology*. 41: 39-49

Page, G. (1968). Some effects of conifer crops on soil properties. *Commonwealth For. Rev*. 47: 52-62

Olsen, S.R. and Dean, L.A. 1965. *Methods of Soil Analysis. Part-2*. Edited, Black, C.A. in American society of agronomy Inc., Publisher, Madison, Wisconsin, USA.

Pagar, D. S. 2008. Phytosociological and correlation studies of the vegetation of Surgana range of Nashik, India. *International Journal of Plant Sciences* 3(1): 308-310.

Pandey, J. And Pandey, U. 2006. Floristic composition and litter dynamics of a dry tropical woodland of Southern Rajasthan. Plant Archives. 6 (2): 495-499.

Paul, K.I; Polglase, P.J.; Nyakuengama, J.G. and Khanna, P.K. (2002). Change in Soil Carbon following afforestation. *For. Ecol. Manag*. 168: 241 – 257.

Rajamannar, A. and Krishnamoorthy, K.K. 1978. A note on the influence of altitude on the physico – chemical characteristics of forest soil. *J. Indian Soc. Soil Sci*. 26 (4): 399 – 400.

Ramchandran, A., Jayakumar, S., Haroon, R.M., Bhaskaran, A. and Arockiasamy D.I. 2007 Carbon sequestration: estimation of carbon stock in natural forests using geospatial technology in the Eastern Ghats of Tamil Nadu, India. Current Science, 92 (3): 323-331.

Rosoman, Grant (1994). The Plantation Effect. An Ecoforestry Review of the Environmental Effects of Exotic Monoculture Tree Plantations in Aotearoa / New Zealand. Greenpeace New Zealand with support from Canterbury Branch Maruia Society

Sahu, S. C., Dhal, N. K., Reddy, C. S., Chiranjibi, P. and Brahmam M. 2007. Phytosociological study of tropical dry deciduous forest of Boudh district, Orissa, India. *Research Journal of Forestry*. 1 (2): 66-72.

Sand and clay mineralogy of sal forest soils of the Doon Siwalik Himalayas
Mukesh1,∗,RKManhas2,AKTripathi1,AKRaina3,MKGupta3 andSKKamboj3
1Earth and Environmental Science, Korea Basic Science Institute, 804-1 Yangcheong, Ochang,
Cheongwon-gun, Chungbuk 363-883, Republic of Korea.
2Department of Botany, S.P. College, Srinagar 190 001, India.
3Forest Soil & Land Reclamation Division, Forest Research Institute, Dehradun 248 006, India.
∗e-mail: mukeshcric@rediffmail.com

Schimel, D.S., Braswell, B.H., Holland, E.A., McKeown, R., Ojima, D.S., Painter, T.H., Parton, W.J. and Townsend, A.R. 1994. Climatic edaphic and biotic controls over storage and turnover of carbon in soils. Global Biogeochem. Cycl. 8: 279 – 293.

Sharma, B.D. and Gupta I.C. 1989. Effect of trees cover on soil fertility in western Rajasthan. *Indian Forester*, 115 (5): 348-354.

Sharma, B.M. 1984. Scrub forest studies - foliar and soil nutrient status of *Prosopis juliflora* DC. *Indian Forester*. 110 (4): 367-374.

Shrivastava, N. and Jain, S. 2006. Floristic diversity in Haroti Region of Rajasthan..*Advances in Plant Sciences*. 19 (1): 209-213.

Singh, G. 2005.Carbon sequestration under an agri-silvicultural system in the arid region. *Indian Forester.* 131 (4): 543-552.

Singh, J., Borah, I.P. and Baruah, A. 1995. Soil characteristics under three different plant communities of northeast India. *Indian For*. 121 (12): 1130 – 1134.

Singh, J.S. 2002. The biodiversity crises: a multifaceted review. *Current Science*. 82: 638-647.

Singh, R. B., Prasad, H. and Argal, A. 2003. Spatial variability of soil properties and phytosociological study under different aged of *Tectona grandis* stands in and around Balaghat (M.P.). *Indian Forester*. 129 (12): 1479-1487.

Singh, S.K., Pandey, C.B., Sarkar, D. and Sagar R. 2011. Concentration and stock of carbon in the soils affected by land uses and climates in the western Himalaya, India *Catena.* 87 (1): 78-89.

Singhal, R.M. and Sharma, S.D. 1989. Phytosociological analysis of tropical forests in Doon Valley of Uttar Pradesh. *Journal of Tropical Forestry*. 5 (1): 57-65.

Soni M.L., Beniwal, R.K., Yadava, N.D. and Talwar, H.S. 2008. Spatial distribution of soil organic carbon under agro forestry and traditional cropping system in Hyper Arid Zone of Rajasthan. *Annals of Arid Zone*, 47 (1): 103-106.

Srinivas, C. and Yadava P. S. 1999. Phytosociological study of four forest sites: correlation of tree species. *Indian Journal of Forestry* 22 (3): 232-240.

Subbiah, B.V. and Asiza, G.L. 1956. A new method of determining Available nitrogen in soil. *Current Science* 25: 259-260.

Tian, H., Melillo J.M. and Kicklighter D.W. 2002. Regional carbon dynamics in monsoon Asia and implications for the global carbon cycle. *Global and Planetary Change,* 37: 201-217.

Tomar, J. M. S., Tripathi, O. P. and Satapathy, K. K. 2001. Studies on phytosociological attributes of upper Shipra watershed in Meghalaya. *Indian Journal of Hill Farming*. 14 (2): 105-11

Totey, N.G. Bhowmik, A.K. and Khatri, .K. 1986. Performance of sal on the soils derived from different parent material in Shahdol forest division, M.P. *Indian For.* 112 (1) : 18 –31.

Vidyasagaran, K., Gopikumar, K. and Ajithkumar, M. 2004. Phytosociological analysis of selected Shola forests of the Nilgiri hills of Western Ghats. *Indian Forester*.130 (3): 283-290.

Walkley, A. and Black, J.A. 1934. An Examination of Degtiga Vett. Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Acid Titration Method. *Soil Sci.* 37:29-37.

Whittaker R.H. 1965. Dominance and diversity in land plant communities. *Science* 147: 250-260.

Whittaker R.H. 1975. *Communities and Ecosystem. (Second ed.)* Macmillan publishing. New York. pp. 385.

Wilde, S.A., Voigt, G.K. and Iyer, J.G. 1964. Soil and Plant Analysis for Tree Culture. Oxford Publishing House, Calcutta, India.

Working Plan of Nagaon District