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Nutrient status of soils in *kans* and non- *kans* of central Western Ghats

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Abstract– Soil samples collected during monsoon, post-monsoon and pre-monsoon seasons from different *kans* and non- *kans* of Central Western Ghats namely Yaana, Vibuthi, Torme, Kathlekan, Hulkodu, Baruru and Hosagunda were analysed to understand the seasonal variations in soil quality of the select regions. Quality of soil samples showed marked seasonal variations. The un-disturbed forest at Hulkod had highest nutrient content (total carbon and total nitrogen) due to the presence of thick vegetation. Wide variations in pH, nutrient and ionic contents were observed in highly disturbed areas compared to un-disturbed areas. Among *kans*, VF7 had highest TN content and pH in monsoon. KK5F2 had highest BD while HulF2 had highest TC (pre-monsoon). Among non-*kans*, KKNKF had highest moisture content, TC and TN (monsoon), highest pH (pre-monsoon) and lowest BD (monsoon). The soil samples showed different patterns due to difference in soil type, land use, rainfall etc.

Key word– *Soil, Forest, Nutrients, Central Western Ghats.*

INTRODUCTION

Soil is an important source of essential elements for plants and provides habitats, controls and regulates biogeochemical cycles, helps in biomass production and maintains biodiversity, supports valuable ecosystem services etc. Accelerated erosion, over-cultivation, inadequate recycling of nutrients, accumulation of salinity, acidic deposition and additions of toxic materials (from wastes as well as agricultural chemicals) are major anthropogenic threats to soil quality (Hoque et al., 2008). Variation in quality of surface soil leads to changes in vegetation. The physical properties of soil also alter the natural distribution, growth and biomass production of plants. Soil structure regulates pore size, number and distribution of pores and total porosity of the soil. Thus, the water holding capacity of soil also varies with soil structure. Movement of soil water described by infiltration, permeability, percolation, drainage, leaching, etc. all depend on soil structure(Osman, 2013). Bulk density depends on soil texture, the percentage composition of sand, silt, and clay and their packing arrangement and organic matter. Soil having high bulk density has poor organic content. Soil organic carbon determines the chemical, physical and biological health of soil samples and helps in assessment of the productivity and fertility of soil (Vashum et al., 2016). Soil organic matter consists of un-humified substances (organic substances including carbohydrates, proteins, fats and waxes) and the humified remains of plant and animal tissues (Stevenson, 1986). Plant tissues (above and below ground litter) are the main source of soil organic matter. Organic matter in soil enhances soil productivity by increasing its nutrient content and water holding capacity, stabilizes soil structure against compaction and prevents soil erosion. Compaction usually increases bulk density, reduces total pore volume causing a reduction in the water holding capacity. Thus, bulk density affects water holding capacity, movement of air and water through soil as well as root growth of plants. The rate of loss of organic matter is greatly influenced by soil temperature, aeration and availability of water. In forest ecosystems, litterfall and litter decomposition plays a crucial role in bio-geochemical cycles and also determines the productivity of forest ecosystems which in turn depends on and varies with environmental conditions, litter quality and soil biota (Kumar et al., 2012). Soil C content mostly depends on variability in season, climate, type of soil, vegetation and land use pattern (Venkanna et al., 2014). Dissolved organic carbon (DOC) consisting of organic compounds, including fulvic and humic acids are derived from root exudates, microbial biomass and the decomposition of plant litter and soil organic matter (Liu et al., 2014).

Biochemical processes like ammonification, nitrification, denitrification and assimilation are responsible for many of the transformations that occur within the soil (Stevenson, 1986). Soil microbial biomass is an important ecological indicator and acts as a source and sink of available nutrient for plant growth (Adeboye et al., 2011). Soil microorganisms play an important role as decomposers are actively involved in organic matter decomposition, nutrient cycling (C, N, P, S), transformation, mineralization (conversion of C, N, P and S to mineral forms) etc. (Haripal and Sahoo, 2014). In swampy habitats, water logged condition causes high losses of nitrogen through leaching

(Vijayakumar and Vasudeva, 2011). The variations in climate, topography, weathering processes, abiotic and biotic factors including microbial activities, land use as well as vegetation cover affect the physico-chemical characteristics of forest soils. Usually, physical and chemical analysis of the soil is carried out to test the efficiency of soil, assess its nutrient availability (for plant growth) as well as identification of the factors affecting soil efficiency and productivity. The results of physico-chemical analysis can be used as a base data for adopting measures to improve soil quality. The physico-chemical parameters analyzed for soil samples were bulk density, moisture content, pH, acidity, alkalinity, electrical conductivity, chloride, sulphate, phosphate, nitrate, sodium, potassium, calcium, magnesium, organic matter, organic carbon and lime requirement (Ramachandra et al., 2012).

The Western Ghat mountains host varied range of forest categories including evergreen to dry deciduous forests, semi-deciduous, swamp areas and sacred groves providing varied ecosystem services (Ray et al., 2015). Forest ecosystems play a crucial role in global carbon cycling acting as sink and source (Mohanraj et al., 2011). The variations in soil quality of different forests in Uttara Kannada depend on soil type, climatic conditions and landscape elements (Saira et al., 2012). The main objective of the study is to assess the soil quality across diverse landscapes of *kan* and non-*kan* forests in the Central Western Ghats and to understand the seasonal variations in soil quality of the select regions.

MATERIALS AND METHODS

Study Area: Soil samples were collected from different *kans* and non- *kans* of Yaana, Vibuthi, Torme, Kathlekan, Hulkodu, Baruru and Hosagunda belonging to Central Western Ghats (figure 1 and table 1)

Sl. No.	Sampling sites	Number and code of sampling sites in brackets	Land use
1	Vibuthi *kan*	2 (VF7, VF4/5)	Evergreen to semi-evergreen forest
2	Mabgi	1 (VNKF)	Evergreen Forest; Moist – dry deciduous forests
3	Yaana	1 (YKF1)	Evergreen to semi evergreen forest
4	Nanalli	1 (YNKF1)	Evergreen to semi evergreen forest
5	Kathale*kan*	2 (KK2F1, KK5F2)	Evergreen forest
6	Kodkani	1 (KKNKF)	Evergreen forests and agricultural fields
7	Torme	1 (TKF3)	Evergreen forest
8	Kanalli	1 (TNKF1)	Evergreen forest with arecanut and paddy fields
9	Hulkodu	1 (HulF2)	Swampy and evergreen forest
10	Pandavarakodlu	1 (PKF2)	Swampy and evergreen forest
11	Hosagunda *kan*	1 (HSKF2)	Evergreen forest
12	Hosagunda non-*kan*	1 (HSNKF2)	Evergreen forest
13	Baruru lake	1 (BKF1)	Evergreen forest
14	Lavigere	1 (BNKF1)	Mixed type with semi evergreen to deciduous forest patches, with agriculture and horticulture.

Table 1: Soil sampling area and its land use type in Central Western Ghats.

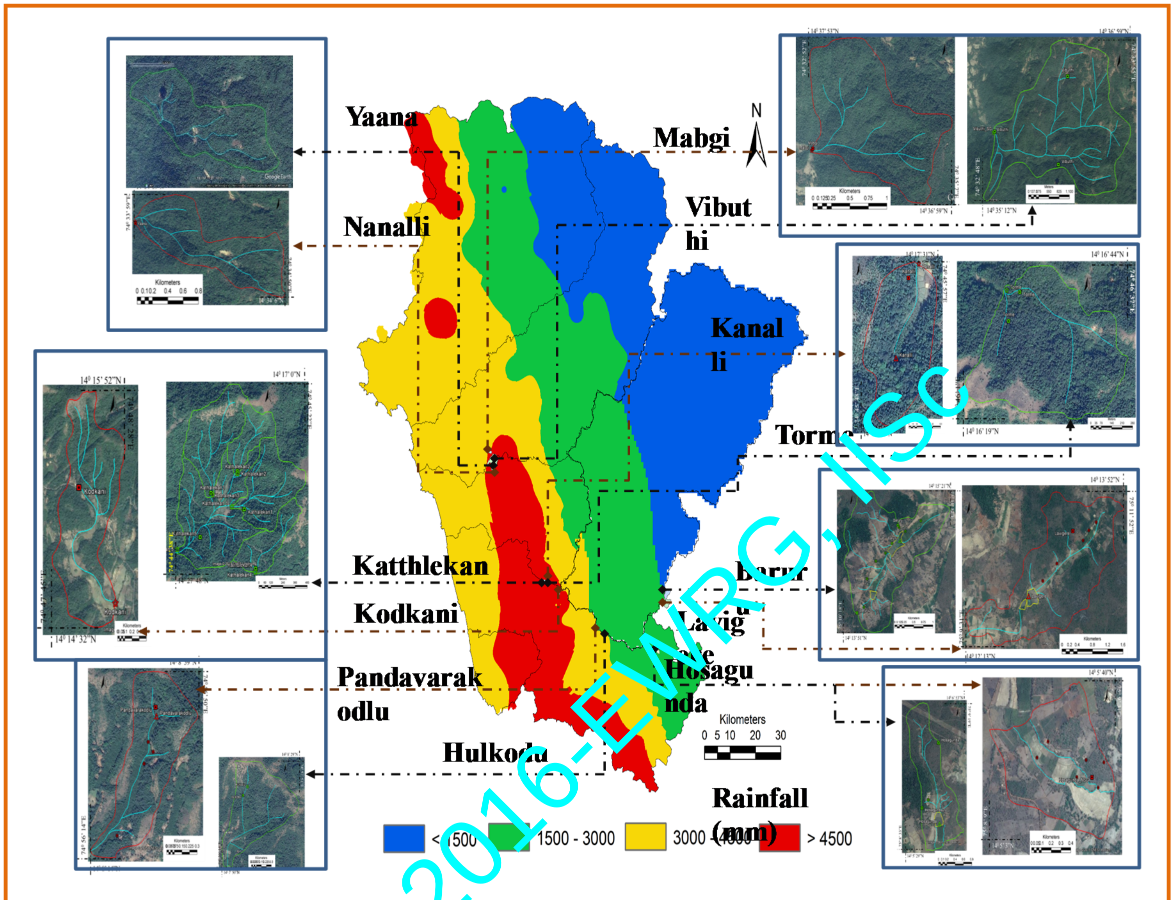


Figure 1: Study area

SOIL QUALITY ANALYSIS

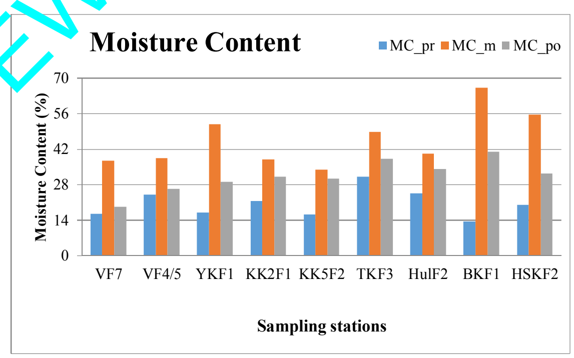
Soil Sample Collection and Analysis: Soil samples were collected with a soil augur so as to get undisturbed pedon of soil and then transferred into air tight polythene bags. Bulk density can be determined by the core method. Standard stainless steel cores with sharp edges may be used. The cores are pushed into soil with the help of a wooden hammer without disturbing its natural structure. After collection, soil is dried in an oven at 105°C for 24 hours and the dry weight of the soil is divided by the volume of the core to obtain bulk density. The soil moisture content was determined by oven drying the soil at 105°C for 24 hours and expressed in g% (w/w). Soils were air dried in the laboratory and sieved with the help of 2 mm mesh. The sieved soil samples were analyzed in the laboratory to study the physico-chemical characteristics of soil. Soil pH was measured using the pH meter dipped in a soil-water ratio of 1:2.5 (w/v). The total carbon and total nitrogen in the soil samples were measured via a dry combustion technique using a CHN Analyser TruSpec.

RESULTS AND DISCUSSION

Soil plays a decisive role in species pattern, distribution and nutrients in soil. The soils in different forest types have different characteristics. Variations in physico – chemical properties of soils are caused due to changes in rainfall, temperature and vegetation type (Vishnu et al., 2017). The variations in moisture content, bulk density, total carbon, total nitrogen and pH of different *kans* and non-*kans* are depicted in figure 2.

Moisture content: Soil moisture is a key mediator between land surface and atmospheric interactions. Soil moisture levels vary with the rainfall pattern, movement of water in and out of the layer and during root uptake (Venkatesh et al., 2011). In this study, among *kans*, Moisture content in pre-monsoon, monsoon and post-monsoon ranged from 13.5 – 31.2 %, 33.9 - 66.3% and 19.2 - 41.1% respectively. Among non-*kans*, Moisture content in pre-monsoon, monsoon and post-monsoon ranged from 4.5 – 25.3 %, 18.7 – 44.9 % and 16 – 28.2 % respectively. Ram et al., 2015 found that soil moisture was highest in the rainy season (23.81% to 26.08 %) and it decreased in summer (6.04% to 17.38%).

Bulk density: Bulk density (BD) is ratio of the mass (oven-dry weight) of the soil to the bulk volume expressed in grams per cubic centimeters (g/cc), which includes the volume of both solids and pore space at a specified soil water content. Bulk density is dependent on and varies with soil organic matter, soil texture, the number of pores present, the density of soil mineral (sand, silt and clay) and their packing arrangement. Loose soils have lower bulk densities whereas compact soils have higher bulk densities. Coarse textured or sandy soils tend to have a higher bulk density (Osman, 2013). Changes in soil bulk density affect several other properties and processes that influence water and oxygen supply (Schoenholtz et al., 2000). Among *kans*, Bulk density in pre-monsoon, monsoon and post-monsoon ranged from 0.93 – 1.44 g/cc, 0.71 – 1.15 g/cc and 0.72 – 1.31 g/cc respectively. Among non-*kans*, Bulk density in pre-monsoon, monsoon and post-monsoon ranged from 1.18 – 1.77 g/cc, 0.79 – 1.25 g/cc and 1.14 – 1.47 g/cc respectively. The pre-monsoon season had highest soil bulk density among both *kans* and non-*kans* due to less moisture as well as organic content with less decomposition activity. The addition of minute quantity of organic material to soil can affect its bulk density (Asok and Sobha, 2014). A reverse correlation existed between organic matter and bulk density of soil (Chaudhari et al., 2013).



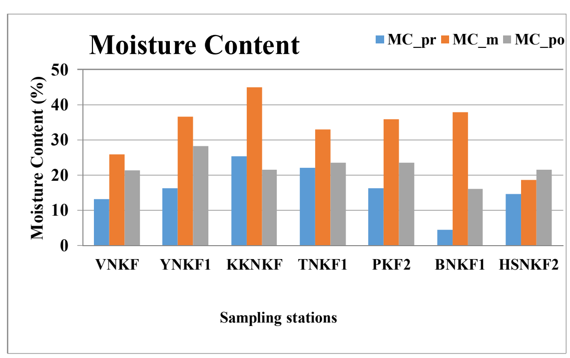


Figure 2: Variations in physico-chemical characteristics of soils in various *kans* and non-*kans*

Nutrients in soil: Organic matter contains the essential elements like nitrogen, phosphorus and sulphur in complex forms which cannot be taken up by the plant. These compounds are decomposed by micro-organisms to simpler forms for example, the nitrogenous compounds are converted to ammonium or nitrate forms, phosphorus compounds to available phosphates and sulphur compounds to sulphate through mineralization (Simpson, 1983).

Total carbon (TC): Soil carbon pool comprises of two components: soil organic carbon (SOC) and soil inorganic carbon (SIC). The SOC pool consists of fertile humus to inert charcoal C. SIC pool includes elemental C and carbonate minerals (e.g. dolomite, gypsum, aragonite, calcite and siderite) (Venkanna et al., 2014). Soil organic carbon constitutes a major pool of carbon within the biosphere (Vashum and S. Jayakumar, 2014). Monsoon season had comparatively higher total carbon than pre-monsoon and post-monsoon season. Total carbon in *kans* in pre-monsoon, monsoon and post-monsoon ranged from 0.6 – 10.85 %, 1.01 – 8.45 % and 2.53 – 5.89 % respectively. Among non-*kans*, total carbon in pre-monsoon, monsoon and post-monsoon ranged from 1.95 – 6.03 %, 0.18 – 6.31 % and 2.73 – 5.63 % respectively. Organic carbon was recorded highest in rainy season as the decomposition of leaf litter and release of nutrients into the soil occurs at faster rate (Chaudhary et al., 2016). The organic carbon content of forest soil varied from 1.71 to 12.59 %. Total carbon stock distribution in Kolli forests, Eastern Ghats (India) varied in the following order: deciduous > mixed > evergreen > open scrub > plantation (Mohanraj et al., 2011).

Total nitrogen (TN): Nitrogen is the most critical element for plant growth as it increases protein content, improves quality and allows rapid growth of plants. Nitrogen exists in soils in organic and inorganic forms, and is present in several oxidation states, from -3 to +6 (Tan, 1994). Nitrogen materializes in soils by microbial activity, nitrogen fixation and addition through manures and fertilizers. Gains in soil N occur through fixation of molecular N_2 by micro-organisms and from the return of ammonia (NH_3) and nitrate (NO_3^-) in rain water whereas nitrogen losses occur through crop removal, leaching and volatilization (Stevenson, 1986). Among *kans*, Total nitrogen in pre-monsoon, monsoon and post-monsoon ranged from 0.01 – 0.68 %, 0.13 – 0.86 % and 0.18 – 0.33 % respectively. Among non-*kans*, Total nitrogen in pre-monsoon, monsoon and post-monsoon ranged from 0.14 – 0.33 %, 0.14 – 0.45 % and 0.12 – 0.25 % respectively. The nitrogen concentration in soil differs significantly with respect to forest types (Divya et al., 2016). The major nutrients i.e. NPK turnover from the litter varied in natural forests of Kodagu in central part of the Western Ghats and was found to be highest in evergreen forest type (9.36 t/ha/yr, 0.57 t/ha/yr, 4.43 t/ha/yr) followed by semi-evergreen (8.42 t/ha/yr, 0.55 t/ha/yr, 4.39 t/ha/yr) and least was found in dry deciduous forest type (2.87 t/ha/yr, 0.30 t/ha/yr, 2.52 t/ha/yr) (Reddy et al., 2012).

pH: Soil pH influences nutrient uptake and tree growth. It indicates the acidity and alkalinity of a soil sample. The availability of many plant nutrients in the soil is mainly controlled by soil pH. Soil acidity and alkalinity are affected by different types of cation (Al^{3+}, H^+, Na^+, K^+, Ca^{2+} and Mg^{2+}) adsorbed on colloidal surfaces. Higher concentrations of $Al^{3+}$and H^+ ions decreases soil pH whereas adsorption of bases like sodium (Na), potassium (K), Calcium (Ca) and Magnesium (Mg) increases soil pH (Tan, K. H., 1994). Among *kans*, pH in pre-monsoon, monsoon and post-monsoon ranged from 5.85 – 6.7, 6 – 7.8 and 6 – 7.1 respectively. Among non-*kans*, pH in pre-monsoon, monsoon and post-monsoon ranged from 6 – 7.01, 6 – 7 and 6.2 – 6.4 respectively.

The soil sampling sites showed wide seasonal variations among *kans* and non-*kans*. Among *kans*, BKF1 had highest moisture content in monsoon whereas lowest in BKF1 in pre-monsoon. VF7 had highest TN content and pH in monsoon. HSKF2 had lowest TN and BD in monsoon. HulF2 had highest TC in pre-monsoon whereas lowest in VF4/5 in pre-monsoon. KK5F2 had highest BD but lowest pH in pre-monsoon. Among non-*kans*, KKNKF had highest moisture content, TC and TN (monsoon), highest pH in pre-monsoon and lowest BD (monsoon). BNKF1 had lowest moisture content (pre-monsoon) and lowest BD (similar to KKNKF in monsoon) whereas YNKF1 had lowest TC (monsoon). HSNKF2 had lowest TN content (in both pre-monsoon and monsoon), lowest pH (monsoon) but highest BD (pre-monsoon). Lowest pH was observed in VNKF (pre-monsoon) and HSNKF2 (monsoon). VNKF has pH similar to HSNKF2.

Thus, bulk density is inversely proportional to moisture content. Among seasons, moisture content was in the order: Monsoon > Post-monsoon > Pre-monsoon whereas, bulk density was in the order: Pre-monsoon > Post-monsoon > Monsoon. Water holding capacity (WHC) of soil increased with increasing organic - C concentrations (Singh et al., 2009). The concentrations of SOC in different soil aggregate fractions and bulk soils also increases with increasing elevation and soil aggregation rate (Li et al., 2016).

In the present study, soil samples having high Total carbon had higher Total nitrogen whereas soil samples having low Total carbon had lower Total nitrogen. Soil microorganisms are responsible for organic matter decomposition, nutrient cycling and degradation of pollutants (Chaudhari et al., 2013). The microbial C, N and P was higher during the rainy season and lower in winter season due to higher decomposition rate of litters and microbial activities during the rainy season (Patel et al., 2010). A decrease in microbial biomass C, N and P occurs due to decrease in water holding capacity (WHC) and concentration of organic C, total N and P in the soil. It also decreases from low to high disturbance regime and also from surface to subsurface soil layers (Barbhuiya et al., 2004). The higher N-mineralization rates in forest ecosystems, as compared to cropland may be due to the higher organic-C and total-N content in the soil as well as higher soil microbial biomass (MB) (Singh et al., 2009).

CLUSTER ANALYSIS

Cluster Analysis (figure 3) of physical and chemical variables in the soil of different *kans* and non- *kans* (16 sampling sites) of central Western Ghats revealed the existence of three groups. Group 1 includes sampling sites like BKF1, KK2F1, TNKF1, PKF2, KK5F2, BNKF1, VNKF and HSNKF2. Group 1 had comparatively higher bulk density than other 2 groups. Group 2 include Hulkod which has higher total carbon and total nitrogen. Group 3 includes sampling sites such as KKNKF, VF7, YKF1, YNKF1, VF4/5, HSKF2 and TKF3 that has higher moisture content and pH.

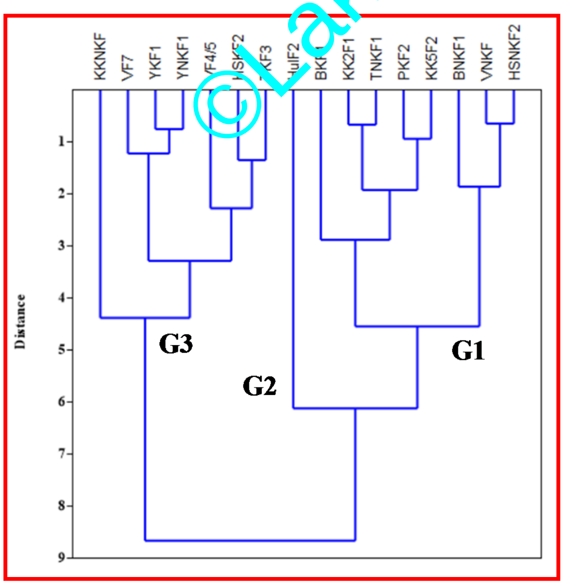


Figure 3: Hierarchical clustering analysis (Wards method) of sampling points in central Western Ghats in Karnataka based on physico-chemical parameters (like moisture content, bulk density, Total carbon, total nitrogen and pH)

CONCLUSION

The results showed marked seasonal variations in soil quality. Hulkod has highest nutrient content (total carbon and total nitrogen) due to the presence of thick vegetation. It is an un-disturbed forest. In highly disturbed areas, wide variations in pH, nutrient and ionic contents were seen compared to un-disturbed areas. The physico - chemical parameters varied widely both spatially and seasonally. These forests had varied soil type and vegetation contributing nutrients that played an important role in soil dynamics. The protection of sacred forests that have religious and spiritual importance with endemic natural flora and fauna helps us to maintain a healthy ecosystem as humans are protecting its water (stream), soil, vegetation/flora as well as the inhabiting fauna.

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