Sahyadri Conservation Series 16

Soil Quality across Diverse Landscapes in Central Western Ghats, India

Ramachandra T.V. **Subash Chandran M.D** **Joshi N.V.**

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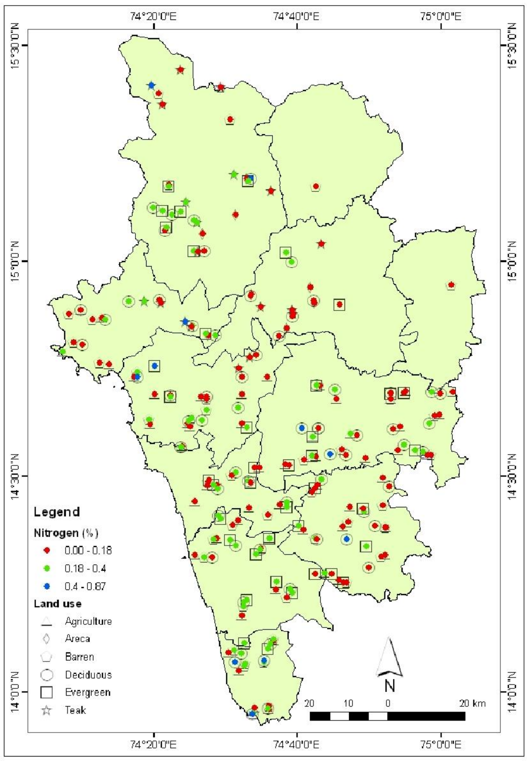

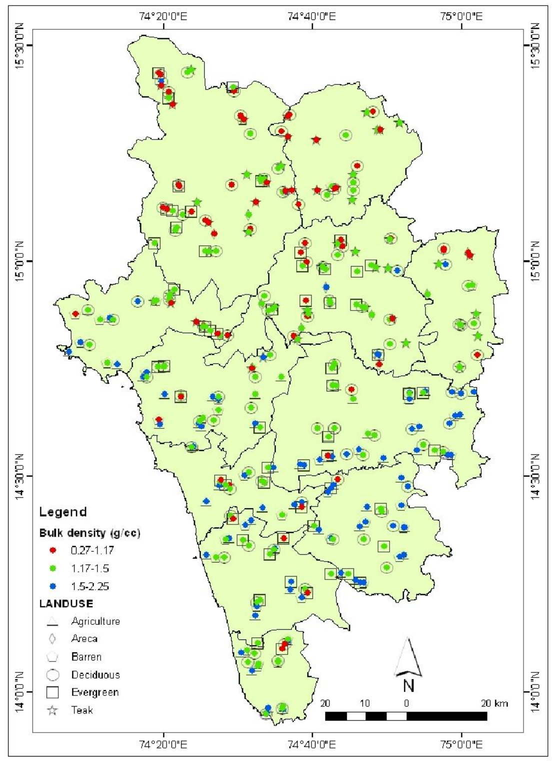

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ENVIS Technical Report: 42

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Summary

Soil is one of the most susceptible landscape elements, to land-use change. We collected and analyzed soil samples from different land-use units like agriculture, barren, evergreen, deciduous, and plantations like Arecanut and teak from Uttar Kannada District in Central Western Ghats, India and analyzed them for various physico-chemical parameters. Spatial analysis of key soil parameters was done to understand the variability with reference to the land uses. Soil carbon and nitrogen were severely low in agricultural and barren soils compared to natural landscapes like evergreen and deciduous. All other parameters like bulk density, pH, Ca, available P, available K, Mg were severely affected in agricultural and barren landscapes. Quality of soil in arecanut plantations were comparable to natural ecosystems due to land management practices such as mulching, etc. The severe degradation of agricultural soils places a wider emphasis on adapting holistic management practices towards sustainable use of these lands in future.

Keywords: Uttara Kannada, soil quality, nutrients, carbon sequestration

INTRODUCTION

Soil is one of the major abiotic factors which support life on our planet Earth. Soils are natural three dimensional bodies used for many purposes; the most important purpose is for food and fiber (USDA Soil Conservation Service). Soils are natural bodies in which the plant grows. It supports crops, grasslands and forests which will provide food, fiber, wood, fuel and building materials. Great civilizations have almost invariably had good soils as one of their chief natural energy resource. Soil mismanagement was associated with the downfall of some of the same civilization that good soil had helped to build. Even today there are many who didn't recognize the long term significance of soils. Soil is an important natural resource. The discovery of agriculture leads to the excessive use of soil by man. With the exception of light, soil can provide all the five elements, like mechanical support, heat, air, water and nutrients for the growth of plants (**Brady, 1984**). Not only it serves to promote and sustain life in its many forms, but it also acts as a living filter for the waste generated by humans and animals.

SOIL AS ECOSYSTEM COMPONENT

The general concept and the definition of soil have been subjected to many alterations (**Wilde, 1946**). According to agronomists "soils are a mixture of sand, clay, lime and humus". Geologists regard soil as "products of weathered minerals and a composition of dead plant and animal remaining (**Fallow**, **1862**) and biologists consider it as "a lithosphere penetrated by the biosphere" (**Stebutt**, **1930**). In general soil is "a portion of the earth surface which serves as a medium for the sustenance of biosphere; it consists of mineral and organic matter, permeated by varying amounts of water and air, and inhabited by organisms; it exhibits peculiar characteristics impressed by the physical and chemical action of the tree roots and forest debris (**Wilde**, **1946**). Soil is a vital component of the ecosystem and many activities in the ecosystem like nutrient cycles takes place through the soil. Soils play a crucial role in biogeochemical cycles as spatially distributed sources and sinks of nutrients. The early observations of the relationship that exist between the soil and vegetation were made by the primitive forest dwellers, hunters and medicine men.

With the advance of research in soil science two basic concepts of soil have evolved. One considers that soil is biochemical weathered product and the other considers that soil is entirely for the growth of plants. This has contributed to two approaches used in soil study; that is pedlogy and edaphology (**Brady**, **1984**). Pedlogy mainly deals with the origin, classification, and the description of the soil while edaphology deals with the relation of plant and soil. Plants play a vital role in the formation and the structure of the soil. Vegetation affects the soil structure through different mechanisms like root penetration, water extraction, and anchorage (**Angers**, **1998**)

SOIL FORMATION AND SOIL PROFILE

Soil formation takes place in the earth due to two distinct forces, one is the destructive force and the other is the synthetic force. Microbial decay and the weathering of the parent material are destructive processes, which result in the formation of a new mineral like clay from the parent material, which is a synthetic process. Examination of the vertical section of soil gives an idea of underlying forces in soil formation. The vertical section of the soil is called the profile and the individual layer is called as horizon (Figure 1). Each horizon has its own peculiarities. The upper layer of soil profile has large amount of organic matter. This is mainly due to decaying organic matter. Variation in color of each horizon is evident as the upper layer has dark color compared to the other underlying layers. The underlying layers which form the subsoil have low organic matter. The uppermost horizon in a typical soil profile is called the O horizon. This horizon is composed mostly of mineral soils. This horizon contains more than 30% of organic matter present in the soil profile. Below the O horizon is the A horizon which is called the fertile top soil. Below the A horizon is the E horizon .The main feature of this horizon is the loss of clay, iron and the aluminum. Mineral horizon with evidence of pedogenesis or illuviation is called the B horizon. Below the B horizon is the un-weathered geologic material commonly called as C horizon. Below the C horizon is the hard bed rock commonly called R horizon (**Miller & Donahue, 1990**). The quality of the soil varies from horizon to horizon.

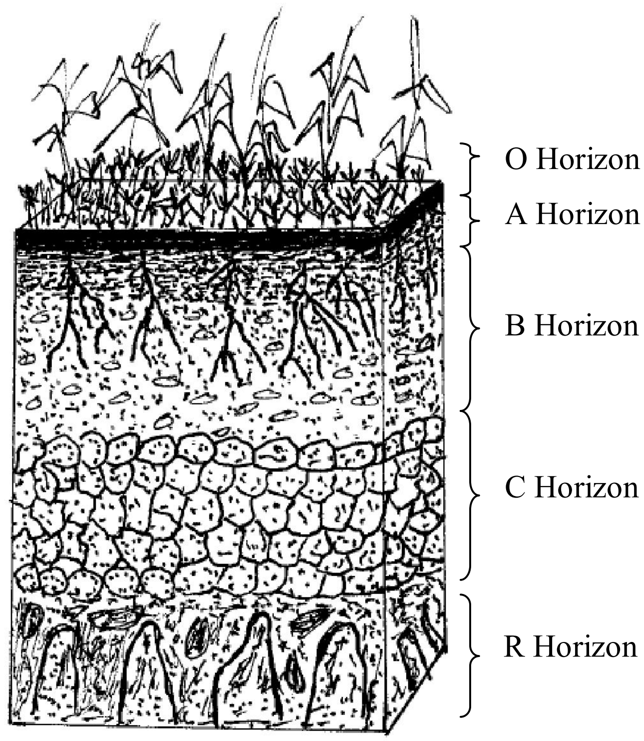


Fig 1: Soil Profile

CONCEPT OF SOIL QUALITY

The soil quality concept evolved throughout the 1990s in response to increased global emphasis on sustainable land use and with a holistic focus emphasizing the sustainable soil management. Soil quality is a concept being developed to characterize the usefulness and health of the soils and depends entirely on the components like soil minerals, organic matter, air, water, and living organisms. This property can change due to human impact on the soil. As soil plays a dominant role in maintaining the ecological balance, it is necessary to maintain the soil quality including soil fertility, potential productivity, resource sustainability and environmental quality (**Moen, 1988; Sheppard *et al*., 1994**). In an agricultural context, soil quality is managed, to maximize production without adverse environmental impact, while in a natural ecosystem, soil quality is observed, as a baseline value or set of value against which further change in the system may be compared (**Sumner, 1999**).

Land use changes modify carbon and litter quality of a location and hence the soil quality (**Ojima, 1994**). Land cover changes associated with different land use are important agents of environmental change and degradation (**Wick *et al.,* 2000**).Land cover changes are happening very rapidly in recent times due to over-exploitation and lack of integrated approaches in planning. This is coupled with growing demands of increasing human population. During the past several centuries humans have modified the environmental systems a lot. Most of the world's forests have been extensively modified by human use of land (**Houghton, 1994**).This global change in land use has influenced adversely human well being as well as the climate.

The main reason for the change in land use of Western Ghats, the focal area of this study, is the clearing of forest for agricultural purposes (**Bhat and Gadgil, 1987**), overgrazing, forest fire and land encroachment, etc. Farming in Western Ghats started about three millennia ago but the pre-agricultural phase of vegetation manipulation to promote favored food plants by hunter gatherers could be older. Western Ghats came under first human influences during the Paleolithic or Old Stone Age, over 12,000 years before present (**Chandran, 1997**). Mesolithic or Middle Stone Age (12,000-5,000 years before present) witnessed the transition of hunter-gatherers into food growers. From this period onwards human beings have an impact on the natural ecosystems. Expansion of traditional agriculture like shifting cultivation in the pre-colonial period and the spread of particularly rubber, coffee and forest tree plantations since the British period beginning two centuries ago, would have wiped out large pockets of primary forests (**Chandran, 1997**). This has affected the natural property of the soils as well. Many agricultural management practices have detrimental effects on the quantity and quality of soil physico-chemical properties (**Caravaca *et al.*, 2002**). In addition to reversible land use changes, the soil quality is impaired due to environmental pollution leading to desertification (**Sumner, 1999**).

In this context, a study has been undertaken to map the soil quality across various land uses in Uttara Kannada district of Central Western Ghats.
The study is undertaken to evolve good soil management practices to suit the central Western Ghats, which form part of a global biodiversity hot spot.

Islam and Weil (2000) studied the changes in biological, chemical and physical properties of soils in response to land use changes and explored relationships among changes in soil properties. Bulk Density varied among cultivated (1.38g/cm3) and natural forest (1.22g/cm3). There was an impact on Water Holding Capacity (WHC) which decreased from 27.9 in natural forest to 22.9 in adjacent cultivated land. Also the cultivated soils were considerably lower in silt and slightly lower in clay than the adjacent soils under natural forest, most likely due to preferential removal of silt by accelerated water erosion during the monsoon month. Compared to natural forest, aggregate stability was lower in cultivated soils, but higher in reforested soils.

Adejuwon and Ekanade (1988) assessed the changes that occur in various soil properties following the removal of forest and cultivation of land to food crops, cocoa and kola. Except for soil texture, all other properties were affected severely. Water holding capacity decreased from forest (60.3%) to cocoa (40.5%). Soil pH differed from 6.8 under forest to slightly acidic under cocoa and kola units. Soil organic matter was 4.7% under forest, 2.6% under fallow, 2.4% under kola and 2.3% under cocoa, while total nitrogen is 0.30% under forest but 0.117% under fallow, and o.15% under both cocoa and kola. Mean values of exchangeable cations viz. Ca, Mg, K and Na are highest under forest and followed by those under fallow. While CEC, is highest under forest i.e. 11.6me/100g while the respective means under fallow, cocoa and kola are 6.4, 5.1 and 4.9me/100g. The study strengthens the point that soil degeneration occurs following the replacement of forest with either tree or arable crops.

Inappropriate land use is one of the main reasons for soil erosion and nutrient loss in the hilly loess area. **Bojie Fu et al (2000)** studies the effects on soil nutrients like total nitrogen, total phosphorus, available nitrogen, available phosphorus, organic matter and moisture in the land use types in the Yangjuangou catchment of Shaanxi province in China. The study revealed that the forest soil has the most abundant nutrients, with grassland as the second highest and slope farmland the least. In the area which was transformed from forest to slope farmland, total N declined by 64%, available N by 67%, available P by 69% and organic matter by 72% to less than the average values for slope farmland. The 0 – 70 cm soil under forest had the least mean water content (14%), under grassland it was 17% and under slope farmland, 18.5%. Because of the sparse vegetation cover and surface ploughing, the moisture content of slope farmland increased with depth more steeply than under forest or grassland. Except for total and available P, the soil under forest had the highest mean concentration of soil nutrients.

Murty et al (2002) reviewed 20 works to assess changes in soil C upon conversion of forests to agricultural land. The study revealed that bulk density of agricultural soils was 13% more compared to that of natural land use patterns. Soil carbon was the most affected factor since conversion, which reduced 30% from the original land use to cultivation purpose.

When studies estimating carbon and nitrogen were considered, the two decreased 24% and 15% respectively, thus affecting the C: N ratio. It was seen that systems with decreasing N showed increase in C: N ratio, while increasing N showed decrease in C: N ratio. Though there were changes in soil carbon and nitrogen since conversion to pasture from forest, they were not significant.

Land use changes, especially cultivation of deforested land may rapidly diminish soil quality, as ecologically sensitive components of tropical forest ecosystems are not able to buffer the effects of agricultural practices. As a result, severe deterioration in soil quality may lead to permanent degradation of land productivity (**Kang and Juo, 1986, Nardi et al**, **1996, Islam et al, 1999)**.

McGrath *et al.*, (2001) reviewed over 100 case studies to understand the effect of land-use change on soil and plant nutrient dynamics in Amazon. Bulk density was significantly higher in pasture than forest due to compaction of soil, which has degraded soil physical properties by decreasing root penetration and consequent water infiltration and gas exchange. This further resulted in the loss of soil organic matter and nutrient runoff. It was found that there is a significant effect on soil pH, bulk density, and exchangeable Ca concentration. Loss of organic carbon (100-300 mg/ha) occur when forests are converted to agricultural lands. Pasture soil have higher total C and N concentration than land use like annual cropping and fallows.

Dinakaran and Krishnayya (2008) studied at Shoolpaneshwar a tropical wildlife sanctuary in Gujarat the influence of different vegetal covers, changes in land use pattern and heterogeneity of physical fractions of the soil organic carbon (SOC) pool on soil carbon. This wildlife sanctuary has some anthropogenic activities, like agriculture by tribal. Soil samples up to 15 cm were collected and analysed for the total carbon. In six sites like Teak plantation, bamboo, mixed vegetation, herbaceous vegetation, paddy field-1 (10 years of cultivation) and paddy field-2 (outside the sanctuary with 50 years of cultivation). The % organic carbon of teak, bamboo, mixed vegetation, herbaceous vegetation, agricultural land-1 and agricultural land-2 are 8.9%, 9.2%, 11%, 2.7%, 3.9% and 2.8% respectively (0.2 cm depth). The paddy field which is continuously used for agriculture shows the lowest organic carbon% than any other land use. The result was that soil organic carbon was much higher in soils with natural tree cover, also the type of vegetal cover has a significant impact on SOC up to a depth of 1.5 m. Changes in land-use pattern severely reduced carbon sink capacity of soils.

Conversion of tropical forests lands to agriculture affects the soil through its effect on soil organic matter and nutrients as well as on physical properties. **Brown and Lugo (1990)** collected soil samples from mature and secondary forests and agricultural sites in three subtropical life zones of Puerto rico and US virgin islands to determine the effects of forest conversion to agriculture and succession on soil organic carbon and nitrogen contents. In order to prevent the impact of landscape position, sites were selected which were having uniform characteristics like slope, aspect etc. Carbon contents of the cultivated sites, as compared to forest percentage were lower in the wet (44%), moist (31%) than in the dry (86%), while nitrogen was high regardless of the life zone.

Conversion of forest to pasture resulted in less soil C and N loss than conversion to crops. They also estimated the succession rate of soil C and N which was found out to be almost same in all the three life zones i.e. 40-50 years for C and 15-20 years for N.

Powers, (2004) studied changes in soil carbon and nitrogen in different land use in Canton in the northern Atlantic lowlands of Costa Rica. Total fifty sites were sampled, and among them 12 were forest to banana transition, 15 pastures to crop transition and four pastures to *Vochysis* tree plantation transition. The forest to banana plantation transition had the organic Carbon from 6.03% to 4.06%. The conversion of pasture to crop transition decreased the total organic Carbon from 5.4% to 3.63%.The conversion of pasture to *Vochysis* tree plantation changed soil organic Carbon from 6.79% to 5.49%.The total nitrogen is also decreased from Forest to banana (0.54% to 0.41%), pasture to crop land (0.55% to 0.33%) and pasture to *Vochysis* tree plantation (0.59% to 0.50%). However, there is an increase in bulk density from forest to banana (0.61g cm^{-3} to 0.74 g cm^{-3}), pasture to crop land (0.79 g cm^{-3} to 0.83 g cm^{-3}) and a slight decrease from pasture to *Vochysis* tree plantation (0.71 g cm^{-3} to 0.70 g cm^{-3}). Due to rapid cultivation of land, soil losses the organic carbon, total nitrogen pools were also reduced after the conversion of forests to banana plantation.

Effects of land use changes to soil chemical and biochemical properties in Semiarid Mediterranean environment was investigated by **Caravaca *et al* (2002)** in four sandy soils under different agricultural practices and four adjacent soils under grass cover. The total organic matter in cultivated soil is 3.2 g Kg^{-1} and that of native vegetation is 21.3 g Kg^{-1} indicating a decline of total organic matter due to the conversion of forests to agriculture. General decline of total organic carbon, extractable humic substances (3.6 g Kg^{-1} to 1.4 g Kg^{-1}), water-soluble carbohydrates (39µg.g^{1} to 14µg.g^{1}), DHase, urease, protease, phosphatase and ß-glucosidase is noticed in different agricultural practices with respect to soil under grass cover.

Wick *et al* (2000) investigated soil quality changes associated with the conversion of a native thorn forest (caatinga) into silvo-pastoral systems (buffel grass) in semiarid North

East Brazil. Soil nutrients, organic matter, microbial biomass and soil enzymes under native caatinga, preserved native and one introduced tree species were compared. The total carbon in caatinga was decreased (14.1 g Kg^{-1}) while converting to buffel grass pasture (12 gKg^{1}).Total nitrogen has declined from 1.1 g Kg^{-1} (caatinga) to 0.98 g Kg^{-1} (buffel grass) .Total phosphorus also declined due to conversion of caatinga (176 mg Kg^{-1}) to silvi-pastoral system (173 mg Kg^{-1}). It also decreases the microbial biomass C and Nitrogen. The complete replacement of natural caatinga with silvo-pastoral system had affected the chemical and biological properties of the soil.

The effect of land use change on soil carbon in forest, pasture, and sugarcane on each end of a rainfall gradient in Hamakua Coast of Hawaii was investigated by **Osher *et al* (2003)** Increase in bulk density was noticed in forest (0.38 mg m^{-2}) to pasture (0.44 mg m^{-2}) and then to sugar cane field (0.44 mg m^{-2}) in the first site. In second site also bulk density increases from forest (0.35 mg m^{-2}) to pasture (0.49 mg m^{-2}) to sugar cane field (0.56 mg m^{-2}). There was a decline in organic matter from forest (31.07 kg m^{-2}) to sugar cane field (25.84 kg m^{-2}). Increase in carbon content of pasture due to increased carbon storage in subsurface horizons. Carbon content of the soil under pasture and sugarcane management significantly differs from that of forest in both high rainfall site and low rainfall site. Pasture management results in a net carbon gain and sugar cane land use resulted in a net carbon loss.

Rhoades *et al* (2000) investigated the soil carbon difference among forest, agricultural and secondary vegetation in western slops of Ecuadorian Andes in tropical lower montane forests. The loss of forest derived soil carbon and the accumulation of carbon from replicate of different land use like sugarcane plantation, *Setaria sphacelata* pasture, mixed pasture, shrub fallow, and second and old growth forest was studied using stable carbon isotope technique. The result shows that the native forest have a pH of 5 in the top 100 cm. Bulk density increases from 0.67 Mg/m^3 in the upper 15 cm to 0.84 Mg/ m^3 in lower 15-30 cm (due to the presence of lower organic carbon in the lower 15-30 cm). Soil carbon averages 6.55% to 2.7% in the 0-15 and 15-30 cm depth respectively. In agricultural sites like sugarcane, mixed species and *Setaria sphacelata* pasture, bulk density was 37%, 32% and 26% more when compared with old-grown forest. They also noticed that sugarcane soils contain 18 Mg/ha less soil C in the upper 15 cm than the native forests (Due to less leaf litter). Mixed species pasture contains 17% less soil carbon than the native forest. This indicates that conversation from forest to crop or pasture has lead to the loss of soil carbon. They also found that continuous production of crop also leads to the reduction of soil carbon.

The effect of soil texture on below ground carbon and nutrient storage in Tapajos National Forest in Brazil of lowland Amazonian forest ecosystem was studied by **Silver *et al* (2004)** using field data and the century ecosystem model. Field data includes the total carbon, total nitrogen, texture, and pH, Ca, Mg and K in different depths (0-400 cm). Total organic carbon is 2.81% in 0-50 cm depth but decreased to 2.26 in 350-400 cm depth (due to the presence of low litter quantity in lower horizon). Total Nitrogen is also declining when they sampled from 0-50 cm (0.15%) to 50-150 cm (0.13%). They found a drastic increase in pH while going from 0-50 cm (pH 3.90) to 350-400 (pH 4.19), due to the decrease in humic acid. Increase in percentage of clay (18 % in 0-50 cm depth and 60 % in 350-400 cm depth) and decrease in percentage of sand (80 % in 0-50 cm depth and 38% in 350–400 cm depth) was noticed. Extractable phosphorus, calcium and magnesium also decline from upper horizon to lower horizon. Sandy soil store more carbon of 113 Mg C ha $^{-1}$ than clay soil of 101 Mg C ha^{-1} up to 1 M depth. It was found that soil texture play an important role in below ground carbon storage and nutrient availability.

Zhong *et al* (2000) performed the organic carbon content and distribution in soils under different land uses in tropical and subtropical China, to investigate the C density, stocks and distribution in soils of this region under different land uses by using soil species data from the Second National Soil Survey and the vegetation map of the People's Republic of China (1:4 M). It was estimated that there is a total of about 28.7±8.2 % organic carbon stored in the upper 1 m of soils of the entire region. Changes in carbon content with depth were observed in the various patterns of land uses. The soils of meadow, herbaceous swamp, and coniferous and broad-leaf forest soils have highest carbon density, while paddy, bush and coppice forest soils showed a low carbon density.

Around the world the regions of immense biodiversity are also the regions which harbour dense human populations. Hence it poses a threat to the natural resources and biodiversity of the region. Due to increasing socio-economic, political and cultural factors, vast tracts of forest lands are brought under cultivation. The soil carbon pool composing of soil organic and soil inorganic carbon is not only critical for soil to perform its productivity and environmental functions, but also plays an important role in global carbon cycle. The sequestration of atmospheric C in soil and biomass not only reduces greenhouse effect but also helps maintain and restore the capacity of soil tom perform its production and environmental functions on sustainable basis **(Sahrawat 2003)**

The top one metre of the world's soils contains approximately 1500 Gt C (**Johnson & Henderson 1995; Bruce et al. 1999)** and even small relative fluxes on a global scale. There is a considerable concern that land use change, in particular, may be leading to a depletion of soil carbon and consequent increases in atmospheric CO2 (**IPCC 1997; Bruce et al. 1999, Houghton 1999**).

Conversion of tropical forest lands to agriculture affects the soil through its effects on soil organic matter and nutrients as well as on physical properties. Organic matter is an important component of soils because of its influence on cation exchange capacity, soil structure, soil-water balance and a source of plant nutrients (**Lal and Kang, 1982**; **Sanchez, 1976)**. Losses of organic matter may lead to soil degradation and low crop yields. Understanding the dynamics of soil organic matter and nutrients in tropical forest soils undergoing change and factors influencing these dynamics is important for addressing such issues as the fragility of tropical soils, their sustainability for production and global biogeochemical cycles.

Available studies on tropical soils suggest a rapid decline in organic matter and nitrogen due to continuous cultivation (**Allen, 1985; Aweto, 1981; Ayanaba et al., 1976; Brams,**

1971; Nye and Greenland, 1964). A recent report (**Baker 2007**) mentions that less carbon would be taken by Southern oceans than the tropical areas, as previously thought. This re-emphasizes the importance of terrestrial ecosystem in global carbon cycle.

While losses of soil carbon under regular cultivation thus appear to be well established, trends following conversion from forest to pasture have been studied less thoroughly. **Lugo and Brown (1993)**, studied the soil carbon in cultivated and pasture lands, and found that soil carbon is lost under cultivation, but no consistent change in grazed, but uncultivated pastures.

Objectives of the study

- Assessment of soil quality status through estimation of physico-chemical parameters across different land use types in Uttar Kannada district, Central Western Ghats through field sample collection.
- Mapping soil quality across the different land uses of Uttar Kannada district, Central Western Ghats.

Study Area

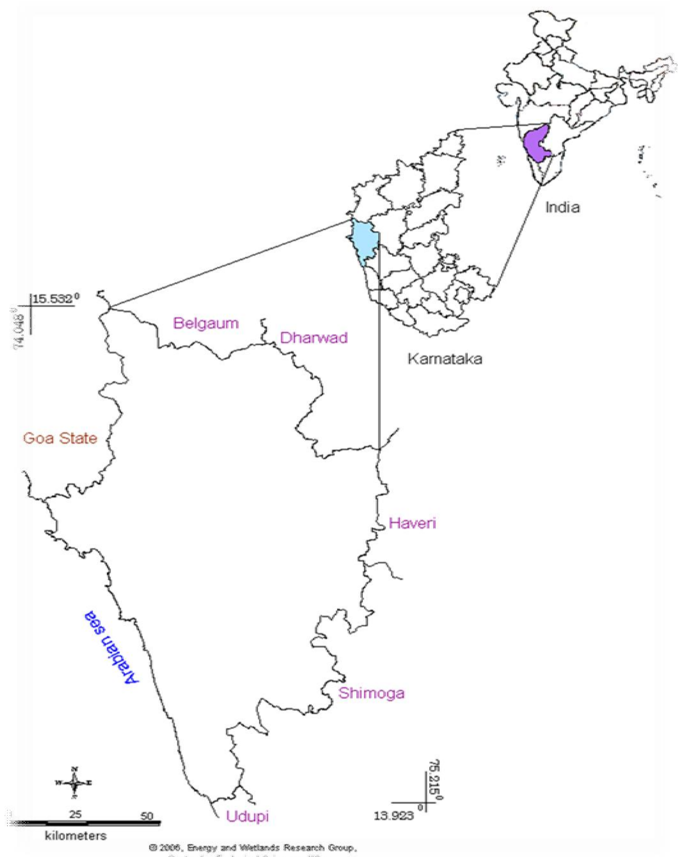


Fig 2: **Study area – Uttara Kannada district, Karnataka state, India**

The Western Ghats or Sahyadri are the main hill range in peninsular India that run along the states of Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu starting from the river Tapti in the north to Kanyakumari in the south, extending over a length of 1300 km is one of the 18 biodiversity hot spots (**Myers, 1990, Gadgil, 1996)** of the world.

Uttara Kannada, one of the 29 districts in Karnataka, India (Figure 2), is a hilly forested terrain situated in the central region of the Western Ghats in South India **(Bhat, 2002)**. It is northernmost of the three coastal districts of the state stretching alongside the Arabian Sea. The Western Ghats divide the district into two parts, five of its talukes are in coastal plains and six of them are above the Ghats. Most of the district is covered with the hill ranges of the Western Ghats, one among the 34 biodiversity hot spots of the world (Myers *et al*., 2000). Over 4,000 species of flowering plants (38% endemics), 330 butterflies (11% endemics), 289 fishes (41% endemics), 135 amphibians (75% endemics), 156 reptiles (62 endemics), 508 birds (4% endemics) and 120 mammals (12 % endemics) are found in the Western Ghats (**Sreekanta *et al,* 2007)**. Various types of ecosystems flourish in the soils of this district. It is one of the biggest districts in Karnataka. Uttara Kannada has great diversity in its landscape, soil and rainfall. It is the richest forest district of Karnataka endowed with a diverse variety of flora and fauna.

The district is located in the mid-western part of the state. It lies between 74°09' to 75°10' east longitude and 13°55' to 15°03' north latitude. Total area is 10,291 sq km which is 5.37% of the total area of the state. It extends to about 328 km north south and about 100 km east west. Most of the district is hilly and thickly wooded. The coast stretches in a long nearly straight line to the south east except the shallow Karwar and Belekeri bays .The population of the district was 1,353,644 according to 2001 census, a 10.90% increase since 1991 census. For administrative purpose the district has been divided into 11 talukes namely Ankola, Bhatkal, Haliyal, Honnavar, Karwar, Kumta, Mundgod, Siddapur Sirsi, Joida and Yellapur. The town of Karwar is the administrative headquarters of the district.

The district is hilly and wooded in most parts. The district has three main regions: The coastlands, the Sahayadrian interior and the eastern margin that merges with the Deccan plains. The coastal lands are best developed areas with a high degree of economic development and a high density of population. The Sahayadrian region is mostly forested and only the roads crossing the Ghats sustain some human life (**Kamath, 1985**). The eastern margin is an undulating land, partly under forest and partly cleared up for agriculture.

GEOLOGICAL SETTING OF THE REGION

The district consists of rock formation of Archaen complex, the oldest of the earth's crust (**Bourgeon, 1989**). The district is traversed by a system of ridges of the Western Ghats and a plateau on the west descending rapidly to a rather narrow strip of lowland covered by alluvium. Gneisses are frequently overlaid by a capping of laterite which is locally the source of Iron and Manganese ores. Eastern part of the district consists of a varied assemblage of Granite and Schist. In Dharwar district adjoining Uttara Kannada, chlorite-schist is dominant. The other rock formations belonging to this district are Quartzite, Magnetic- Quartzite, Limonite Quartzite, Lime-stones and other basic igneous rocks.

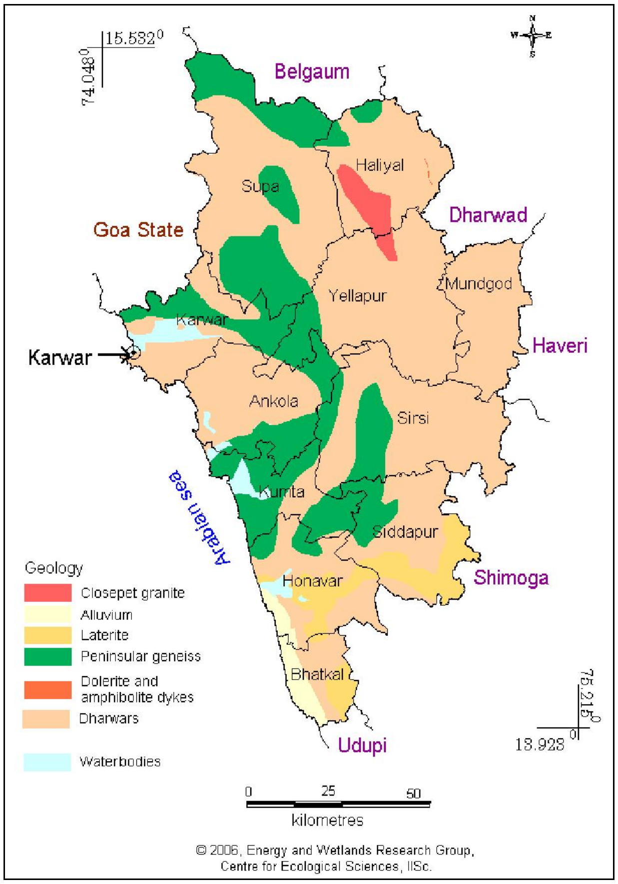


Figure 3: Geology of Uttar Kannada

South-west monsoon winds contribute an average rainfall of 2,835.5mm.to the district. Coastal zone receives an average of 3500 mm of annual rainfall. Heavy rain occurs during the three months from June to August and later decreases rapidly towards October-November. July is the rainiest month. In the district nearly 80% of the land is under the control of the forest department. According to the Landsat imagery out of the 10, 291 sq km of the total geographical area of the district 67.04% is under forest, 1.94 under paddy and millet cultivation, 1.26 under coconut and areca garden, 1.94% under rocky and the remaining 27.8 is under habitation and reservoirs (**Ramachandra *et a*l, 1999).** The tropical evergreen forest, the planet's most productive, diverse, and the oldest ecosystem still persists in their primeval glory on the Ghats of Uttara Kannada

(**Chandran, 1984**). The main types of forest found in this district belong to evergreen, semi-evergreen, moist deciduous and dry deciduous types. Forests on degradation produce scrub, savanna and grasslands (**Arora, 1961; Pascal et al French Inst maps**). The evergreen forests are found in places where rainfall is more than 225 cm. The different forest types are having a relationship with the amount of rainfall. The summer is pretty hot and winter is cool. The minimum temperature is 18°C and maximum is 38 °C.

Materials and Methods

Uttara Kannada, Central Western Ghats) was divided into 5*5' grids (Figure 3) corresponding to a grid in 1:50000 toposheets of the Survey of India for soil sampling the sampling was carried out in two phases- first during January to March 2008, and next from October 2008 to January 2009.

During the first field work, soil samples were collected from talukes like Bhatkal, Siddapur, Honnavar, Kumta, Sirsi, Ankola and small portion of Karwar. Bhatkal, Karwar, Ankola, Honnavar, Kumta are coastal talukes where, Siddapur and Sirsi is in the Ghat region. Although all these talukes come under the high rain fall region, the Coastal talukes receive more rain (>3000 mm). Soil samples were collected in 49 grids (about 50% of total grids).

During the second phase of field work, soil samples were collected from talukes like Yellapur, Mundgod, Haliyal and Joida and some parts of Sirsi and Karwar talukes. During the second phase, soil samples were collected from 68 grids.

Landscape elements sampled: Soil samples were collected in such a way that samples represent all major land uses (evergreen forest, deciduous forest, paddy field, Arecanut gardens and open grass land, teak plantations) in the respective grid, wherever it was possible by at least a motorable road.

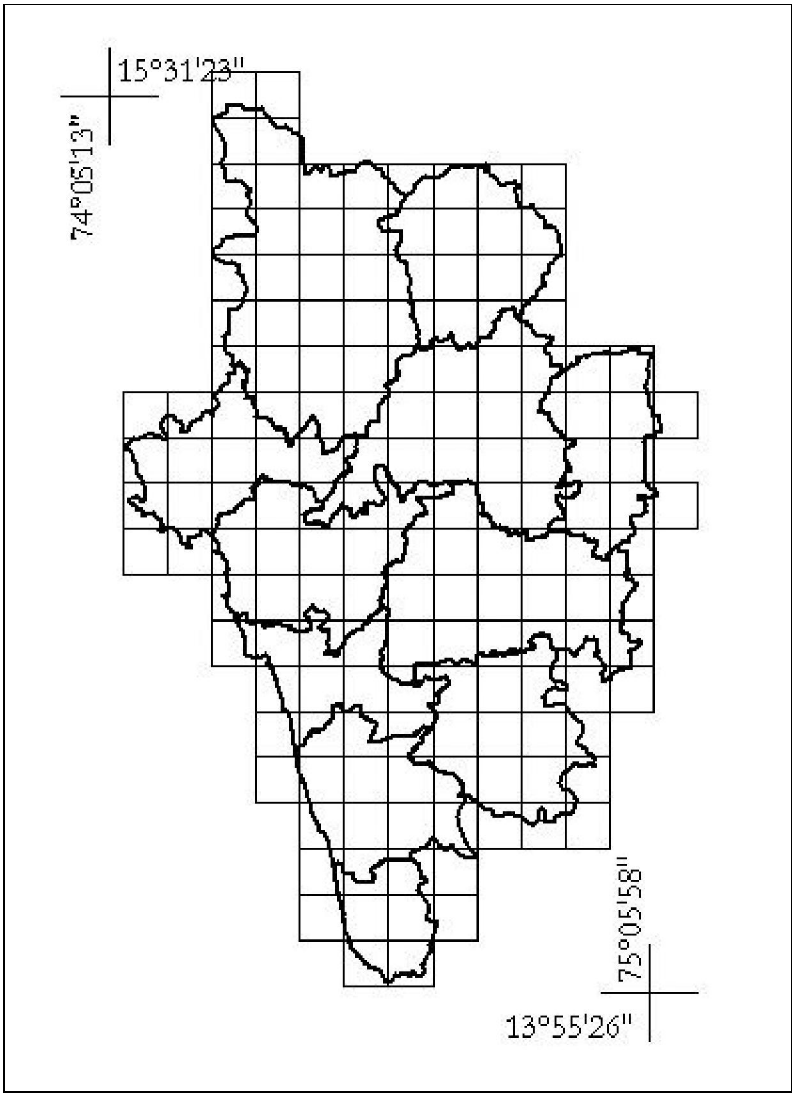


Fig 4: **Division of Uttara Kannada into grids (5'x5') for soil sampling**

Method of sample collection: Samples were collected by inserting an augur of length 14.8 cm and diameter of 9 cm. Undisturbed core sample (approx 1000 gm) was then transferred to a 2 kg capacity air tighten polythene cover. A small portion of sample (approx 100 gm) is stored in 500 gm capacity double air tighten polythene cover to estimate soil moisture. The collected samples were kept in shade to avoid direct contact of sunlight. In the lab, soil moisture was estimated by gravimetric method. Soil samples were air-dried and sieved through 2 mm sieve.

Soil parameters studied: Soil parameters studied were **bulk density, soil pH, soil moisture, soil texture, total carbon, total nitrogen, sodium, potassium, calcium and magnesium.**

Methods used for soil analysis (listed in Table 1)

T able 1: Parameters and method used for the analysis

No:	**Parameter**	**Method**
1	Bulk density	Gravimetric method
2	Soil moisture	Gravimetric method
3	pH	Potentiometer method
4	Texture	Density method
5	Total Carbon	Elemental Analyzer method
6	Total Nitrogen	Elemental Analyzer method
7	Available Phosphorus	Colorimetric method
8	Available potassium	Flame photometry
9	Soluble Sodium	Flame photometry
10	Calcium	Complex metric titration method
11	Magnesium	Complex metric titration method

Bulk Density

Bulk density or apparent density, is the ratio of the mass of the soil to that of its total volume, include any air space and organic materials in the soil volume (Allen, 1989). It is determined by the oven dry weight of a unit volume of soil, expressed in g/cm^3, Bulk density is inversely proportional to the pore space of the soil, Soil with high bulk density are less in the pore space and hence compact in nature and soil with low bulk density are highly porous and loose in nature. Bulk density of soil generally increases with depth due to decrease in soil organic matter. Bulk density is also an indicator of aeration status of the soil.

The bulk density of soil is measured by taking an undisturbed block of soil with a cylindrical metal core. Determine the volume of the core and the weight of the soil.

$$\text{Bulk Density } (g/cm^3) = \frac{\text{Soil mass (g)}}{\text{Soil volume } (cm^3)}$$

Soil moisture

Water is an essential component for the soil life forms. It is necessary for microbial activity and actions, nutrient mobility and aid as a lubricating agent for the penetration of roots. Changes in the soil water content and its energy status affects many soil mechanical properties namely strength, compactability, bulk density and root penetration. Many hydrological processes are fundamentally related to soil moisture condition.

Mass or gravimetric soil water content is expressed relative to the mass of oven dry soil. 10-20 gm of fresh sample is taken in the dry, weighed evaporating basin and the sample is dried in an oven at 105° C for24 hour (Baruah, 1997). Final weight is measured after cooling the over dry sample in a desiccator. Large stone and roots were removed without weighing to avoid bias.

$$\text{Moisture content \%} = \frac{\text{(Mass of the wet soil – mass of the oven dry soil)} \quad \text{x } 100}{\text{(Mass of the oven dry soil)}}$$

pH

pH is the measure of H^+ ion activity of the soil water system as it indicates whether the soil is acidic neutral or alkaline in nature and is defined as the logarithm to the base 10 of the reciprocal of H^+ ion concentration. Based on the pH spectrum **(French pedological reference, Bertrand, 1984)** soil is classified as:

Table: 2 pH spectrum of soil

pH	**Classification**
pH < 3.5	Hyper acid
3.5-5	very acid
5 to 6.5-	Acid
6.5 to 7.5	Neutral
7.5 to 8.7	Basic
> 8.7	very basic

On the basis of the ionization theory, acids are those substances that yield hydrogen (H^+) ions on dissociation. Strong acids and bases are highly ionized substances and weak acids and bases are poorly ionized substances in aqueous solutions. For the H^+ ion concentration, consider the dissociation of pure water at 25^0c, which yield one OH^- ion for each H^+ ion (**Tomer, 1999)**, Pure water which is a very weak electrolyte, which on dissociation at 25^0C furnishes only 10^{-7} mole H^+ ion per litre. since water produces one OH^{--} ion for each H^+ ion on dissociation, the concentration of [OH] ion is equal to [H^+] ions concentration, i.e. 10^{-7} moles/L .Thus for pure water at25^0C,

$$[H^+] = [OH^-] = 10^{-7}$$

Therefore,

$$K_w = 10^{-7} \times 10^{-7} = 10^{-14}$$

Addition of acid to water ionizes and release more H^+ ions into the solution, solution concentration of H^+ ions becomes more than 1×10^{-7} moles/L and the solution is said to be acidic. Similarly, if a base is added to water it furnishes OH^- ions on ionization, which increases the concentration of OH^- ions to more than 1×10^{-7} moles/L .This solution is said to be basic or alkaline. Thus, the ionization product of water enables the solution to be classified as acidic, neutral, and alkaline by considering the H^+ or OH^- ion concentration.

$$pH + pOH = 14$$

On this basis, a pH scale has been developed ranging from 0 to 14. A solution having pH equal 7 is neutral, the one having a pH value < 7 is acidic, and one having pH $> 7 \leq 14$ is basic in nature.

Weigh 10 g of the soil dried at room temperature and sieved to 2mm and add 20 ml DDW. The suspension is stirred at regular intervals for 30 minutes and the pH is recorded.

Soil Texture

The amount of sand, silt, and clay ultimately makes up the class of the soil. To determine the class type of an unknown soil, the ratio of sand, silt, and clay particles in a specific volume of soil is determined. Soil particles are categorized into groups according to size.

Clay = less than 0.002 mm,
Silt = 0.002 to 0.06 mm,
Sand = 0.06 to 2.0 mm,
Gravel = greater than 2.0 mm.

Using comparative volumes to determine the ratio of these particles, based upon the fact that different particles of different sizes will fall out of solution at different rates.

Reagent: Calgon solution (5%): Dissolve 50 g of sodium-hexameta-phosphate in distilled water and make up the volume to one litre, Hydrogen peroxide 6%.

Calgon contains a dispersing agent called sodiumhexametaphosphate. In this process, the Na+ ions replace the polyvalent cations (usually Ca^{++}) that form interparticle linkages; once the polyvalent cations are free; they react with phosphorus and precipitate out.

Take three centrifuge tubes **A, B,** and **C.** Take Soil which is sieved through 2 mm sieve. Add 6% H_2O_2 to remove all the organic matter. Take the soil which is free of organic matter and put it in a 15 ml in centrifuge tube **A**. Add more soil, if necessary, to the 15 ml mark. Add 1 ml of the soil dispersing agent (Calgon) to the soil, and add tap water to the level of 45 ml. Place the stopper firmly in the tube. Holding the stopper, shake the tube for two to 5 minutes. Remove the stopper and place the centrifuge tube in the stand for 30 seconds. The time is critical. If you allow more than 30 seconds to pass, shake the tube again and allow the tube to stand for another 30 seconds. Pour all the solution from the centrifuge tube **A** into centrifuge tube **B** (leaving the soil particles that settled out). Gently tap tube **A** on the table to level the soil left in the tube and return to the stand. Allow tube **B** to stand undisturbed for 30 minutes. At the end of the 30 minute standing time, carefully pour the solution from centrifuge tube **B** into centrifuge tube **C** (again leaving the particles that settled). Read the volume of soil particles, as accurately form tubes **A** and **B**.

Calculations: The mineral particles in separation tube **A** are sand. They are the largest and heaviest particles. Therefore, they settle out first. The particles in separation tube **B** are silt. Since they are lighter than sand, they take longer to settle out. The particles remaining in the final tube are clay. Clay particles swell when placed in water, and they tend to remain in water. This tube is not an accurate indication of the amount of clay in the sample. The amount of clay is more accurately determined mathematically

The Percent of Sand in the soil sample:
Volume in tube **A** (sand) divided by 15 ml x 100 gives the % **Sand**.

The Percent of Silt in the soil sample:

Volume in tube **B** (silt) divided by 15 ml x 100 gives the **% Silt**.

The Percent of Clay in the soil sample:

Add the volumes of tubes **A** and **B** then subtract that answer from 15 ml (total sample). This is the volume of clay.

Volume of clay divided by 15 x 100 gives the **% Clay**

Total Organic Carbon in the soil

Soil organic carbon exists both with in the active soil biomass and in the soil organic matter. Soil organic carbon is considered to be an important soil component in agronomic and natural system and has a role as a carbon reservoir in the terrestrial systems.

Total Organic carbon is determined using a **Leco Truspec CHN analyzer.**

Principle: The sample is oxidized at a high temperature of 950°C in a furnace. Oxygen is flushed into the furnace for the complete oxidation. The product of the combustion is again passed through a secondary furnace of 850° C for further oxidation and particulate removal. The combustion gas was then collected in a vessel called Ballast. The homogeneous combusted gas in the ballast is then purged through the CO_2 and H_2O infra red detector and 3cc aliquot loop. Carbon is measured as CO_2 by the CO_2 infra red detector.

Calculations: Directly from the instrument.

Total Nitrogen in the soil:

Nitrogen is one of the major elements required for the growth of plant. It is an integral component of many compound essential for the growth of plants include chlorophyll and many enzymes. Total nitrogen is an indicator of the soil potential for the element. Plants receiving insufficient nitrogen are stunted in growth and possess poor root system.

Principle: The sample is oxidized at a high temperature of 950°C in a furnace. Oxygen is flushed into the furnace for the complete oxidation. The product of the combustion is again passed through a secondary furnace of 850°C for further oxidation and particulate removal. The combustion gas was then collected in a vessel called Ballast. The homogeneous combusted gas in the ballast is then purged through the CO_2 and H_2O infra red detector and 3cc aliquot loop. The gas in the aliquot loop to the Helium carrier flow is passed through a hot copper to remove O_2, CO_2 and H_2O. A thermal conductivity cell will determine the Nitrogen content.

Calculations: Directly from the instrument.

Available Phosphorous in the soil (Bray, 1945**)**

Phosphorus is a second key nutrient found in the soil. The amount of P available to plants is generally not exceeded 0.01% of the total Phosphorous. The total Phosphorous in soil found between 0.02 - 0.10 % by weight. Two forms of Phosphorous are found in the soil

Organic P (20-28%) and the rest are in organic Phosphorous. There has been no report of plant absorbing organic Phosphorous either from solid or solution phase of the soil. Inorganic Phosphorous occurs as orthophosphate ($H_2PO_4^-$ and HPO_4^{2-}) in several forms and combinations (Baruah, 1997).

Principle: The principle of this method is that the soil is mixed thoroughly with an extraction solution of 0.03 N NH_4F in 0.025 N HCl. The combination of NH_4F and HCL will extract easily acid soluble forms of P largely Ca- phosphates, Al- phosphates and Fe-phosphates. The NH_4F dissolve Al, Fe and Mn phosphates by forming complex ion with these metal ions in the acid solution and there by release phosphate ion into the solution. In the presence of Chloromolybdic acid in an acidic medium, the phosphate ion forms a hetropoly compound of P. On reduced by $SnCl_2$ impart molybdenum-blue color. The intensity of blue color on reduction provides a measure of the concentration of P in the test solution. This intensity can be measured at 660 nm, using the spectrophotometer (Baruah, 1997).

$3NH_4F + 3HF + AlPO_4 \rightarrow H_3PO_4 + (NH_4)_3AlF_6$

$3NH_4F + 3HF + FePO_4 \rightarrow H_3PO_4 + (NH_4)3FeF_6$

$H_3PO_4 + 12H_2MoO_4 \rightarrow H_3P(Mo_3O_{10})_4 + 12H_2O$

Reagents:

i. Ammonium fluoride (NH_4F), (1 N): Dissolve 37 g of NH_4F in DDW and dilute the solution to 1 liter. Store the solution in polythene bottle.

ii. HCL, (0.5N): Dilute 20.2 ml conc. to a volume of 500 ml with DDW

iii. Extracting solution: Add 15 ml of 1 N NH_4F and 25 ml of 0.5N HCL to 460 ml of DDW. This gives a solution composition of 0.03 N NH_4F in 0.025N HCL

iv. Dickman and Bray's reagent: Dissolve 15 g of ammonium molybdate (AR) in 300 ml DDW, warm to about 60 ^{o}C, cool and filter add to it 342 ml conc. HCL and make up to 1 liter. This is 1.5% ammonium molydbate in HCL.

v. Stannous chloride solution: Dissolve 10 g of $SnCl_2.2H_2O$ (AR) crystals in 25 ml of conc. HCL and store in a brown bottle .This is 40% stannous chloride stock solution

vi. Stannous chloride working solution: Dilute 0.5 ml of the stock solution to 66 ml with DDW. Prepare the solution just before use.

vii. Preparation of standard Phosphorous solution: Dissolve 0.439 g of potassium dihydrogen phosphate (AR) in about half a litre of DDW .Add to it 25 ml of 7 N H_2SO_4 and make up to 1000 ml with DDW. This gives 100 ppm of stock solution of P. From this prepare a 2 ppm solution by 50 times dilution of the stock solution.

Procedure: For the extraction of P, weigh 5 g soil and transfer it to a 100 ml conical flask._Add to it 50 ml of extracting solution. Shake the content of the flask for exactly 5 minutes and filter through Whatt Mann No: 42 filter paper. A blank should be made by adding all reagents except the soil.

Colorimetric estimation of P: Take 5 ml of the soil extract as well as different concentration of P by pipetting out 0 (blank), 1, 2, 3, 4, 5, and 10 ml of 2ppm phosphate solution in 25 ml volumetric flask, add 5 ml of extracting solution of each of the P standard solution followed by the addition of 5 ml of Dickmans and Bray's reagents in all the flask. Mix the condense of the flask thoroughly with about 5 ml of DDW to remove the adhering ammonium molybdate. At last add 1 ml of working stannous chloride solution with immediate mixing and make up to the mark with DDW. Once again mix the solution thoroughly. The intensity of the blue color is measured at **660 nm** just after 10 minutes and determines the concentration of P from the standard curve.

Calculation:

Available phosphorus in the soil = A x 50 x 2.24 kg/ ha

Where A = concentration of phosphorus read from the standard curve

Available Potassium in the soil

Exchangeable potassium is the major source of K to plants. The available potassium in the soil is the sum of water soluble and exchangeable potassium. The neutral ammonium acetate solution extracts both water soluble and exchangeable potassium. The term available potassium in cooperate both exchangeable and water soluble forms of nutrients present in the soil. The readily exchangeable plus water soluble potassium is determined in the neutral normal acetate extract of the soil.

Principle: The method is based on the principle of equilibrium of soils with an exchanging cation made of the solution of neutral normal ammonium acetate in a given soil: solution ratio. During the equilibrium, ammonium ions exchange with the exchangeable K ions of the soil. The K content in the equilibrium solution is estimated with a flame photometer. Since NH_4^+ holds highly charged layers together just as K, the release of the fixed K, in an exchangeable form, is retarded during ammonium acetate extraction (Baruah, 1997).

Reagents:

i. Neutral NH_4OAc solution (1N): Dissolve 77.09 g of NH_4OAc in DDW and make up to 1 litre. Adjust the solution pH to 7 by adding either NH_4OH or glacial acetic acid.
ii. Stock potassium chloride solution: Dissolve 1.098 g of AR grade potassium chloride (Dried at 60° c for I hour) and make up the volume to I L using

DDW. It gives a 1000 mg/L K solution and is treated as stock solution of potassium.

iii. Working Potassium solution: From the stick take aliquots and dilute with ammonium acetate solution to get 10-80 ppm of potassium solution.

Procedure: Weigh 5 g of the soil in a 100 ml of conical flask. Add to it 25 ml of neutral 1 N NH_4OAc solution. Shake the condense of the conical flask on a electric shaker for 5 to 10 minutes and filter through a filter paper What man no. 1. Feed the filtrate into the atomizer of the flame photo meter and not down the reading.

W

Calculation

$$\text{Available K (kg/ha)} = \frac{R \times V \times 2.24}{W}$$

Where,

R= ppm of K in the extract

V = volume of the soil extract in ml

w = Weight of air dry samples taken for extraction in gm

Soluble Sodium in soil

Sodium (Na) can be extracted with ammonium acetate solution in the same way as K. Subsequently, Na in the extract can be determined by flame photometry.

Principle: Certain elements, including Na, have the property that, when their salts are introduced into a flame, they emit light with a wavelength (color) specific to the element and of intensity proportional to the concentration.

This is especially true for Na emitting a sparkling yellowish-red color.

Reagents

1). Standard Stock Solution

Dry about 5 g sodium chloride (NaCl) in an oven at 110°C for 3 hours, cool it in a desiccator, and store in a tightly closed bottle.

Dissolve 2.5418 g dried sodium chloride in DI water, and bring to 1-L final volume with DI water. This solution contains 1000 ppm Na (Stock Solution). Prepare a series of Standard Solutions from the Stock Solution as follows:

Dilute 2, 4, 6, 8, 10, 15, and 20 ml Stock Solution to 100 ml final volume by adding DI water or 1 N ammonium acetate solution, Diluted Stock Solution. These solutions contain 20, 40, 60, 80,100, 150, and 200 ppm Na. Standard Solutions for measuring soluble Na should be prepared in DI water, but for measuring extractable Na the standards should be made in ammonium acetate solution.

Procedure: Operate Flame Photometer according to the instructions provided for the equipment. Run a series of suitable sodium standards. Measure Na^+ in the samples, by feeding the filtrate into the flame photometer.

Calculations:

Sodium (mg/L) in soil: S/A x (Reading displayed for Na)

Where S = Sum of concentration of standard solution

A = Sum of the absorbance of the corresponding standard solution

$$\text{Sodium (mg/g)} = \frac{(A \times B)}{S \times 10000}$$

Where A = Sodium content of soil extract (mg/L)

B =Total volume of Soil extract

C = Weight of air-dry soil which is taken for the extraction

Multiply the final answer with the dilution factor.

Calcium and Magnesium in the soil

Calcium and magnesium are the two most abundance alkaline earth metals in soil. They occur as soluble ions in the soil and ions on the absorbed state (Baruah, 1997). The average calcium content of the soil is estimated to be 1.4% and it may vary from soil to soil depending upon the climate condition. The average Mg content of the soil is estimated approximately 0.5 %, where its concentration in soil water is estimated to be 10 mg/L. Quantitatively, the lowest amount of Mg occurs in podzolised and sandy soil.

Principle: The most widely used method for the determination of Ca and (Ca + Mg) is by complex metric titration, involving ethylene tetra-acetic acid (EDTA), (Schwartzenbach *et at*, 1946).The most widely used salt of EDTA is the disodium salt with the formula $Na_2H_2Y.2H_2O$, where Y is the tetravalent anion of EDTA. When Ca^+ and Mg^+ are treated with H_2Y^{-2} very stable complexes of calcium and Magnesium are formed (CaY^{-2} and MgY^{-2} respectively) in alkaline condition. For the combination determination of Ca^{2+} and Mg^{2+} Erichrome Black T (EBT) is used as an indicator. The optimum pH for the formation of Mg complex is less stable than the MgY^{-2} complex.
Ca $^{2+}$ is complexed before Mg^{2+} and the indicator changes from red to blue, when the Mg^{2+} end point is reached. The reaction is as follows

$MgI^- + H_2Y^{-2} \rightarrow MgY^{-2} + HIn^{-2} + H^+$

The classical indicator employed for Ca^{2+} titration is ammonium purpurate (murexide). Murexide, at pH 11, is purple in colour in the absence of Ca^{2+} ions; it forms a pink complex, which has a dissociation constant greater than the CaY^{-2} complex. Thus using murexide as an indicator, Ca^{2+} can be titrated with EDTA even in the presence of other alkaline earth ions.

$$H_2Y^{-2} + Ca^{2+} \rightarrow CaY^{-2} + 2H^+$$

Reagents:

i. Buffer solution: Dissolve 67.5 g of NH_4Cl in 400 ml of distilled water, then add 570 ml of conc. NH_4OH and dilute up to one litre.
ii. Standard EDTA solution: Dissolve 1.86 g of disodium salt of EDTA in distilled water and make up to 1L to get 0.01N solution.
iii. Eriochrome Black-T (EBT) indicator: 0.5 g of Eriochrome Black-T indicator is dissolved in 100 ml of triethanolamine.

iv. Murexide indicator: Mix 0.2 g of 40 g of finely grounded potassium sulphate and grind again in agate pestle and motar

v. 10% NaOH solution: Dissolve 10 g of NaOH in distilled water and make up to 100 ml.

vi. Buffer complex solution: Mix 50 ml of each of KCN solution , hydroxylamine hydrochloride solution, potassium ferro-cyanide solution and triethanolamine with 800 ml of buffer solution (should not be kept more than a week)

vii. Neutral NH_4O Ac solution (1N): Dissolve 77.09 g of NH_4OAc in DDW and make up to 1 liter. Adjust the solution pH to 7 by adding either NH_4OH or glacial acetic acid

Procedure: 1)Calcium and Magnesium: Transfer 10 ml of ammonium acetate soil extract into a conical flask and add 5 to 10 ml buffer complex to get pH of about 10, add EBT indicator and titrate the content with standard EDTA till color changes from pink to blue.

2) Calcium: Transfer 10 ml of ammonium acetate soil extract into a conical flask and add sufficient quantity of 10% NaOH solution to attain a pH of 12 or more. Now add a pinch of Murexide indicator and titrate it against standard EDTA solution till the colour changes from pink to violet.

Calculation:

$$\text{M.equ. (Ca + Mg) per 100g} = \frac{\text{Burette reading x N of EDTA x Vol made x100}}{\text{Weight of soil x Aliquot taken}}$$

$$\text{M.equ. Ca per 100g} = \frac{\text{Burette reading x N of EDTA x Vol made x 100}}{\text{Weight of soil x Aliquot taken}}$$

M.equ. (Mg) per 100g = M.equ. (Ca + Mg) per 100g - M.equ. Ca per 100g

RESULTS AND DISCUSSION

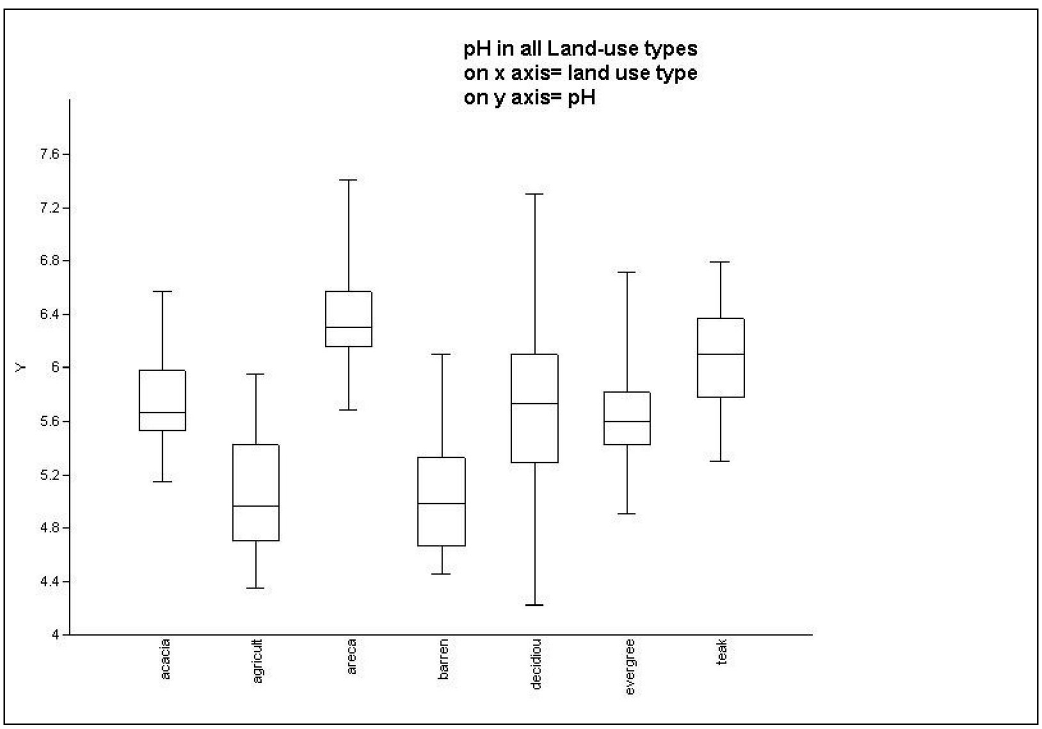
Soil pH

	Agriculture n=54	Barren n=45	Deciduous n=108	Evergreen n=63	Teak n=53	Areca n=17
Min	4.35	4.45	4.22	4.9	5.3	5.68
Max	5.95	6.1	7.3	6.71	6.79	7.4
Avg.± std dev.	5.05±0.4	5.05±0.5	5.7±0.5	5.66±0.3	6.07±0.3	6.37±0.46

Pair wise Wilcox Test

	Areca	Agriculture	Barren	Deciduous	Evergreen
Agriculture	S				
Barren	S	NS			
Deciduous	S	S	S		
Evergreen	S	S	S	NS	
Teak	S*	S	S	S	S

*$p<0.05$, $p<0.001$, S=significant; NS=non-significant



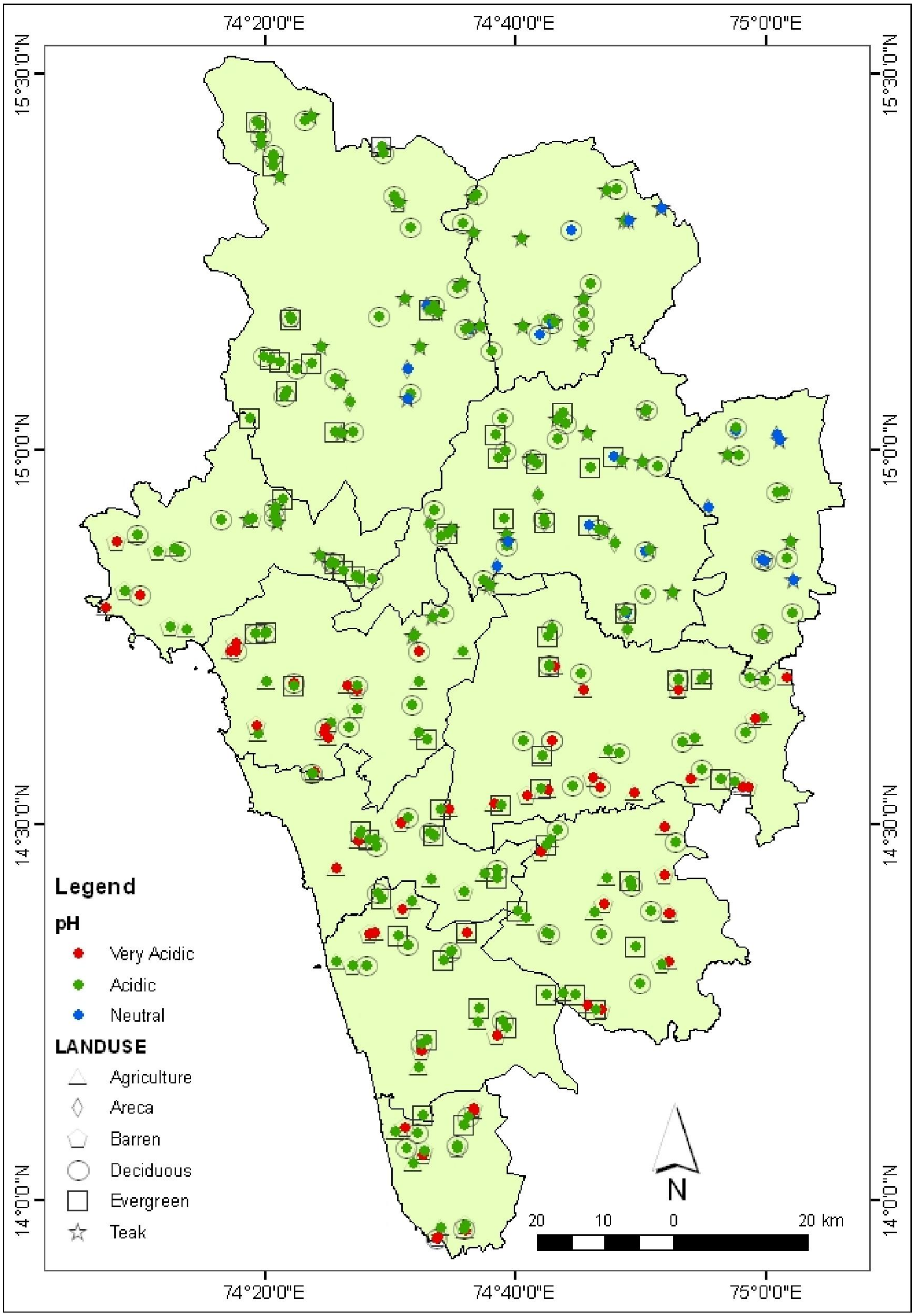


Fig 5: pH across different land-use types in Uttar Kannada district

In the agricultural soils which cultivated rice, pH ranged from 4.35 at Harsikattai in Siddapur taluk to 6.11 at Pudavarabail. Almost all the samples in the coastal talukes were found to be acidic (5-6), according to the reference scale given by **Bertrand (1984)**. Due to heavier rainfall (>3000mm/year) and the general uneven topography, bases are leached, and the leaching is more in steeper topography. In Sirsi taluk where the rainfall is around 2500mm and the land is more of undulating nature the pH is slightly higher although still acidic. pH of open grasslands and fallow lands ranged from 4.45 at Manaki in Honnavar taluk of coast to 6.1 at Sirugunji in coastal Kumta taluk.

The pH in the three talukes of Mundgod, Yellapur and Haliyal show pH more towards neutral (>6.5) which may be due to the influence of the Dharwar Schist's (**Bourgeon 1989**). The Dharwar Schist's which form part of Deccan trap is rich in calcium in form of carbonates compared to the other areas in the study site. These carbonates are responsible in contributing to the higher pH regime in this area.

The reason behind higher pH range in the Arecanut plantations (6.37±0.2) may be due to management practices like mulching. Mulching plays an important role in maintaining the soil chemical balance (**Ekanade and Adejuwon, 1988**). The pH in the deciduous forest ranged from 4.22 to 7.3. It was found that the coastal talukes and taluks in the Sahayadrian range have acidic pH range (5- 6.5), but the forests in the taluks in the plateau region have pH which is in the neutral regime (6.5-7.5). This may be due to the fact that the region forms the outcrop of the Deccan trap (**Bourgeon, 1989**).

A study conducted in the same region by **Bourgeon** (**1989)** informs that pH in the coastal region which is laterite, is acidic, about 5.2 – 5.5, even under the forest cover. pH in the Western Ghats ranges from acidic to very acidic, which is again confirmed by this study. In case of the semi arid Karnataka plateau, the pH sometimes exceeds 7, in the presence of the carbonates.

The pH in agriculture (5.05±0.4) was lesser than the pH in the evergreen (5.66±0.3) and the deciduous (5.70±0.5) land use. Tilling of land for agricultural purposes plays a vital role in leaching out of bases, as has been already found out in the earlier studies. These may have been responsible for lowering of the pH in the agricultural soils. The pH of the barren land (5.05±0.41) was less compared to those in natural vegetations like teak (6.07±0.3), evergreen (5.66±0.3) and deciduous (5.70±0.5).

As per the study carried out by **Islam and Weil (2000)**, pH in the natural vegetations and the reforested lands is acidic as compared to grasslands and cultivated lands, which was due to the naturally acidic behaviour of the soils, due to presence of aluminium in these soils and intense leaching of base cations during monsoons in these soils (**Hassan and Majumdar 1990).**

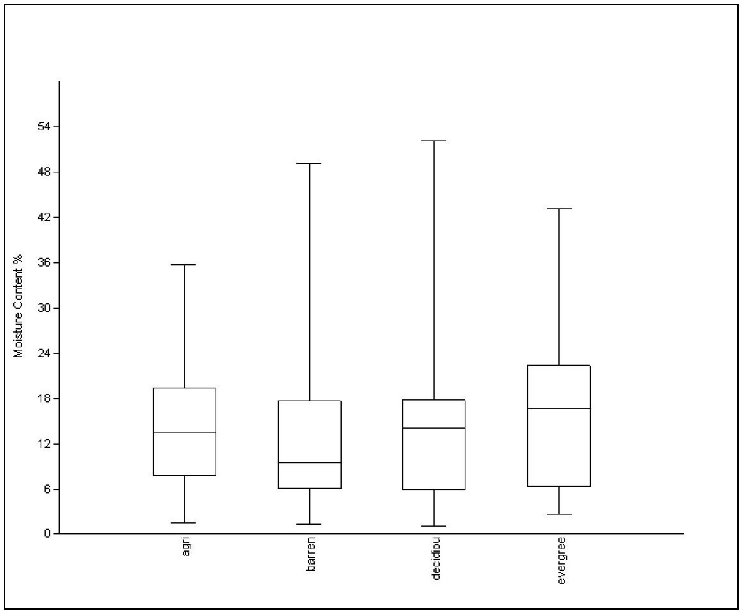
Swamy and **Proctor (1994)** studied the soils of rainforests of the Sringeri area of the Western Ghats, which is to the South of the present study area. It was found out that pH of the soils was mildly acidic i.e. 5.2 – 6.0.

The conversion of forest to agricultural and pasture purposes involves the improvement of soil fertility by adding base cations mineralized from combusted forest biomass, which raises soil pH and increases cation exchange capacity (CEC) **(Nye and Greenland 1964)**. In our analysis, we found that agricultural and pasture/barren lands had lower pH (5.05±0.4) compared to that under natural vegetation cover (5.68±0.4).

Soil Moisture

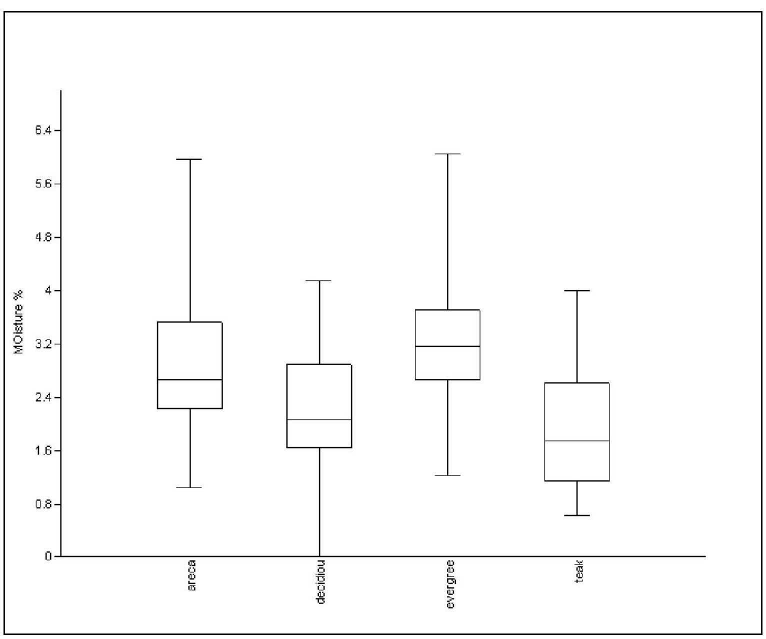
First field data

	Agriculture n=54	Barren n=38	Deciduous n=49	Evergreen n=35
Min	1.4	1.29	1.07	1.27
Max	35.6	49.15	52.14	43.17
Avg± std dev	13.9±7.8	12.5±9.6	14.5±10.6	16.5±10.4



Second field data

	Arecanut N=17	Deciduous N=62	Evergreen N=29	Teak N=52
Min	1.04	1.0	1.21	0.6
Max	5.9	4.1	6.0	3.9
Avg± std dev	2.9±1.2	2.1±0.8	3.2±1.1	1.87±0.9



Soil moisture is a very critical property which is greatly influenced by seasonal changes.In the first phase of field study, soil moisture was found to be highest in evergreen (16.5±10.4) land use type followed by deciduous (14.5±10.6) and agricultural soil systems. The lower bulk density in evergreen soils, leads to higher pore size, which increases the capacity to retain soil moisture. Agricultural (13.9±7.8) and barren (13.9±7.8) soils being open become compact after a period of time, which decreases their pore size, thus resulting in lower soil moisture.

In the second phase Arecanut (2.9±1.2) plantations and evergreen (3.2±1.1) forest had highest soil moisture than other land use systems. Arecanut plantations due to drip irrigation, maintains the soil moisture.

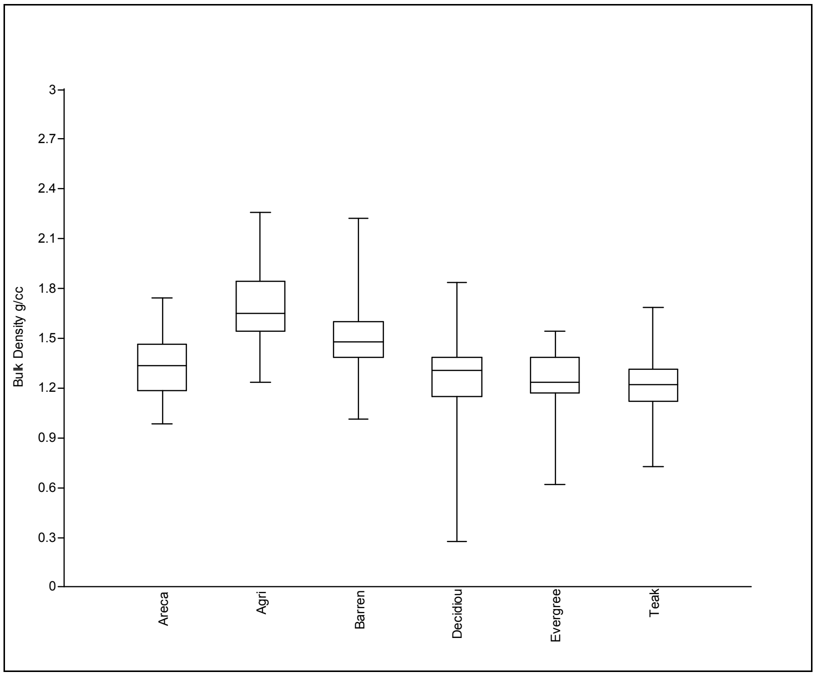
Soil Bulk Density

	Agriculture n=54	Barren n=45	Deciduous n=108	Evergreen n=63	Teak n=53	Areca n=17
Min	1.22	1.007	0.27	0.61	0.72	0.98
Max	2.25	2.22	1.83	1.53	1.62	1.73
Avg± std.dev	1.67±0.2	1.48±0.2	1.28±0.2	1.25±0.1	1.21±0.2	1.32±0.2

Pair wise Wilcox Test

	Areca	Agriculture	Barren	Deciduous	Evergreen
Agriculture	S				
Barren	NS	S			
Deciduous	NS	S	S		
Evergreen	NS	S	S	NS	
Teak	NS	S	S	NS	NS

$p<0.001$; S=significant; NS=non-significant



The bulk density of the agricultural soils (1.67 ±0.2 g/cc) was found to be higher than that compared in natural vegetation like deciduous (1.28 ±0.2 g/cc) and evergreen (1.25 ±0.1 g/cc). Forest soils usually have lower bulk density. Frequent cultivation, in particular, tends to break soil aggregates and can compact existing soil. Bulk density increased upon conversion from forest to agricultural land, which in some cases was extreme i.e. 60% (**Murty et al, 2002)**.

In a study conducted in a tropical landscape in Bangladesh, it was found that soils under cultivation **(1.38g/cc)** had higher bulk density than the adjacent soils under well stocked *S.robusta* natural forest (**1.22g/cc**), Acacia reforestation (**1.18g/cc**) and grass (**1.18g/cc**) **(Islam and Weil, 2000)**. The cultivated soils were considerably lower is silt and slightly lower in clay than the adjacent soils under natural forest, most likely as a result of preferential removal of silt by accelerated water erosion during the monsoon months **(Hassan and Majumdar, 1990**). In a study conducted in Puerto rico it was found that in the agricultural soils of dry and moist life zones, had higher bulk density than that in the forests (**Brown and Lugo 1990)**.

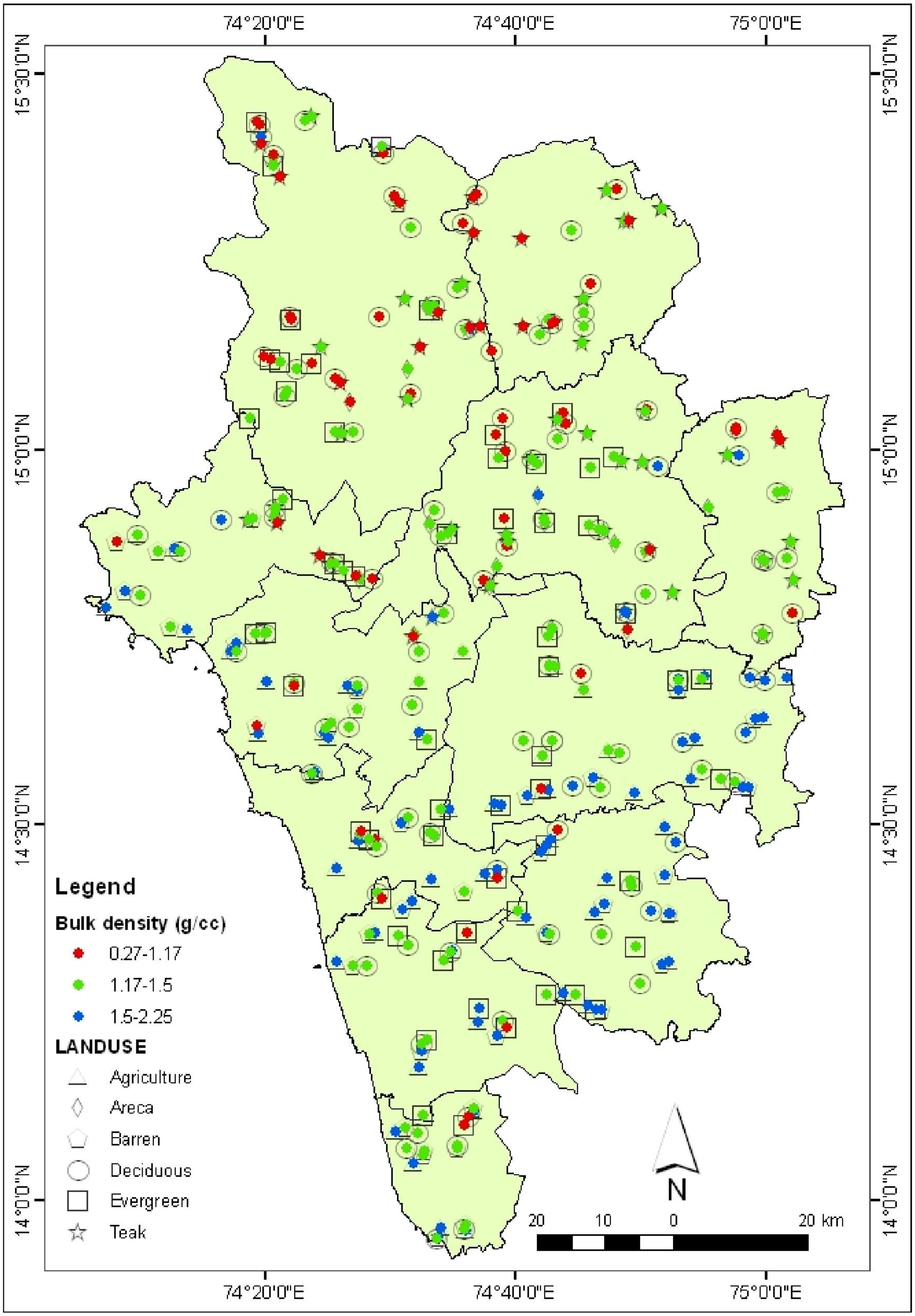


Fig 6: Bulk Density across different land-use types in Uttar Kannada district

The bulk density of soil samples ranges from (1.25 ±0.1 g/cc) evergreen, (1.28 ±0.2 g/cc) deciduous and **(**1.32 ±0.1 g/cc) arecanut plantation. The bulk density of teak (1.21±0.2 g/cc) was found to be similar to that of the deciduous (1.28±0.2 g/cc) and evergreen (1.25±0.1 g/cc) land use types.

Enhanced aggregate stability of reforested soils is consistent with greater input of labile C contributed by high quality litter fall **(Islam and Weil 2000)**. In contrast organic matter in cultivated soil has less physical protection than that in the uncultivated soils because tillage periodically breaks up macro-aggregates and exposes previously protected organic matter in soil macro-aggregates (**Nardi et al. 1996).**

The bulk density of the barren/ pasture land (1.48±0.2) was higher than that of the evergreen (1.25±0.1 g/cc) and deciduous (1.28±0.2 g/cc) land use types. Bulk density remains low in primary forest and plantations due to higher porosity of soil and enhanced microbial activities, which is an important property preserved under the tree- based land uses (**McGrath et al, 2001**). Conversion of forest to barren/ pasture land decreases soil mixing by fossorial arthropods and small mammals (**Clark 1990**), especially the formation of macro-channels. In addition cattle trampling in a grazed area acts as a physical force, directly reducing the large pore spaces and increasing bulk density **(Reiners et al, 1994).** The current study considers the top 15 cm soil layer. Earlier studies indicated that bulk density in pasture and forest soils remain same for the top 10 cm soil layer, but differed significantly in the 10 – 20 cm layer **(Celik 2005)**. Agricultural soils had higher bulk density than the forest and pasture soils.

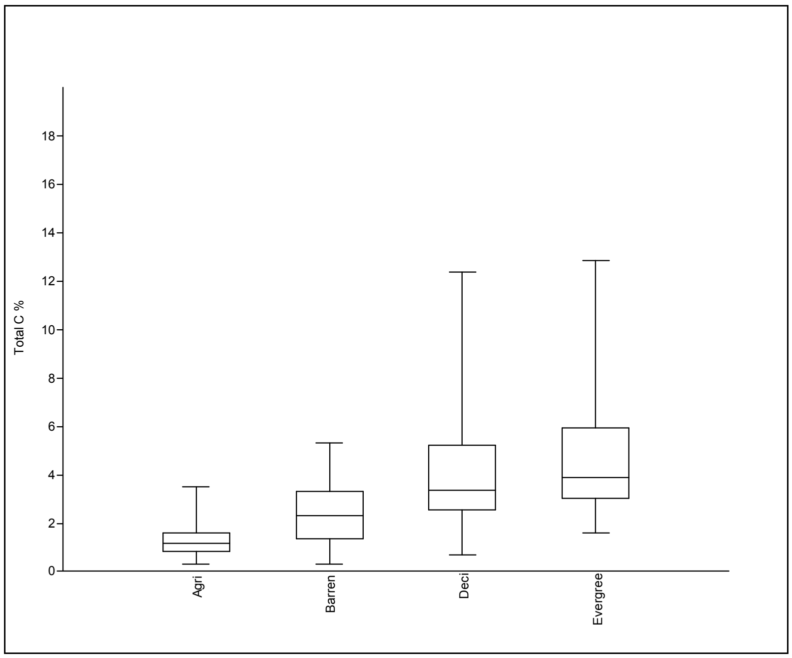
Total carbon

	Agriculture n=54	Barren n=38	Deciduous n=49	Evergreen n=35
Min	0.31	0.31	0.66	1.56
Max	3.5	5.28	12.38	12.84
Avg ± Std dev.	1.27±0.6	2.42±1.3	4.06±2.2	4.47±2.2

Pair wise Wilcox Test

	Agriculture	Barren	Deciduous
Barren	S		
Deciduous	S	S	
Evergreen	S	S	NS

p<0.001, S=significant; NS=non-significant



The total carbon was highest in evergreen (4.47±2.2 %), followed by deciduous (4.06±2.2%), barren (2.42±1.31%) and was lowest in agricultural soils (1.27±0.6%). Significant variations in total carbon have been observed across land uses: agricultural (4.06±202%), evergreen (4.47±2.2 %) and deciduous (4.27±0.6%). Soil C is most susceptible to change at the surface (**Desjardins and others 1994**), where physical changes i.e. removal of live vegetation and forest floor litter exacerbate the processes such as erosion, runoff and leaching of mineral N not taken up by plant. Studies on tropical soils suggest a rapid decline in organic matter and nitrogen due to continuous cultivation (**Allen, 1985; Aweto, 1981; Ayanaba et al., 1976; Brams, 1971; Nye and Greenland, 1964**).

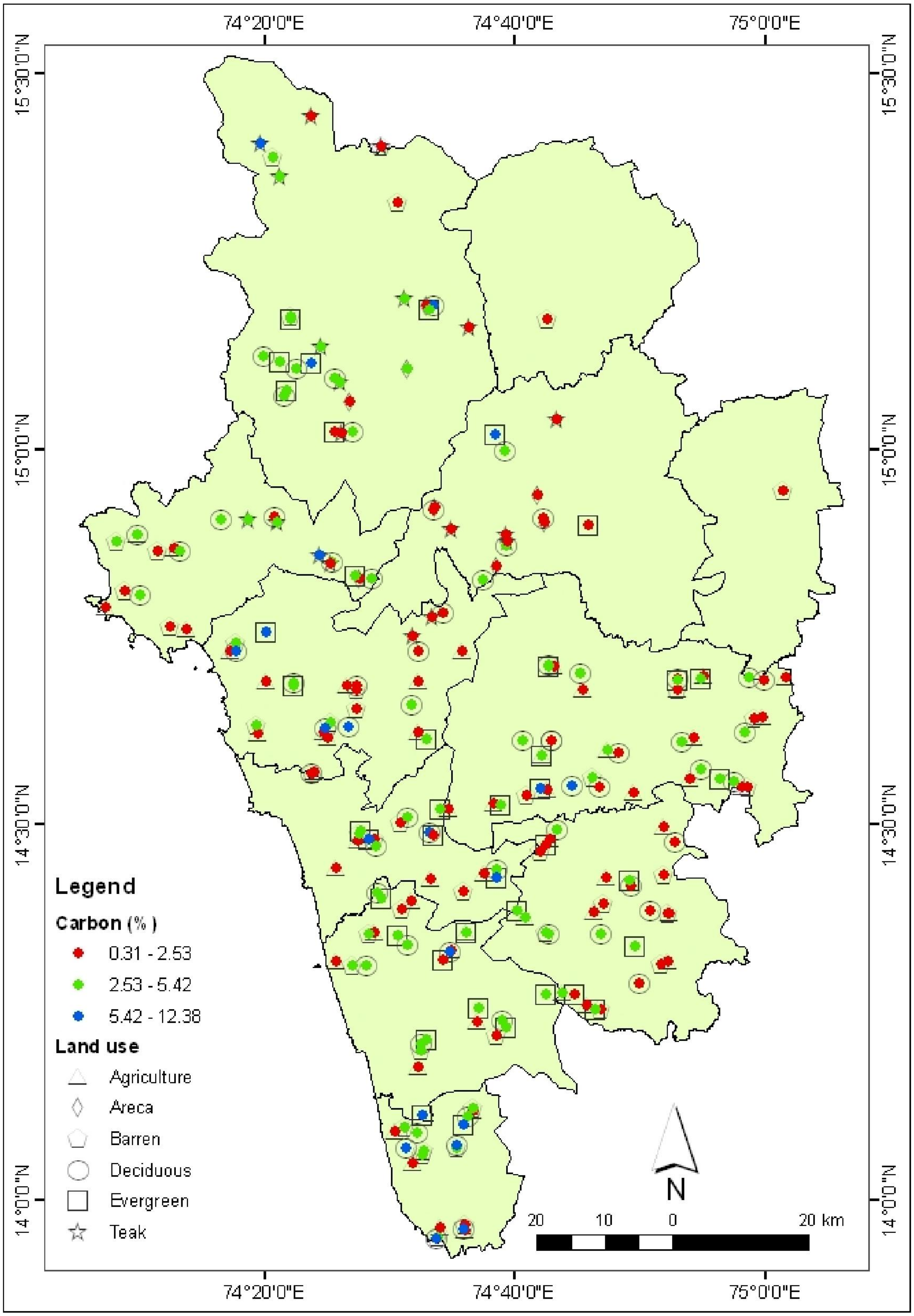


Fig 7: Total Carbon across different land-use types in Uttar Kannada district

Carbon is a major contributor to organic matter, which influences cation exchange capacity, soil structure, soil water balance and it also acts a source of plant nutrients (**Lal and Kang, 1982; Sanchez, 1976).** Conversion of forests to agricultural systems changes soil physical, chemical and biological properties due to changes in the quantity and quality of organic carbon inputs to soil, nutrients inputs and losses and stimulation of decomposition through soil disturbance. Studies have indicated that significant amounts of carbon could be lost upon conversion of forest to cultivated lands (**Murty et al., 2002**). Upon conversion to crops, the high organic inputs typical of tropical forests **(Brown and Lugo, 1982, 1990)** decrease markedly, but the warm humid climate favors continuous decay of mineralizeable soil C and N and high rates of leaching. The present study is in agreement with the earlier studies and conforms that changes in land uses significantly impacts the total carbon of the soil.

Houghton (1999) estimated a total carbon loss due to land use changes as 124 Gt C per year during 1850-1990. Most of this loss was from the conversion of tropical forests with croplands or pastures contributing 68% and 13% to the loss, respectively. There is a transition to a system in which a high proportion of organic C stored would gets removed with annual harvest, when a previously forested soil is converted to soil under cultivation (**Vitousek 1983, Smil, 1999**).

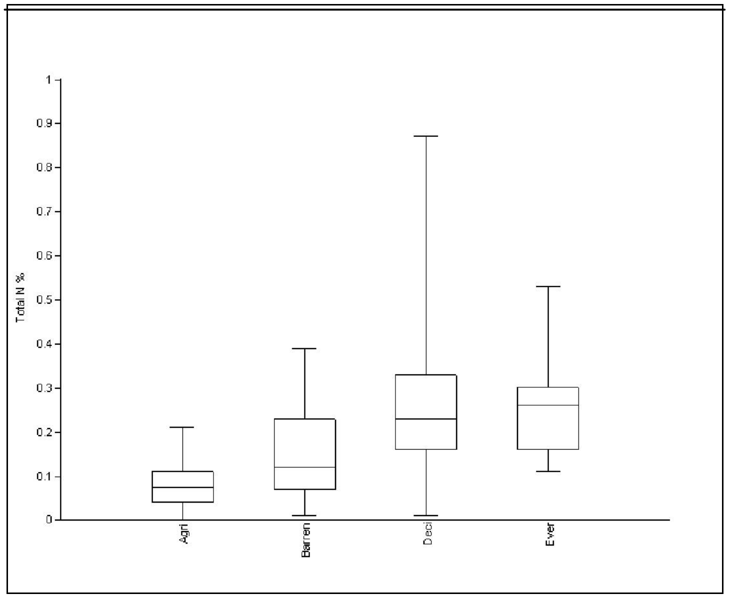
Total Nitrogen

	Agriculture n=54	Barren n=38	Deciduous n=49	Evergreen n=35
Min	0.0	0.01	0.01	0.11
Max	0.21	0.31	0.87	0.53
Avg± Std.dev	0.08±0.05	0.14±0.09	0.26±0.1	0.25±0.1

Pair wise Wilcox Test

	Agriculture	Barren	Deciduous
Barren	S		
Deciduous	S	S	
Evergreen	S	S	NS

$p<0.001$, S=significant; NS=non-significant



In agricultural soils total nitrogen was significantly less (0.08±0.05) compared to land uses under evergreen (0.25±0.1) and deciduous (0.26±0.1). Grasslands / pastures showed lower soil total N (0.14±0.09) compared to the evergreen (0.25±0.1) and deciduous (0.26±0.1), but higher than agricultural soils. Earlier studies on tropical soil suggest a rapid decline in organic matter and nitrogen due to continuous cultivation (**Allen, 1985; Aweto, 1981; Ayanaba et al., 1976; Brams, 1971; Nye and Greenland, 1964**). The loss of soil N due to forest conversion to crops has been related to the initial N content (**Allen, 1985**). Upon conversion to crops, the high organic inputs typical of tropical forests **(Brown and Lugo, 1982)** decrease markedly, but the warm humid climate favors continuous decay of mineralizeable soil C and N and high rates of leaching. In cultivated systems the rate of nutrient uptake exceeds the rate of nutrient return to the soil, causing decline in the soil nutrient status (**Adejuwon and Ekanade 1988**). Removal of vegetation cover accelerates the decrease of N, due to increased susceptibility of surface N to the various physical forces like erosion, runoff and leaching of mineral N **(McGrath et al., 2001).**

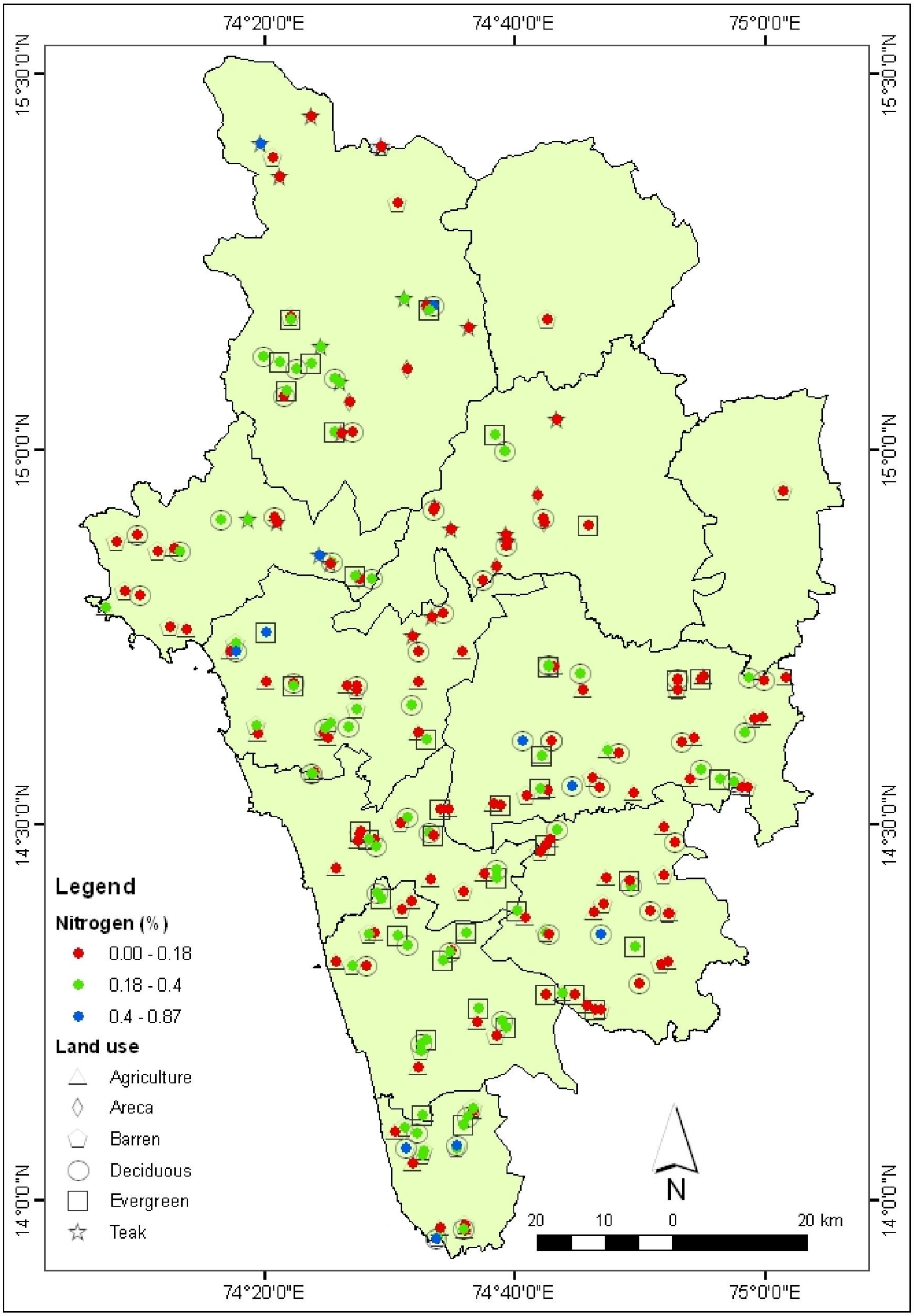


Fig 8: Total Nitrogen across different land-use types in Uttar Kannada district

Studies indicate that there is no significant change in total N among pastures/barren and natural forest systems (**McGrath et al., 2001; Islam and Weil, 2000; Brown and Lugo, 1990**).

There is no significant variation amongst the total N of deciduous (0.26±0.1) and evergreen (0.25±0.1) systems. This may be due to the leaf-litter quantities in these forest systems. Tree cover too plays an important role in maintaining total N and preventing it from leaching due to physical forces.

Available Phosphorus

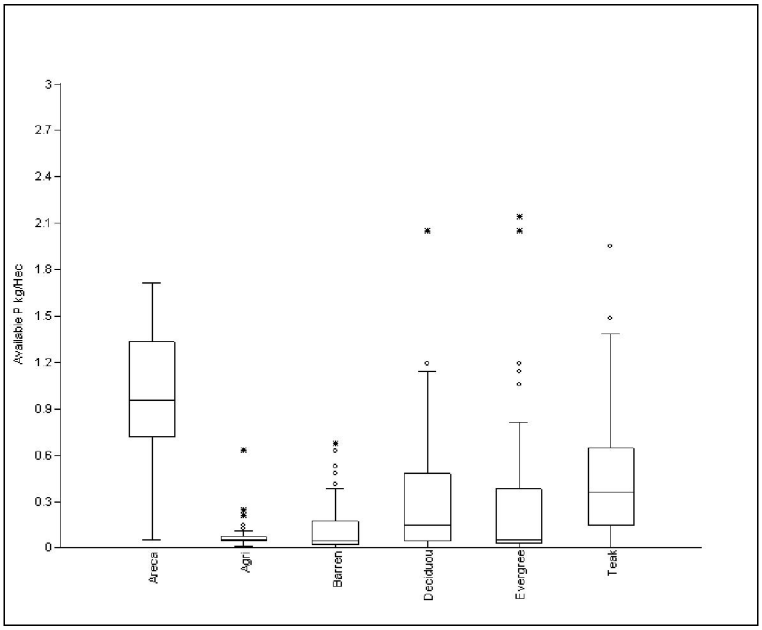
Available Phosphorus (kg/Hec)

	Agriculture n=54	Barren n=45	Deciduous n=108	Evergreen n=63	Teak n=53	Areca n=17
Min	0.01	0.01	0.01	0.01	0.05	0.05
Max	0.63	10.57	2.05	2.14	1.95	5.57
Avg ± Std.dev	0.06±0.08	0.37±1.58	0.28±0.3	0.27±0.4	0.49±0.4	1.23±1.22

Pair wise Wilcox Test

	Areca	Agriculture	Barren	Deciduous	Evergreen
Agriculture	S***				
Barren	S***	NS			
Deciduous	S***	S	S*		
Evergreen	S***	NS	NS	NS	
Teak	S**	S	S***	S**	S***

*p<0.05, **p<0.01, ***p<0.001; S=significant; NS=non-significant



Phosphorus is one of the major nutrients required for growth by plants. Soil P impoverishment has been widely cited as the principal cause for declines in soil fertility that have forced land owners to abandon both pastures and crop fields, often only few years after forest conversion **(Serrao and others 1996).** Higher organic mineralization occurs in soils treated with management practices like mulching, subsequently leading to higher phosphorus levels. Available Phosphorus was significantly higher in Arecanut (1.23±1.22) than in any other land use types. Lowest amount of phosphorus was found in agricultural (0.06±0.08) soils, which may be due to continuous cultivation pressure on the soil leading to depletion of soil available phosphorus. Poor management practices in these land use types too are responsible for lower phosphorus levels.

In our study, phosphorus was significantly lower (0.06±0.08) in the soil samples collected from agricultural lands than deciduous (0.28±0.3) and teak (0.27±0.4) land use types, but not comparable to soil from evergreen forests.

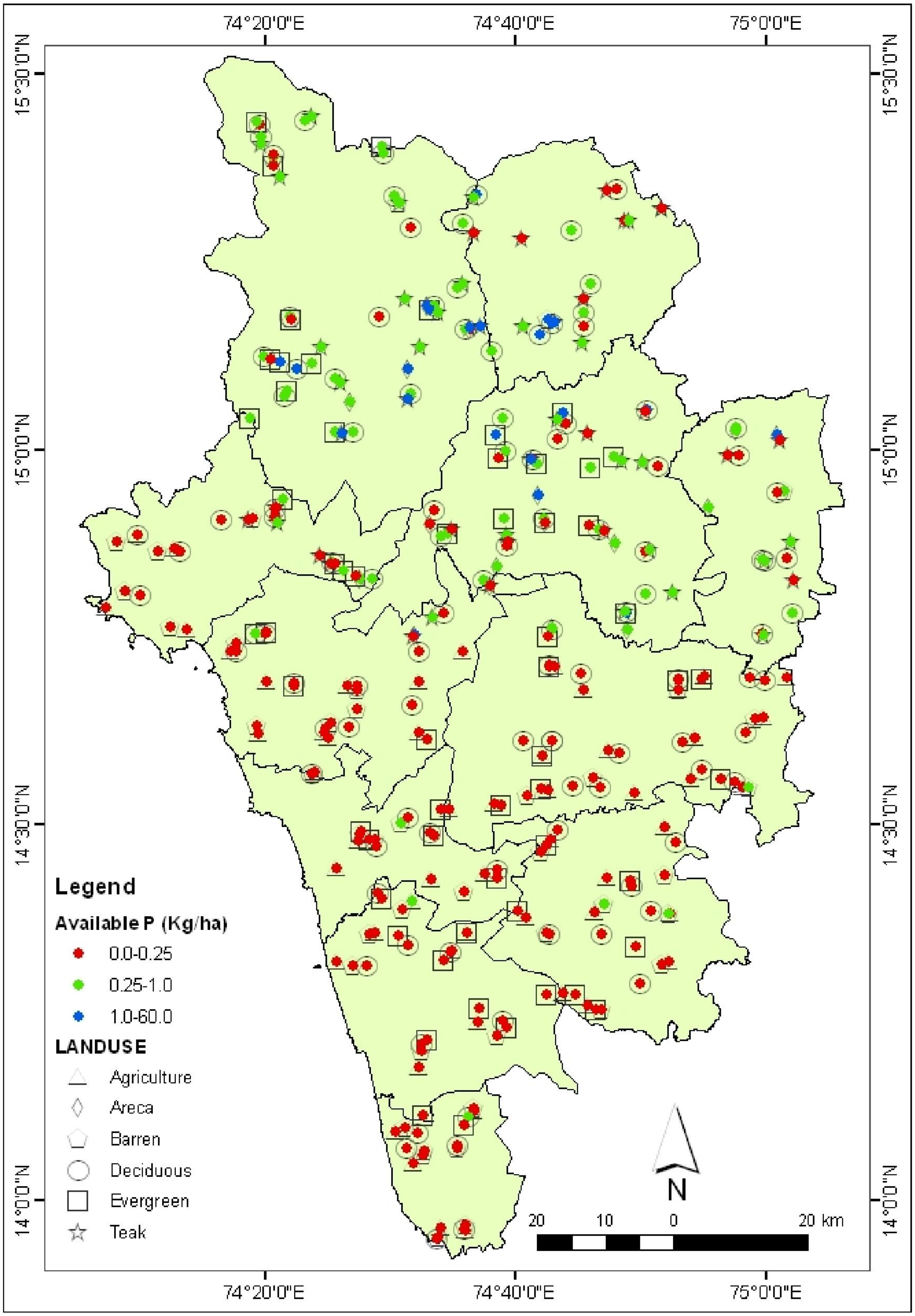


Fig 9: Available Phosphorus across different land-use types in Uttar Kannada

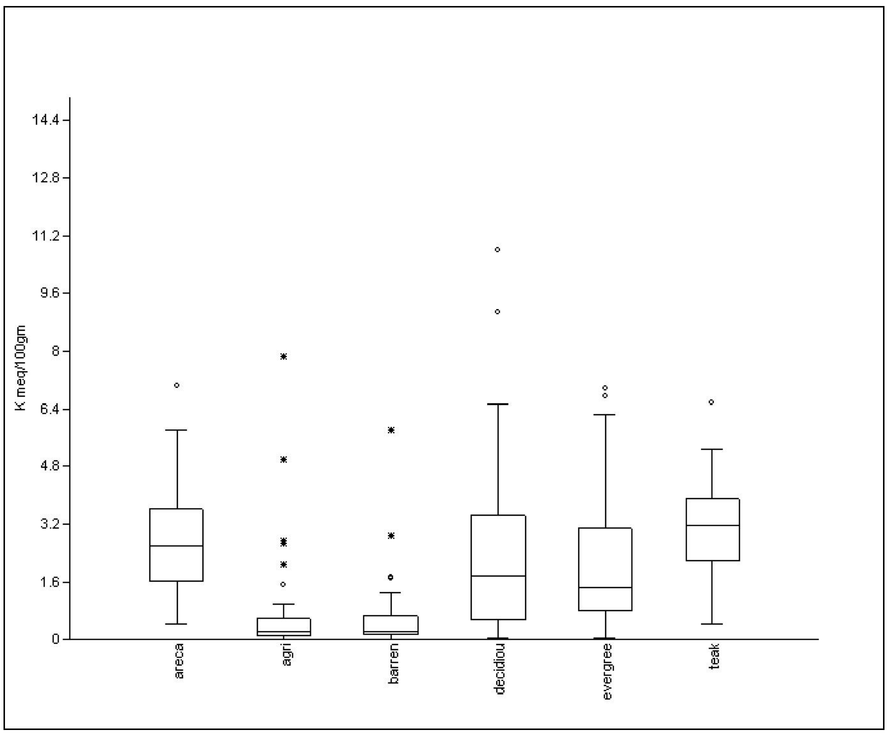
Available K

	Agriculture n=54	Barren n=45	Deciduous n=108	Evergreen n=63	Teak n=53	Areca n=17
Min	0.01	0.01	0.03	0.02	0.44	0.43
Max	7.3	5.81	16.22	6.94	6.56	7.00
Avg.± std.dev.	0.7±1.3	0.5±0.9	2.3±2.4	1.9±1.6	3.0±1.4	2.9±1.9

Pair wise Wilcox Test

	Areca	Agriculture	Barren	Deciduous	Evergreen
Agriculture	S***				
Barren	S***				
Deciduous	NS	S***	S***		
Evergreen	NS	S***	S***	NS	
Teak	NS	S***	S***	S**	S***

*p<0.05, **p<0.01, ***p<0.001; S=significant; NS=non-significant



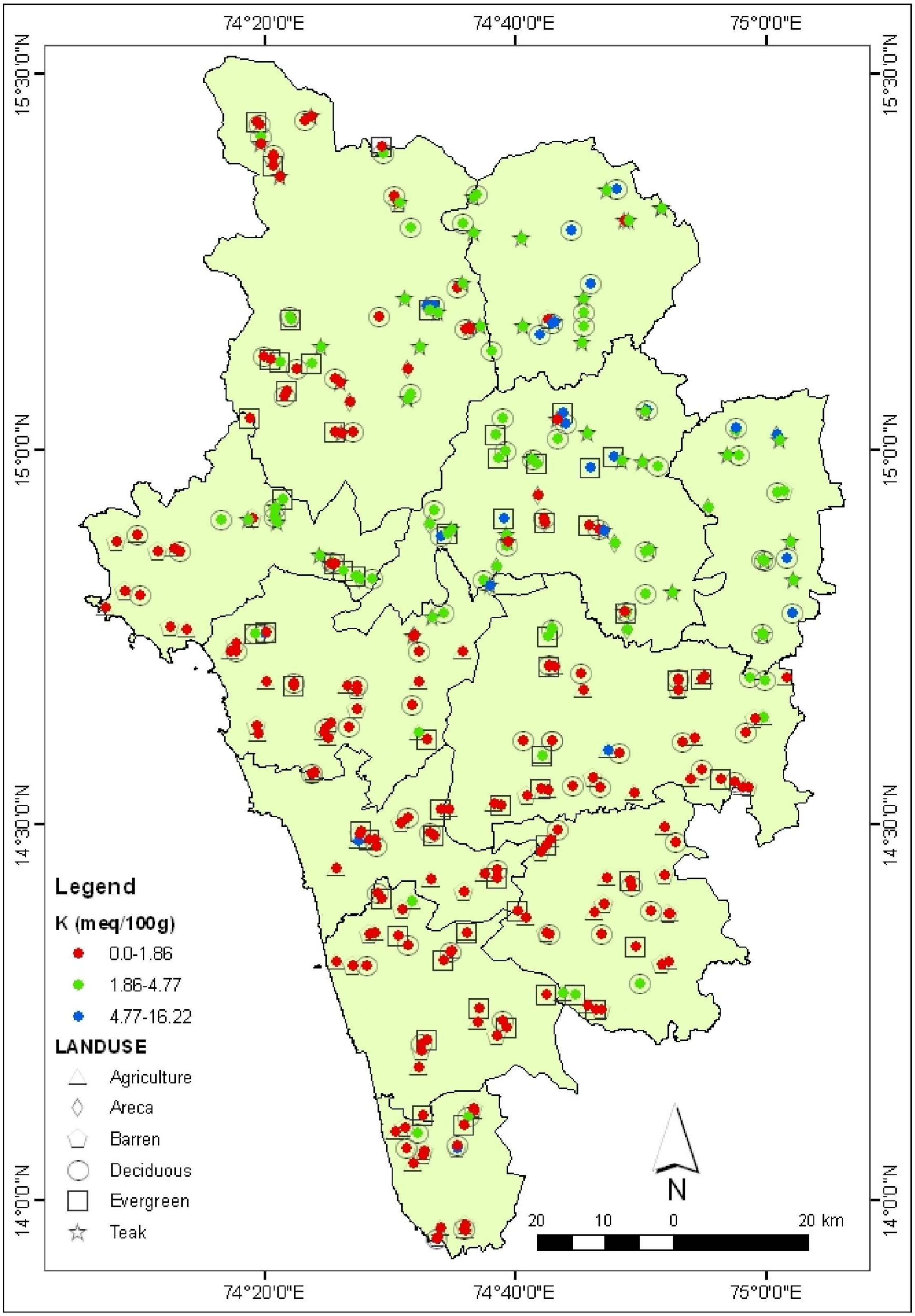
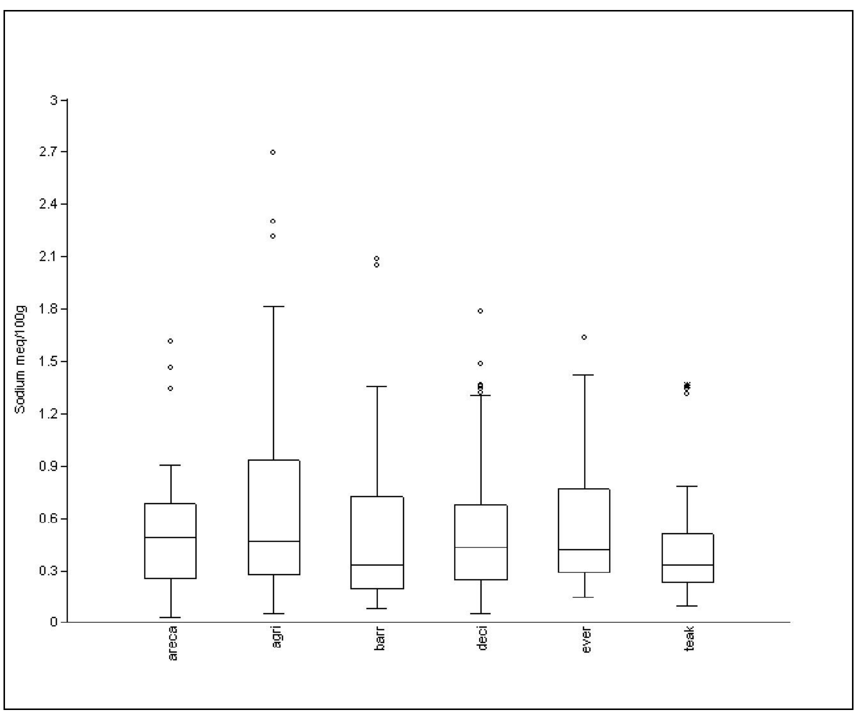


Fig 10: Potassium across different land-use types in Uttar Kannada district

Potassium is a major macro nutrient required for plant growth. In natural soils available K is very high, but cropping for many years will reduce the availability of this element (**Brady 1984**). Potassium was significantly lower in soil samples of agriculture (0.7±1.3) and barren (0.5±0.9) lands than other tree based land use types. It is observed that nutrient immobilization and subsequent removal in these systems is not matched by the rate of nutrient return to the soil through the fall and mineralization of litter (**Lal 1975**). Potassium was higher in Arecanut (2.9±1.9) compared to natural land use types. The reason for higher concentration of potassium in Arecanut garden is due to addition of ash by farmers in this region (**Chandran, pers. comm.).** Potassium is also found to higher in teak (3.0±1.4) plantations.

Sodium

	Agriculture n=54	Barren n=45	Deciduous n=108	Evergreen n=63	Teak n=53	Areca n=17
Min	0.05	0.08	0.05	0.14	0.09	0.03
Max	2.69	6.3	4.27	1.63	1.36	1.61
Avg. ± Std.Dev	0.71±0.6	0.80±1.2	0.58±0.5	0.57±0.4	0.47±0.3	0.59±0.4



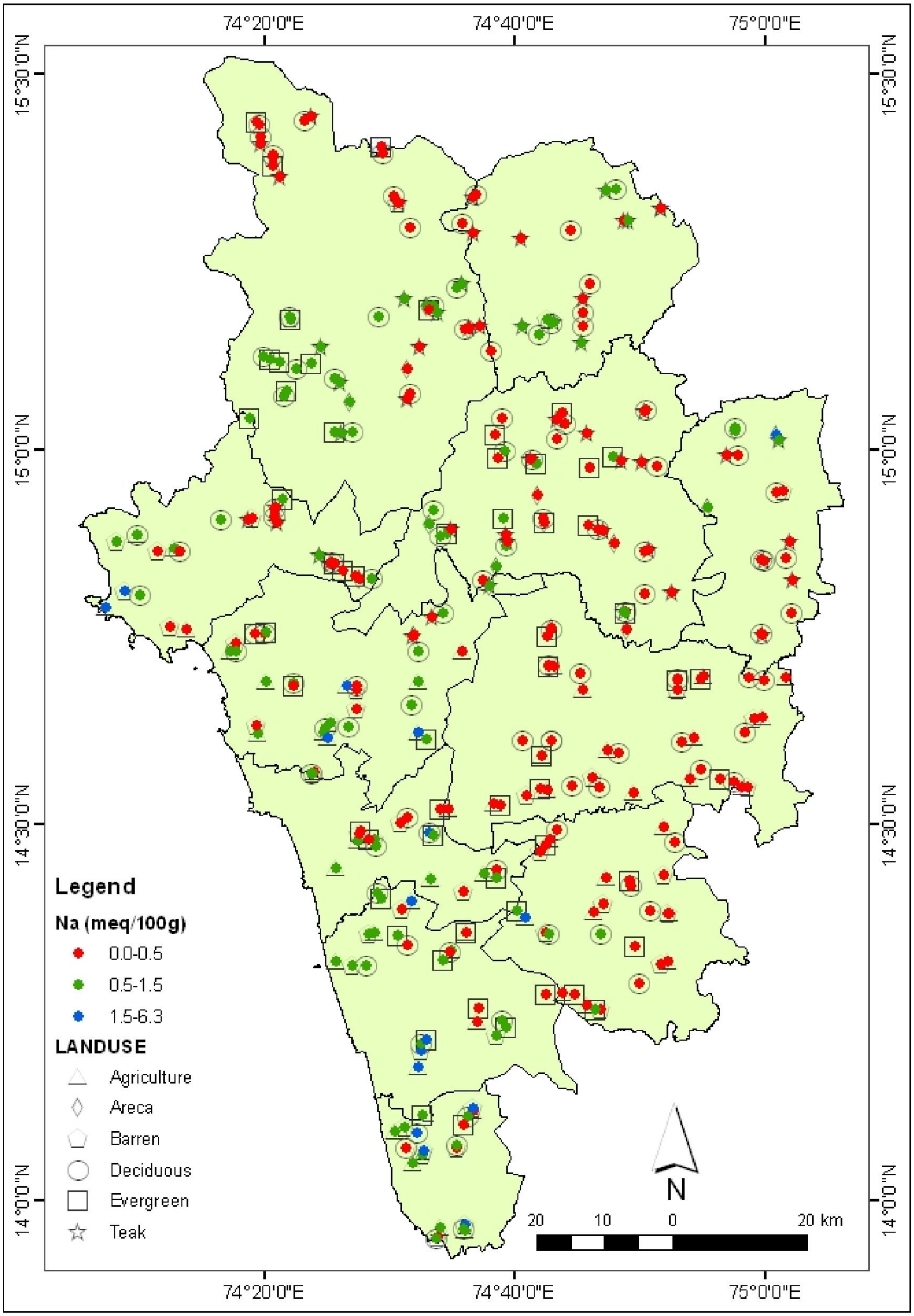


Fig 11: Sodium across different land-use types in Uttar Kannada district

Soil sodium ranged from 0.05 to 2.69 meq/100gm in agricultural soils, while it ranged from 0.08 to 6.3 meq/100gm in barren/ pastures. In deciduous soils it ranged from 0.05 to 4.27 meq/100gm, while in evergreen it was 0.14 to 1.63 meq/100gm. In teak plantation it was ranging from 0.09 to 1.36 meq/100gm, while in Arecanut it ranged from 0.03 to 1.61 meq/100gm. Though there was no significant variation among the sodium in the various land use types, it is highest under barren followed by agriculture, Arecanut, deciduous, evergreen and teak. Sodium is one of the important cation, which is responsible for osmotic balance and cell cationic charges in vegetation (**Miller, 1990**). Barren soils have highest sodium than all other tree based land uses like Arecanut, evergreen, deciduous and teak. The reasons for the higher sodium content in barren are unknown. Irrigation water can be responsible for higher sodium in soil in case of agriculture and Arecanut. In a study conducted by **Adejuwon and Ekanade** (**1988**), sodium was found to be highest in the natural forest then followed by fallow, and cultivated soils.

Although the dynamics of soil sodium are not clearly understood, without other cationic bases, the natural forests seem to have lesser sodium than the human influenced systems.

Calcium

	Agriculture n=54	Barren n=45	Deciduous n=108	Evergreen n=63	Teak n=53	Areca n=17
Min	2.0	0.1	0.2	0.2	2.1	2
Max	14.9	5	40.4	12.5	24	14.9
Avg± Std.Dev	0.62±0.4	0.94±1.2	4.94±5.7	3.36±3.4	7.66±4.2	6.68±3.2

Pair wise Wilcox Test

	Areca	Agriculture	Barren	Deciduous	Evergreen
Agriculture	S				
Barren	S	NS			
Deciduous	NS	S	S		
Evergreen	S	S	S	NS	
Teak	NS	S	S	S	S

p<0.001; S=significant; NS=non-significant

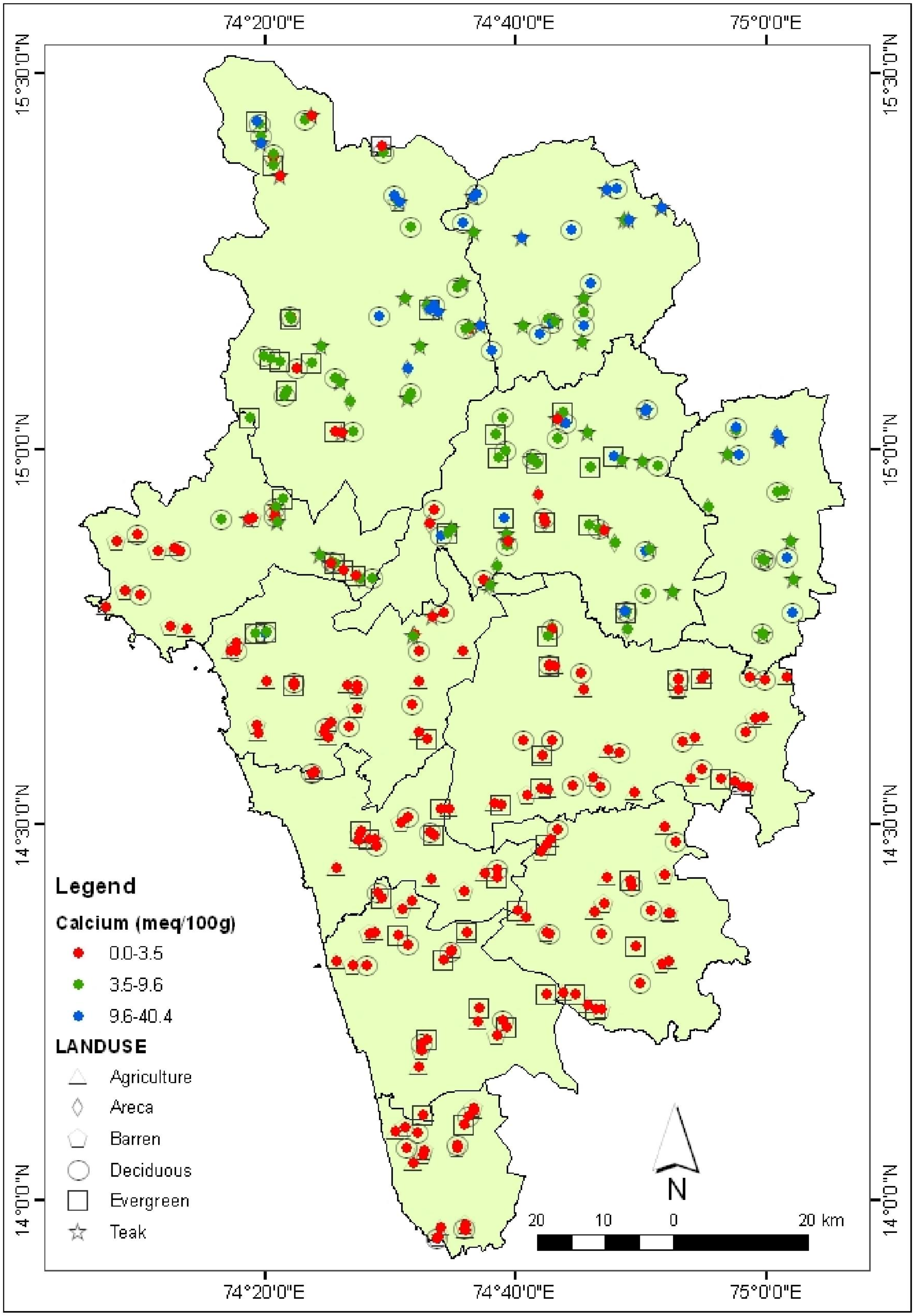
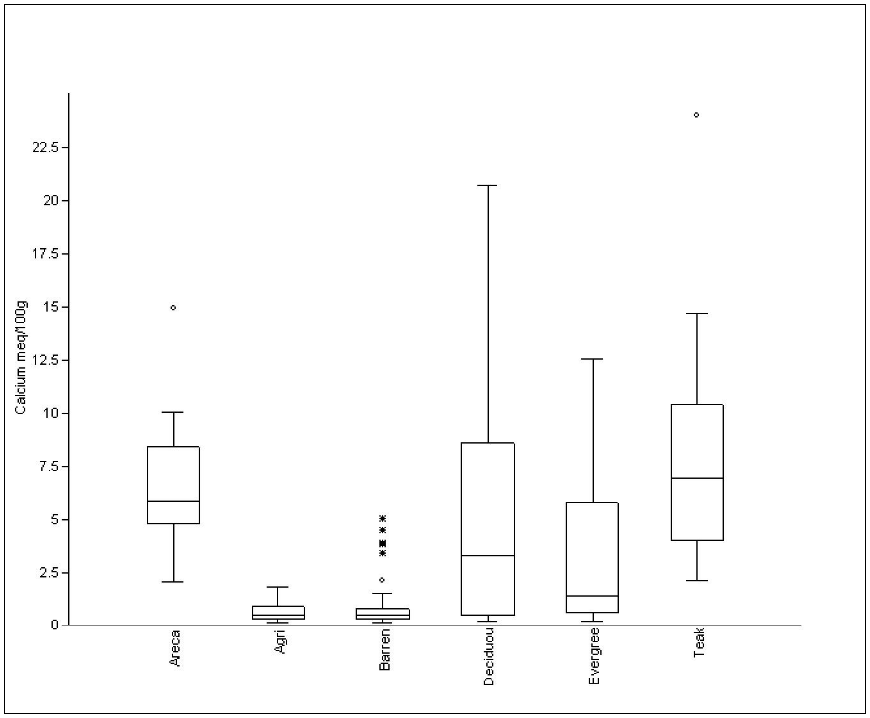


Fig 12: Calcium across different land-use types in Uttar Kannada district



It was found that calcium levels are higher in the land use types which are under tree based systems. Lower amounts of calcium was found in agricultural (0.62±0.4) and barren (0.94±1.2) soils, which can be due to exposure of these lands to heavy rain, which may cause leaching of the bases. Studies have found that repeated harvesting results in significant losses of soil Ca because Ca rich woody biomass is removed from the site (**Brouwer and Riezebos 1998**). Studies have also shown that increased organic matter mineralization and decreased plant uptake may increase soil availability of base cations such as Ca and Mg, for substantial periods (**McNabb and others 1997).** Decomposition of foliage is a major factor for higher level of base cation availability in soils. Hence litter fall in the forest systems may be playing a vital role for elevated Ca concentrations than that compared to that in barren and agricultural landscapes. Activity of mulching and adding ash to the soils in Arecanut gardens may be responsible for the higher Ca levels. When base rich ash is incorporated into the soil, H^+ ions are dissociated from the exchange complex, which increases the capacity of soil to retain and exchange base cations (**Brady and Weil 1999**).

According to **Bourgeon (1989)** the total exchangeable bases in the Western Ghats region is 0.2 meq/100gm (Ca+ Mg+ Na+ K). The reason behind this appears to be the parent material found in this region. It is indicated from the map that soil calcium is lower in the coastal talukes while it is higher in the talukes such as Mundgod, Yellapur, Supa and Haliyal, which form part of the semi arid Karnataka plateau.

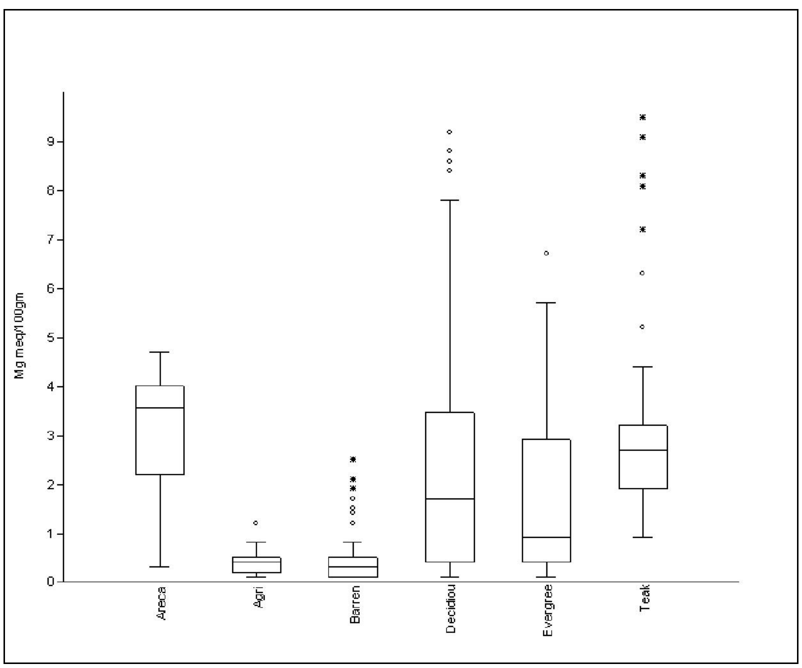
Magnesium

	Agriculture n=54	Barren n=45	Deciduous n=108	Evergreen n=63	Teak n=53	Areca n=17
Min	0.1	0.1	0.1	0.1	0.9	0.3
Max	1.2	2.5	13.8	11.6	13.4	4.7
Avg. ± Std.Dev	0.37±0.2	0.5±0.6	2.4±2.6	2.0±2.3	3.3±2.4	3±1.4

Pair wise Wilcox Test

	Areca	Agriculture	Barren	Deciduous	Evergreen
Agriculture	S***				
Barren	S***	NS			
Deciduous	NS	S***	S***		
Evergreen	NS	S***	S***	NS	
Teak	NS	S***	S***	S**	S***

*p<0.05, **p<0.01, ***p<0.001; S=significant; NS=non-significant



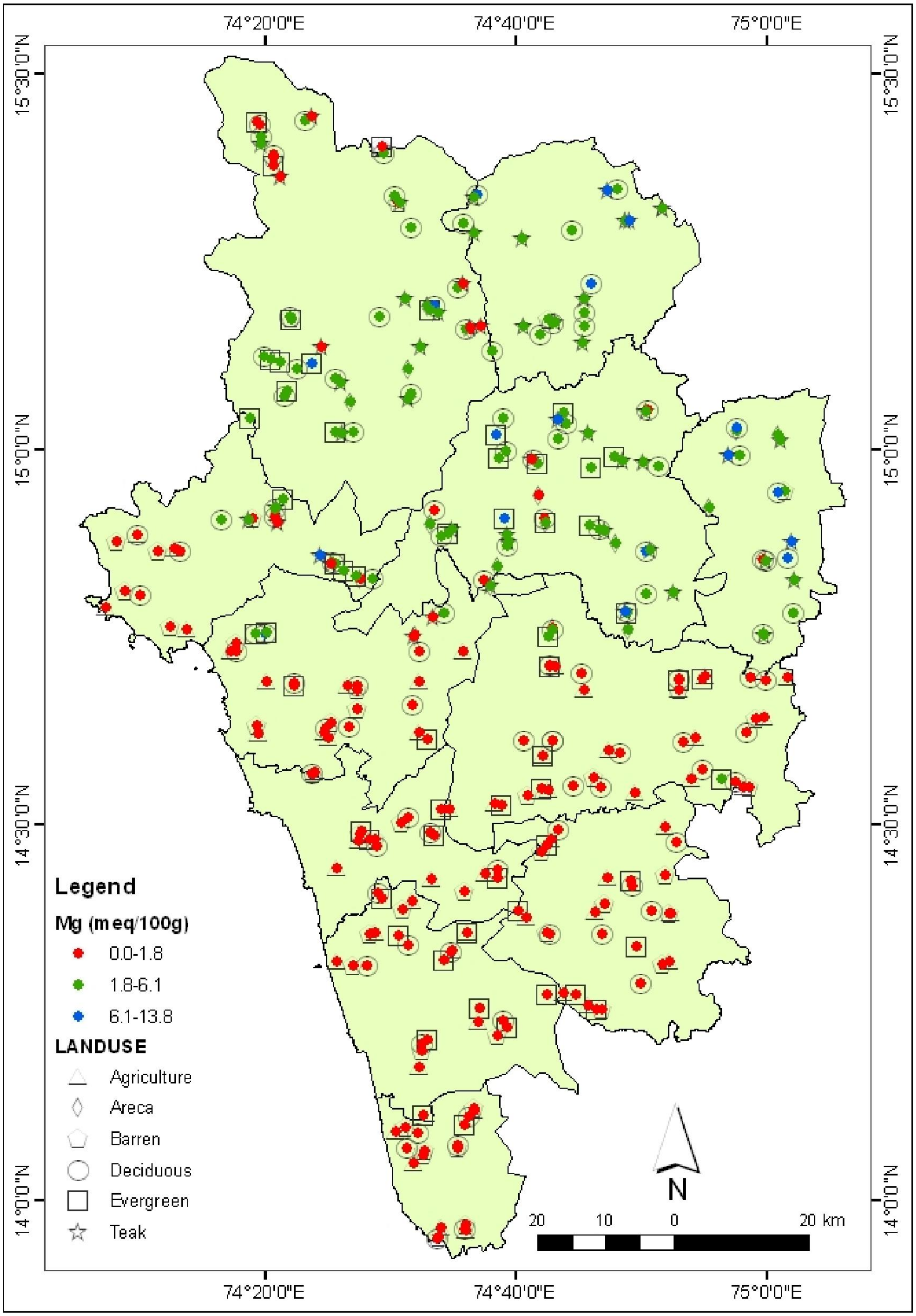


Fig 13: Magnesium across different land-use types in Uttar Kannada district

There is significant variation among mg of Arecanut (3±1.4) and that of agriculture (0.37±0.2) and barren. Barren (0.5±0.6) and agriculture lands had the lowest magnesium levels indicating degradation of soil. Magnesium in agriculture (0.37±0.2) varied immensely from that in the evergreen (2.0±2.3), deciduous (2.4±2.6) and teak plantations. Teak (3.3±2.4) plantations too had lower Mg levels compared to evergreen (2.0±2.3) and deciduous (2.4±2.6) land use types. Leaf litter plays a vital role in cycling of most of the nutrients in the soil. Substantial amounts of magnesium in evergreen and deciduous suggest that decomposition of leaf litter, which leads to increased organic matter mineralization, may be responsible of maintaining the levels of exchangeable bases in the soils.

Soil texture

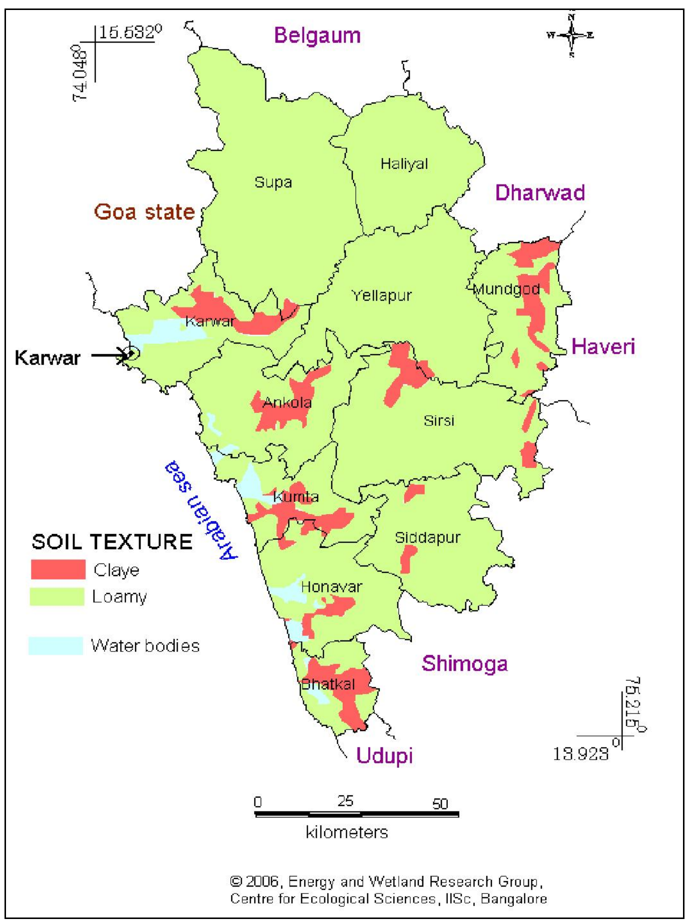


Fig 13: Soil Texture in Uttar Kannada district

About twelve different patterns of soils were identified in the current study context. Agricultural soils ranges from clay, clay loam and loamy while barren/pasture land showed sandy loam, sandy clay and clayey loam. Agricultural soils have more clay content due to continuous disturbance caused by agricultural practices like ploughing. However, agricultural and barren/pasture shows more or less similar soil patterns except few exceptions. Deciduous vegetation has the entire soil pattern except the clay loam and clay. The majority of the evergreen soils are sandy loam due to low disturbance. Most coastal districts showed sandy loam and sandy soil types. Talukes like Bhatkal, Mundgod, Karwar Ankola and Kumta had higher percentages of clayey soil types.

Conclusion

Soil carbon sequestration plays an important role in global carbon cycle. Increasing green house gases had lead to emphasis on carbon sequestration into various forms around the globe. The top one metre of soil contains 1500 Gt C (**Johnson and Henderson 1995**) and small relative fluxes into and out of this pool can amount to large fluxes on a global scale. Soil carbon is significantly lower in human altered landscapes compared to natural systems like evergreen and deciduous. There is a considerable concern that land use change, in particular may lead to depletion of soil carbon and consequent increase in atmospheric CO^2 **(IPCC, 1997; Bruce et al. 1999).** This leads to a major concern about soil carbon status in agricultural or human influenced land use systems in the Western Ghats. Soil carbon is an important indicator of soil health.

Soil pH is mostly acidic throughout the district which may be due to the parent material i.e. laterite, granite and gneiss. Slightly neutral soil pH was found in the talukes of Haliyal, Mundgod, Yellapur; which may be due to the Dharwar schist's which is predominant in the region. It was found that soil bulk density was higher in case of agricultural soils than that in other natural land use systems like evergreen, deciduous forest. Bulk density is a function of soil water holding capacity. It has an inverse relationship with porosity. When the forest are cleared for pastures and agricultural purposes, soil aggregates break down due to activities such as tilling leading to compaction of soil, which influences the soil porosity. Such soils have poor soil moisture content which invariably affects the cation exchange capacity in such soils. Significantly lower amount of nitrogen were found in agricultural and barren soils which may be due to leaching out of soil nitrogen sue to physical forces such are runoff and soil erosion. The leaf litter contributes as a major source of soil nitrogen in the natural forests. In agricultural systems soil uptake of nutrients is not compensated by replenishing soil with organic mater from leaf litter **(Adejuwon and Ekanade, 1988)**.

Arecanut plantations with good land management practices have relatively good soil quality. Various practices like drip irrigation, organic mulching and addition of ash are responsible for maintenance of soil properties. Available Phosphorus, calcium, available potassium were found to be higher in this land use type compared to all others.

Amongst the exchangeable bases, available K, calcium and magnesium were significantly lower in agricultural soils than that compared to other land use forms. Soil properties in monoculture plantations (acacia, etc.) are comparable to the natural evergreen and deciduous forest.

The soil quality of barren lands was found to be poor as compared to natural forest systems. Soil carbon and nitrogen are degraded, which is a matter of concern. Apart from looking at these lands just as pasture lands it is necessary to address the current grave conditions facing such lands which are in quite a large number in the entire district. The degradation of soil due to various anthropogenic activities has affected the endemic species, and also hydrologic regime in the ecologically sensitive Western Ghats, a global biodiversity hotspot, evident from earlier studies (**Ali et al. 2007).** The study informs a major concern regarding agricultural soil quality which is seen to be degrading rapidly compared to the optimal situations which are assumed to be the natural forest systems. In order to improve the life of the soil and to utilize it for longer time for agricultural purposes there is a need of devising proper management plans which will help sustainable use of these lands in future.

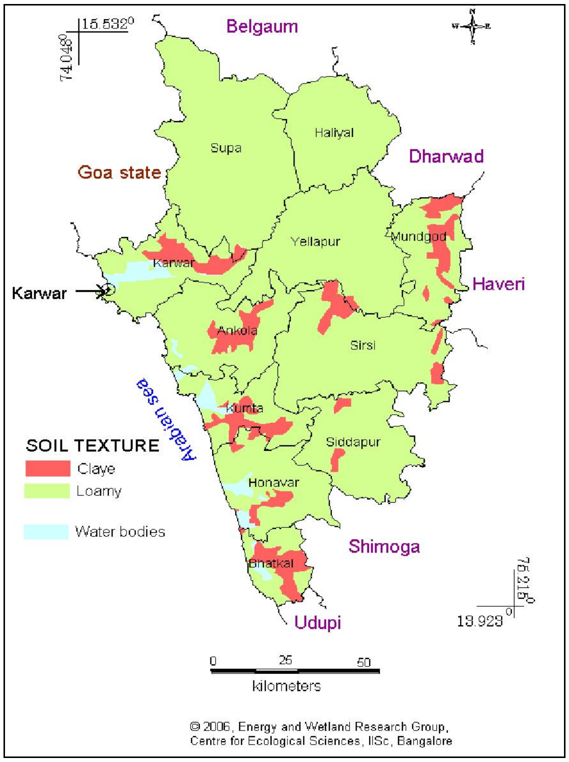
References:

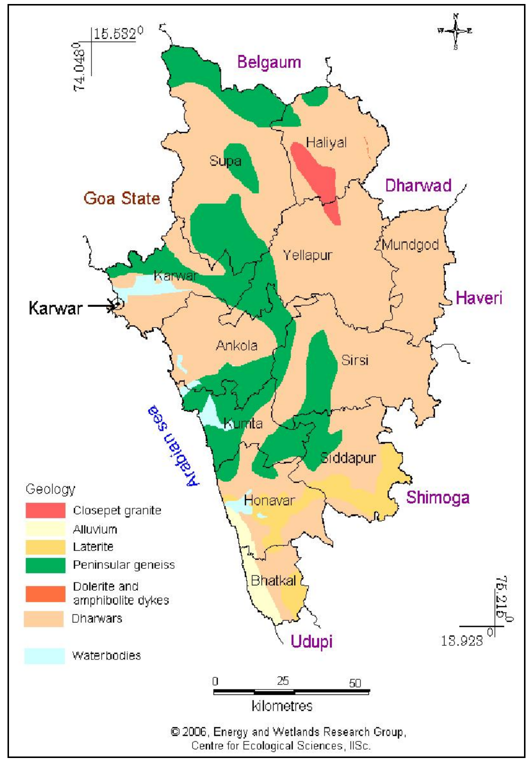
1. Adejuwon, J.O. and Ekanade O, 1988, A comparison of soil properties under different land use types in a part of the Nigerian Cocoa belt, Catena, vol.15, p.319-331
2. Arora, R.K.1961, The forests of Northern Canara district. Journal of Indian Botanical society, 40(2), 187-200.
3. Baruah, T.C. and Barthakur, H.P., 1997, A textbook of soil analysis, Vikas publishing house pvt Ltd. New Delhi.
4. Bertrand, R., Falipou, P., Legros, J.P. 1982.-S.T.I.P.A., 1.-Notice pour lentree des description et analyses de sols en banque de donnees. ACCT, Paris.
5. Bhatt, D.M. and Gadgil, M, 1987. Above ground herb productivity under different land use system in Uttara Kannada district of Karnataka. CES technical report
6. Bhatt.D.M, Murali.K.S, Ravindranath N.H. 2002. Carbon stocks dtnamics in tropical rain forests of Uttara Kannada district, Western Ghats, Inda. CES Techinical report no: 96
7. Bojie F, Chen L, Ma K, Zhou H, Wang J, 2000, The relationships between land use and soil conditions in the hilly area of the loess plateau in northern Shaanxi, China; Catena, vol.39, p.69-78
8. Bourgeon, G. 1989. Explanatory booklet on the reconnaissance soil map of forest area, Western Karnataka and Goa. Institut Francais De. Pondichery.
9. Brady, N.C, 1984. The nature and property of soils. Collier Macmillan Publishers. London.
10. Bray, R. H and Kurtz, L. T. 1945. Determination of total, organic and available forms of phosphrous in soils. *Soil Sci*. 59 : 39-45
11. Bruce JP, Frome M, Haites E, Janzen H, Lal R, Paustian K, 1999, Carbon Sequestration in Soils, Journal of Soil and Water Conservation, 54, 382-389
12. Caravaca, F., Masciandaro, G. Ceccanti, B. 2002. Land use in relation to soil chemical and biochemical properties in a semiarid Mediterranean environment. *Soil & Tillage Research*, 68, pp. 23-30.
13. Chandran, M.D.S. 1984. Ecosystem studies and management in Uttara Kannada District. CES Technical report 3

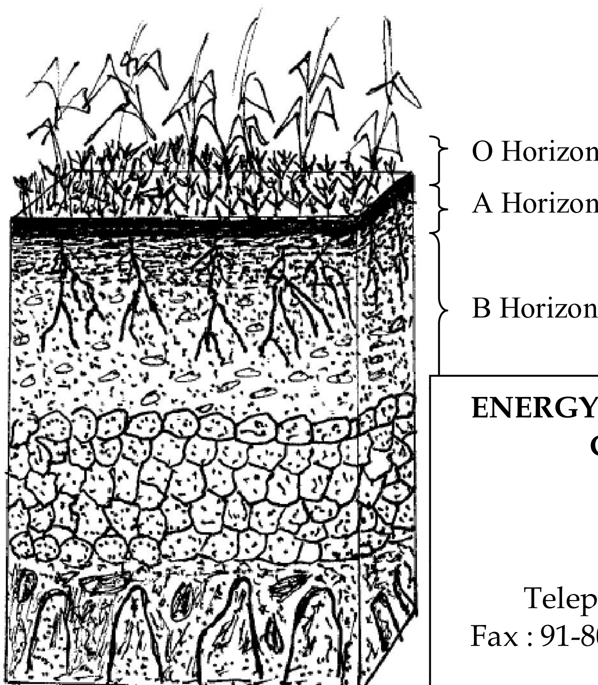
14. Chandran, M.D.S. 1997. On the ecological history of the Western Ghats. *Current science*, 73(2), pp-146-155
15. Dinakaran, J. Krishnayya N. S. R. 2008. Variations in type of vegetal cover and heterogeneity of soil organic carbon in affecting sink capacity of tropical soils. *Current science*, 94,(9), pp. 1144-1150.
16. Fallou, F.A. 1862: pedilogie oder allgemeine und besendere Bodenkunde.Dresden
17. Fernandes, D. N. & Sanford, Robert L., J. (1995), Effects of Recent Land-Use Practices on Soil Nutrients and Succession under Tropical Wet Forest in Costa Rica, *Conservation Biology* 9(4), 915 - 922.
18. Houghton R.A.1994. The World wide extent of land use change *Bioscience* 44: 305-313
19. Houghton R.A.1999, Annual net flux of Carbon to the atmosphere from changes in land use 1850-1990, Tell Us, 51B, 298-313
20. IPCC, 1997, Guidelines for National Greenhouse Gas inventories, Vol 3; IPCC, Meteorological Office, Bracknell, UK
21. Islam, K.R., Kamaluddin, M., Bhuiyan, M.K. and Badruddin, Abu., 1999. Comparative performance of exotic and indigenous forest species for tropical semi-evergreen degraded forest land reforestation in Bangladesh. *Land Degrad. Dev.* 10, pp. 241–249.
22. Islam K.R and Weil R.R, 2000, Land use effects on soil quality in a tropical forest ecosystem of Bangladesh, Agriculture, Ecosystems & Environment 79 (1), pp. 9–16
23. Kamath, U.S. 1985.Karnataka state Gazetteer-Uttara Kannada District. V.B Subbaiah & sons. Banglore.
24. Kang, B.T., Juo, A.S.R., 1986. Effect of forest clearing on soil chemical properties and crop performance. In: Lal, R., Sanchez, P.A., Cummings, Jr., R.W. (Eds.), Land Clearing and Development in the Tropics. Belkema, Rotterdam, pp. 383–394
25. Malcolm E.Sumner, 1999. Hand book of soil sciences. CRC press. Washington, D.C

26. McGrath, D.A., Smith, C.K, Gholz, H.L, Oliveira, F.A. 2001. Effect of land-use change on soil nutrient dynamics in Amazonia. *Ecosystems*. 4(7), pp. 625-645.
27. Meyers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A and Kent, J. Biodiversity hot spots for conservation priorities. Nature, 2000, 403, 853-858.
28. Miller, R.W., Donahue, R.L. 1990. Soils: An introduction to soils and plant growth. Prentic-hall, USA.
29. Moen, J.E.T 1988. Soil protection in The Netherlands. Kluwer Academic Publishers, Dordrecht, Netherlands. p. 1495-1503
30. Murty D, Kirschbaum M.U.F, Macmurtrie R.E, McGilvray H, 2002, Does conversion of forest to agricultural land change soil carbon and nitrogen? A review of the literature, Global Change Biology, 8, p.105-123
31. Nardi S., Concheri G., Dell'Agnola G., 1996, Biological activity of humus. In. Piccolo, A. (Ed.), Humic Substances in Terrestrial Ecosystems. Elsevier, New York, pp. 361–406.
32. Ojima D.S., Galvin K.A, and Turner B.L., 1994. The Global Impact of Land-use Change. *Biosciences* 44: 300-303.
33. Osher, L.J., Matson, P.A, Amundson, R. 2003. Effect of land use on soil carbon in Hawaii. *Biogeochemistry*. 65(2), pp. 213-232.
34. Powers, J.S. 2004. Changes in soil Carbon and Nitrogen after constrasting land-use transition in North Eastern Costa Rica. *Ecosystems*, 7(2), pp. 134-146.
35. Ramachandra, T.V. and Kumar, R. (year). water, soil and sediment investigation to explore status of Saravathi river basin, Western Ghats. (publication not known)
36. Ramachandra, T.V., Subramanian, D.K., and Joshi, N.V. 1999. Hydroelectric resource assessment in Uttara Kannada district, Karnatakas state India, *Journal of cleaner production* 7 pp 195-211.
37. Rhoades, C.C. Eckert, G.E. Coleman, D.C. 2000. Soil carbon difference among forest, agricultural and secondary vegetation in lower Montane Ecuador. *Ecological Applications*, 10, (2), pp. 497- 506.
38. Schwartzenbach, G., Biedermann, W. and Bangerter, F. 1946.Komplexone VI. Neueeinfache titriermethoden zur Bestimmung der Wasserharte. *Helv. Chim.Acta 29*: 811-818.

39. Sheppard,S.C., C.Gaudet, M,I Sheppard, P.M Cureton, and M.P.Wong. 1992. The development of assessment and remediation guidelines for contaminated soils, review of the science. Can. J. *Soil sci.*45: 257-268.
40. Silver, W.L. Neff, J. McGroddy, M. Veldkamp, E. Keller, M. Cosme, R. 2000. Effect of soil texture on below ground carbon and nutrient storage in lowland Amazonian forest ecosystem. *Ecosystems*, 3(2), pp. 193-209.
41. Sreekantha., Chandran, M.D.S., Mesta, D.K., Rao, G.R., Gururaja, K.V and Ramachandra, T.V. 2007. Fish diversity in relation to landscape and vegetation in Central Western Ghats, India. *Current Science*, 92(11), pp 1592-1603.
42. Stebutt, A. 1930: Lehrbuch der allgemeinen Bodenkunde.Berlin
43. Stewart E.Allen.1989. Chemical analysis of ecological materials. Blackwell scientific publications. United Kingdom.
44. Swamy, H. R. 1994. Rain forests and their soils in the Sringeri area of Indian Western Ghats. *Global Ecology and Biogeography Letters*, 4(5), pp. 140-154.
45. Tomer, M. 1999. Quality assessment of water and waste water, Lewis publication, United States of America. 85-88.
46. Tomer, M. 1999. Quality assessment of water and waste water, Lewis publication, United States of America. 85-88.
47. Wick, B., Tiessen, H. Menezes, S.C. 2000. Land quality changes following the conversion of the natural vegetation into silvo-pastoral systems in semi-arid NE Brazil. *Plant and soil science*, 222, pp. 59-70
48. Wilde.S.A, 1946. Forest soils and forest growth. Chronica Botanica Company. USA.
49. Zhongl, L. Qiguo, Z. 2001. Organic carbon content and distribution in soils under different land uses in tropical and subtropical China. *Plant and Soil*. 231, pp. 175–185.







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