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Special Variability Study on Physical Properties of Forest Soil

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Abstract: *Soils are a product of the factors of formation and continuously change over the earth's surface. The analysis of the spatial variability of soil properties is important for land management and construction of an ecological environment. Soils are characterized by high degree of spatial variability due to the combined effect of physical, chemical or biological processes that operate with different intensities and at different scales. The spatial variability of soil physical properties is inherent in nature because of geological and pedological factors. Soil physical properties such as soil particle size distribution, bulk density, porosity and organic matter content are interrelated and have important effects on watershed hydrology. The primary objective of this study was to analyze the spatial variability of soil physical properties of forest soils of Pavanje river basin. It was observed that, the spatial variability of sand silt and bulk density increased from top to bottom depths, but in clay, spatial variation decreased from top depths to bottom depths. Spatial variation of organic matter content was relatively more in the top layer and it decreased in the bottom layers. The above findings indicate that environmental factors may lead to differences in spatial variability among soil physical properties.*

Keywords: *spatial variability, soil physical property, forest soil, bulk density, organic matter content*

1. Introduction

Analysis and interpretation of spatial variability of soil properties is a keystone in site specific management. Spatial variability of soil physical properties within or across the fields is inherent in nature due to geologic and pedologic soil forming factors, but some of the variability may be induced by tillage and other management practices. These factors interact with each other across spatial and temporal scales, and are further modified locally by erosion and deposition processes. Spatial variability of various soil properties are scale-dependent, especially the water transport properties of soils; therefore, it is a prerequisite to quantify the spatial variability of soils before designing site-specific applications like variable rate irrigation, seed rate, fertilizer rate, and strategies for future soil sampling.

1.1 Literature Review

Soils are characterized by high degree of spatial variability due to the combined effect of physical, chemical or biological processes that operate with different intensities and at different scales. Young and Hammer [1] and mainly of original material, Cunha et al.[2] studied the variation of the textural characteristics of soil occur in response to the deposition of sediment, vegetation, and relief that governs the time of exposure of materials to the action of weathering. Yang Qiu et al. [3] studied soil moisture variation in relation to topography and land use in a hillslope catchment of the Loess Plateau, China. They characterized the profile types as well as additional profile features of soil moisture content and the relationships between each of these profile features, to understand the relative importance of land use and topography on profile features of soil moisture. They used correlation analysis, to analyze soil moisture data and spatial variation of soil moisture content across landscape. They concluded that, spatial variability of soil moisture across landscape varies with both soil depths and temporal evolution. Javed Iqbal et al. [4] analyzed spatial variability of physical properties of alluvial soils. Their research work was to determine the degree of spatial variability of soil physical properties and variance structure, and to model the sampling interval of alluvial floodplain soils. They used Auto correlation and Moran's *I* statistics to investigate the adequate sampling interval for various soil physical properties. All the correlograms showed positive spatial autocorrelation without any cyclicity. They observed that land use and management practices may contribute to the spatial variability of soil physical properties. Price et al. [5] found that soil physical properties such as soil particle size distribution, bulk density, porosity and organic matter content are interrelated and have important effects on watershed hydrology. These properties influence runoff, infiltration, percolation, subsurface storage and the transmission rate of water into stream networks. Venkatesh et al. [6] analyzed the observed soil moisture patterns under different land covers in Western Ghats, India and also studied the spatio-temporal variability of soil water potential and soil moisture content under different land covers in the humid tropical Western Ghats region. They evaluated the relationships between soil moisture at different depths using correlation analysis. Knowledge of the spatial variability of soil properties is important in several disciplines, including agricultural field trial research and precision farming. Therefore an

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appropriate understanding of spatial variability of soil properties is essential for modeling at landscape scale. While, many researchers have studied the horizontal variation and temporal changes of soil properties, little attention has been paid to the spatial and profile features of soil physical properties. The primary motivation for conducting this study was the lack of spatial study on soil physical properties of Pavanje river basin soils. Correlation analysis technique has been used to analyze various soil properties. This study characterized the profile types as well as additional profile features of various soil properties such as particle size distribution, bulk density and organic matter content). Study also quantified the spatial variation of soil properties at layers under the study area.

2. Materials and methodology

2.1 Descriptions of the study area and soil sampling

In the present study, the Pavanje river basin in Dakshina Kannada district of coastal Karnataka is considered. The Pavanje river originates in the foothills of Western Ghats and flows towards west to join the Arabian Sea and lies between North latitudes12°57'30" to 13°07'30" and East longitudes 74°45'00" to75°02'30". The basin lies within the Dakshina Kannada district of Karnataka State, India. It is planked on the east by the foothills of the Western Ghats and on the west by the Arabian Sea. The soils of the basin mainly consist of coastal alluvium and lateritic soils. Coastal alluvium is relatively rare and contains river sand and silt. Lateritic soils are formed on the crust of the lateritic hills. The soils are yellowish red to dark red, or reddish brown to brown in color. In texture, they vary from clay loam to gravelly sandyloam in the surface, and clay loam to gravelly sandy clay in the subsurface horizon. The study area has a hot humid climate. The climate of the region is marked by heavy rainfall (about 95%) during the southwest monsoon (June to September). The mean daily temperature from March to May is 35°C and from December to February is 23°C. Average values of evapotranspiration are about 5 mm/day during summer and 2.5 mm/day during winter. The area of catchment is 202.33 km^2. Soil sampling was carried out on a forested hillslopes of the Pavanje river basin. A total of fifty six soil samples were collected from eight different elevations distributed from the crest to the footslope. For the each elevation, all physical properties of seven soil layers with the thickness of 10, 20, 30, 40, 50, 60 and75 cm were determined.

2.2 Laboratory measurements and soil sample analysis

Cores were used for soil sampling and volume of the core was 1020 cm^3. All the undisturbed and disturbed soil samples collected were subjected to laboratory measurements to determine bulk density, particle-size distribution, specific gravity, porosity and organic carbon content. Undisturbed soil samples were oven dried at 105°C to determine dry bulk density. Total porosity was calculated from the measured oven-dry bulk density and a soil particle density by using the relationship of (1-bulk density/particle density). Organic carbon content was determined with the Walkley and Black method. Organic matter was then calculated by a factor of 1.724 (Van Bemmelen's Correction Factor). Particle-size distribution was determined using sieve analysis and hydrometer. Sand, silt and clay contents are expressed as a percentage by mass of the fine earth fraction and soil texture is identified according to the United States Department of Agriculture (USDA) system of particle-size classification.

2.3 Calculations of variables

The overall methodology adopted in this study focused on analyzing spatial characteristics of measured soil physical properties. Yang Qiu et al [3] proposed computation of several variables to characterize temporal and spatial variability in a quantitative manner. Calculations of several variables used in this study are demonstrated as follows: Let the soil properties of site i and the layer j be expressed as $M_{i,j}$, N_p is the number of sites and N_l is number of sampling layers or depths. The following variables may be defined as:

i. Mean of soil variable of site i, (M_i)

$$M_i = \frac{1}{N_l}\sum_{j=1}^{N_l} M_{i,j} \tag{1}$$

ii. Mean of soil variable at soil layer j, (M_j)

$$M_j = \frac{1}{N_p}\sum_{i=1}^{N_p} M_{i,j} \tag{2}$$

iii. Profile variability of soil variable on plot, i, (VP_i)

$$VP_i = \sqrt{\frac{N_l\sum_{j=1}^{N_l}(M_{i,j})^2-\left(\sum_{j=1}^{N_l} M_{i,j}\right)^2}{N_l(N_l-1)}} \tag{3}$$

iv. Spatial variability of layered averaged soil variable at soil layer$j$, (VS_j)

$$VS_j = \sqrt{\frac{N_p\sum_{i=1}^{N_p}(M_{i,j})^2-\left(\sum_{i=1}^{N_p} M_{i,j}\right)^2}{N_p(N_p-1)}} \tag{4}$$

The four variables defined by eqns. (1)-(4) were computed for eight elevations in forested hillslopes of the Pavanje river basin at different depths (N_l) for all physical properties.

3. Results and discussion

In this study, four different variables such as mean of soil property of sites, mean of soil property at soil layers, profile variability of soil property on sites and spatial variability of layered averaged soil property at soil layers have been studied. The bar charts are drawn for all variables of each soil physical properties. Considerable differences were found in all the variables for each soil property across the forest lands. Also, every variable of each soil property of individual sites within each land cover recorded different values.

3.1 Analysis of different variables of physical properties of forested hillslope soils

The present study then focused on the analysis of different properties of forested hillslope soils. The different variables were computed for both physical (sand, silt, clay, bulk density and organic matter content) and hydraulic properties (θ_{33}, θ_{100}, θ_{300}, θ_{500}, θ_{1000}, θ_{1500} and k_s) at different elevations. The elevations were from crest to foot of the hillslope i.e., at 30, 40, 50, 60, 75, 90, 105 and 120 m elevations. At first, different variables were computed for physical properties of forested hillslope soils. i.e., mean of the elevations, mean at soil layers, profile variability of the elevations and spatial variability at layers were computed for sand, silt, clay, bulk density and organic matter content using the eqns. (1)-(4). In bar charts, number of elevations 1 to 8 represents 30 m to 120 m elevations and layers 1, 2, 3, 4, 5, 6 and 7 represent 10, 20, 30, 40, 50, 60 and 75 cm respectively.

At first, the study was carried out to analyze the different variables of sand, from forested hillslopes. The bar charts are drawn for the four different variables of sand as shown in Figure 1. To find the mean sand of the elevation, the percentage of sand from all the depths (layers) from 10 to 75 cm at one elevation was considered and computed the mean sand of that elevation using the eqn. (1). The same procedure was repeated for the other remaining elevations also. It could be observed from Figure 6.13 that, mean sand was maximum in the fourth elevation i.e. at 60 m, (54.71%). In other elevations, it was ranging from 39.71 to 45.28%.

Then mean sand at each soil layers (depths) from 10 to 75 cm was computed using the eqn. (2). Here the percentage of sand was taken from one particular depth (layer) of each elevation and mean sand at that depth (layer) was determined. It could be seen from Figure 1 that, the mean sand content was quite more in second layer i.e., at 20 cm depth (47.63%) and minimum in fourth and fifth layers (42%), at 40 and 50 cm depths. In other layers, small variations were found ranging from 42.75% to 45.38%.

The profile variability of sand was computed using the eqn. (3). At one elevation, by considering percentage of sand from all depths, the profile variability was determined. The same procedure was followed for other elevations also. The profile variability in fifth and eighth elevations i.e. at 75 m and 120 m elevations was ranging from 7.86% to 8.2% and reported less in the fourth elevation i.e., at 60 m (1.98%). In other elevations, some variations were found ranging from 3.53% to 6.09%. The spatial variability of sand at different depths (layers) was then calculated. The percentage of sand from one particular depth at different elevations was considered and calculated the spatial variability using eqn. (4). The same procedure was followed for the other depths also. Spatial variability was maximum in the seventh layer i.e., at 75 cm depth (10.18%). In other layers, spatial variability was from 5.22% to 7.62%. Figure 1, shows the spatial variability of sand in different soil depths.

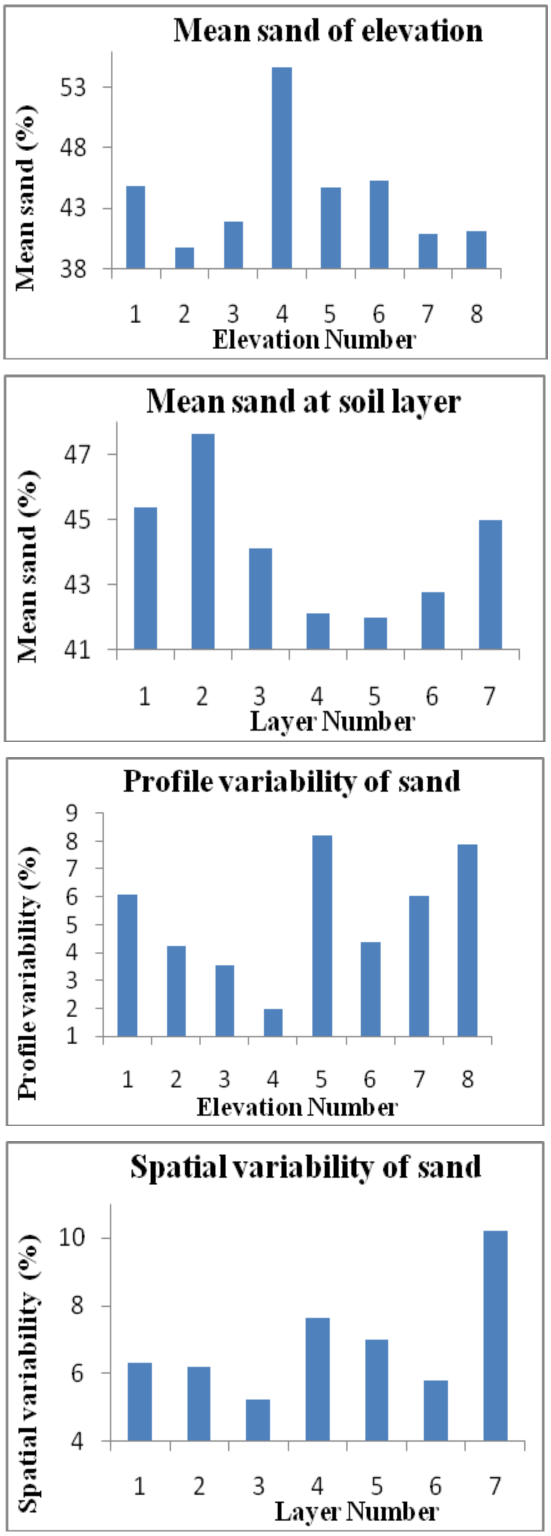

Figure 1: *Different variables of sand*

The present study was then continued with the computation of different variables of silt. Mean silt of the elevation was analyzed; it was observed that mean silt was more in first elevation (33.43%), and it decreased in second and third elevations (18%) and again increased in the fourth elevation (29.43%). It was almost same in all other elevations. Mean silt at layer was also determined; it was less in second layer (24.25%) and attained maximum in the first and seventh layer (27%). In other layers, small differences were found. Higher profile variability was observed in the first elevation (7.59%) and was quite moderate in second and fourth elevations ranging from 1.77% to 1.9%. Small variations were observed in other elevations ranging from 3.1% to 6.24%. Low spatial variability was found in the first and second layers ranging from 4.83% to 5.51%, attained maximum in the third layer (10.05%) and in other layers it was 6.16% to 8.93%. The bar charts are drawn for the different variables of silt property (Figure 2).

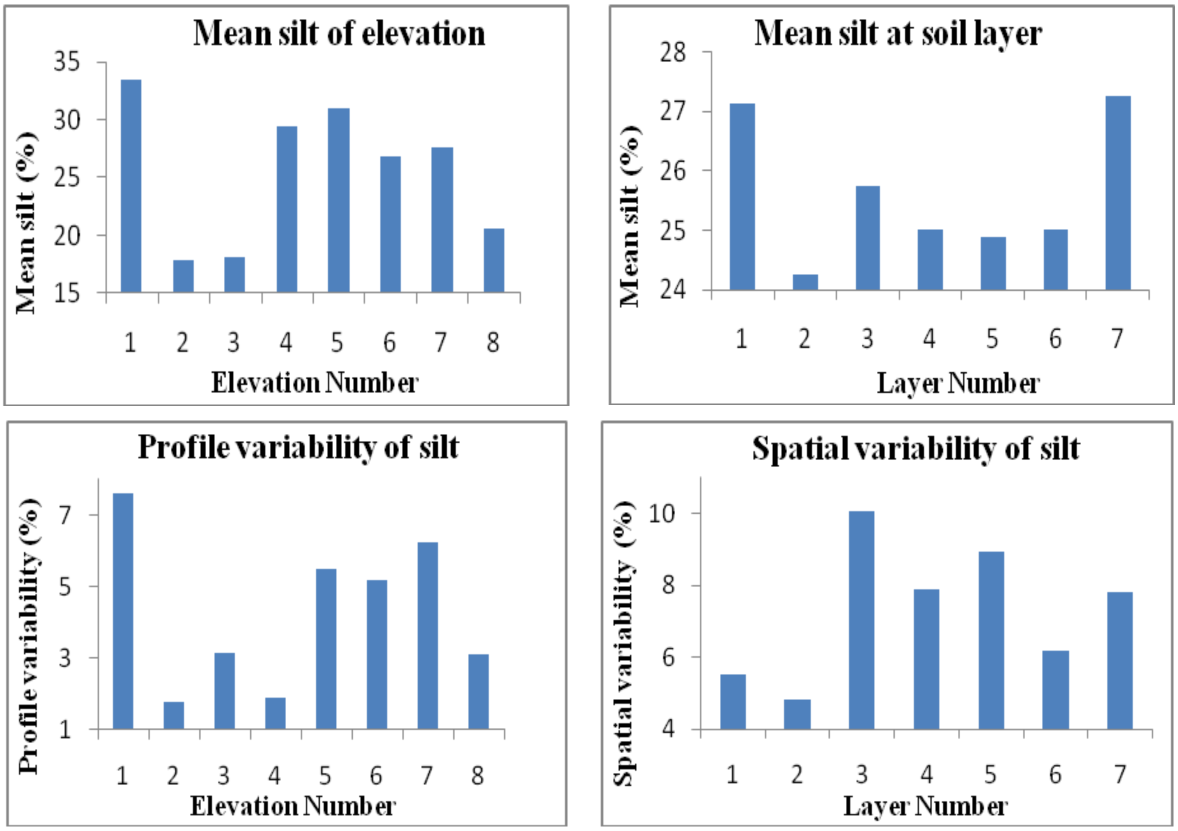

Figure 2: *Different variables of silt*

The different variables of clay were then calculated using eqns. (1)-(4). Mean clay of the elevation was 2.57% in fourth elevation and decreased in third, sixth and eighth elevations, ranging from 0.29% to 0.43%; in other elevations not much variation was observed. The mean clay at different layers was then analyzed. It was observed that, mean clay was less in first and second layers (0.75% to 0.88%), and in other layers small variations were observed ranging from 1.13% to 1.75%. Profile variability was quite low in the third, sixth and eighth elevations (0.5%) and increased in fifth elevation (1.53%). Some minor profile variations were observed in other elevations. The spatial variability was maximum in third layer (1.98%) and in other layers, it was ranging from 0.99% to 1.17%. The different variables of clay are shown in Figure 3.

The bulk density was then taken into consideration for the calculation of different variables. Mean bulk density of the elevation was high in the second elevation and low in the fourth elevation and in other remaining elevations, not much variation was found. Mean bulk density at the layer was maximum in first layer and minimum in sixth layer when compared to other layers. More profile variability was observed in first layer, minimum in second layer and in other remaining layers small variations were found. The spatial variability was in the increasing mode from first to fourth layer, but it decreased in the fifth layer, again increased in the sixth layer and decreased in seventh layer. The different variables of bulk density are shown in the Figure 4.

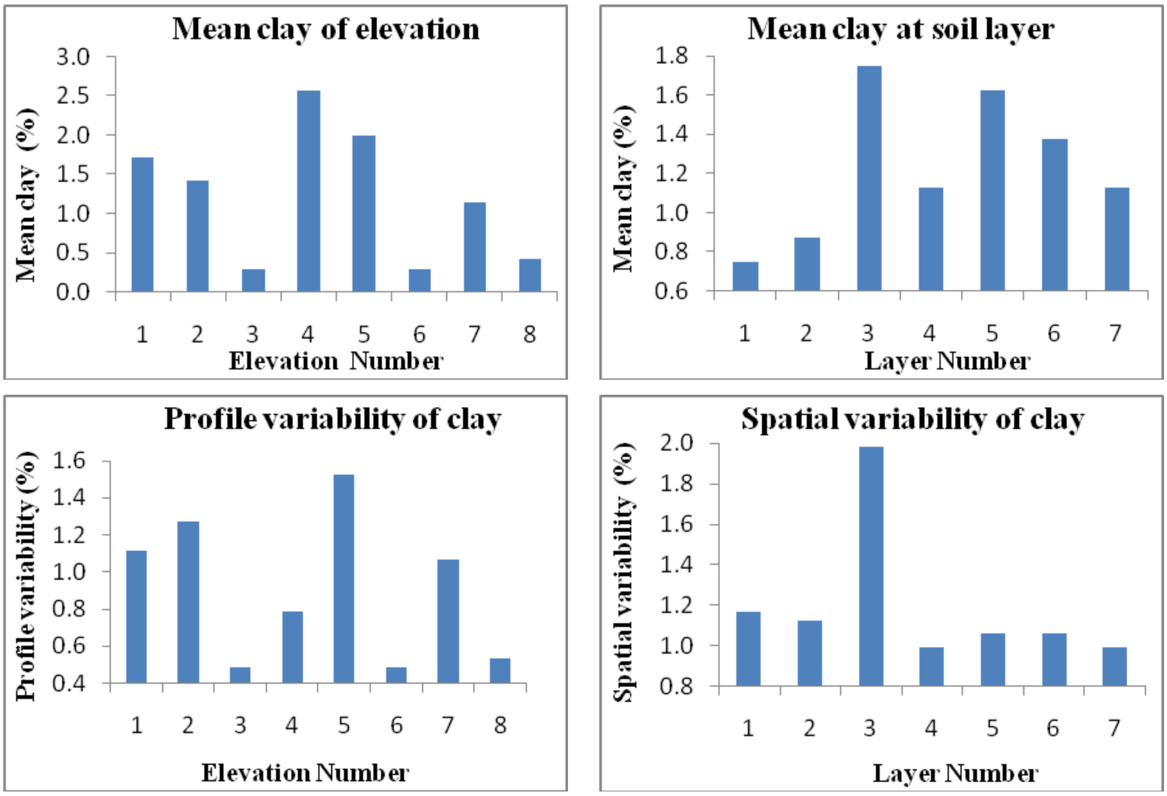

Figure 3: *Different variables of clay*

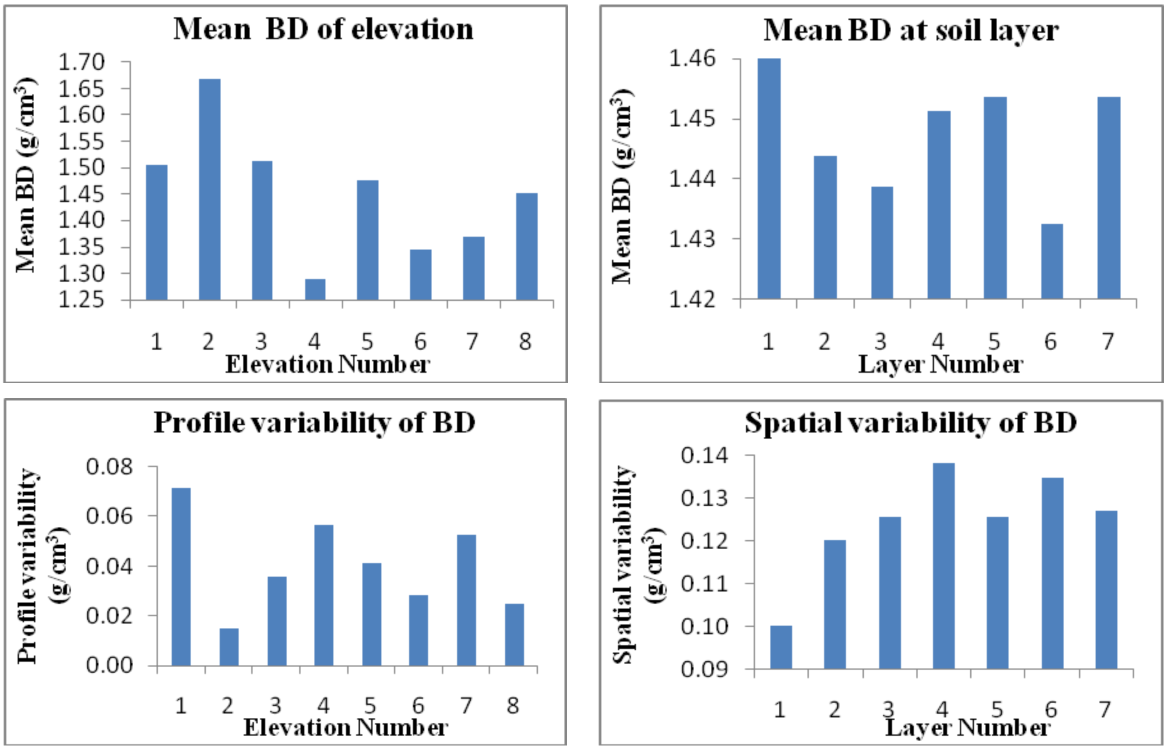

Figure 4: *Different variables of bulk density*

The present study was then taken up the analysis of different variables of organic matter content. Mean organic matter content of the elevation was computed and observed some variations in each elevation. It was maximum in the seventh elevation (4.02%) and minimum at the third and fourth elevations (1.3%). In other elevations, it was from 1.57% to 3.64%. In first and second layers, mean organic matter content was almost same, and then it decreased from third layer to seventh layer in the range of 2.82 to 1.31%. Higher profile variability was observed at the top elevations i.e. at 75 m, 105 m and 120 m elevations ranging from

1.59% to 2.55%. In other elevations profile variability was observed in the range of 0.54% to 0.79%. Spatial variability at layers was almost in the decreasing mode from fourth layer to last layer ranging from 1.69% to 0.3%. In first two layers, it was same about 2% and in the third layer 1.52%. The bar charts (Figure 5) are drawn for the different variables of the organic matter content.

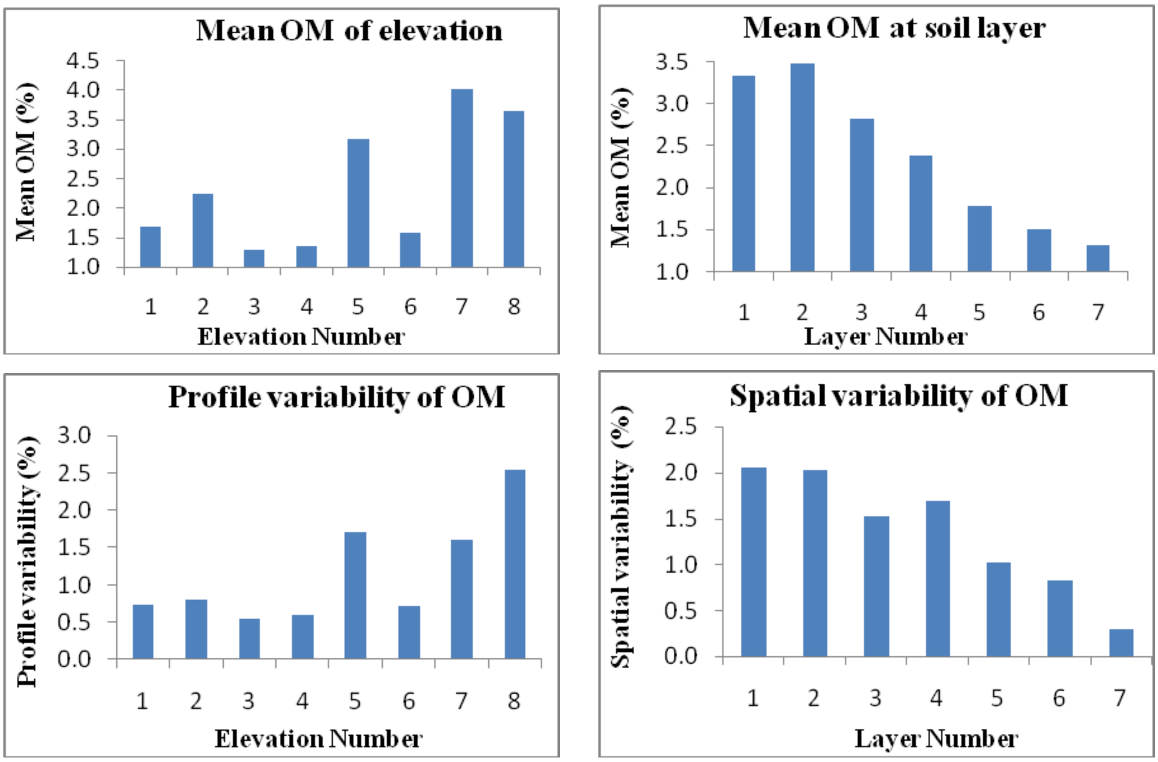

Figure 5: *Different variables of organic matter content*

Overall it was observed that, the spatial variability of sand increased from top to bottom depths about 6.3% to 10.18%. In silts also, same trend was observed. Spatial variation was from 5.52% to 7.82%, but in clay, spatial variation decreased from top depths to bottom depths i.e., 1.17% to 0.99%. In bulk density, spatial variation increased from top layer to bottom layer in the range of 0.1 to 0.13g/cm^3. Spatial variation of organic matter content was relatively more in the top layer and it decreased in the bottom layers ranging from 2.05% to 0.3%. Spatial variability of soil properties is inherent in nature because of variations in soil parent materials and microclimate. However, geological, pedological and land use factors interact with each other on spatial and temporal scales. Duffera et al. [8] found that soil physical properties had moderate to strong spatial dependence, especially in topsoil.

4. Conclusions

An understanding of soil variability is necessary to characterize the linkages between a region's hydrology, ecology and physiography. Spatial variability of physical properties of the soil is quite significant for heterogeneous unsaturated zone environments. In order to gain a better understanding of soil variations in relation to land use and topography, the present study used correlation analysis to analyze the soil properties obtained from forest land covers. The aim was to characterize the different variables of soil properties i.e., mean of each soil property of the site, mean of each soil property at layers, profile variability of each soil property and spatial variability of each soil property at layers across forested hillslope soils. In the forested hillslope soil of Pavanje river basin has almost all the top soils were found to belong to the sandy loam soil class. Basin has less sand content, more organic matter content and porosity is marginally higher. Spatial variability of sand and silt increases from top to bottom depths, but for clay, spatial variation decreases from top to bottom depths. The spatial variation of bulk density increases from top layer to bottom layer and spatial variation of organic matter content is more in the top layer and it decreases towards the bottom layers. The above findings indicate that environmental factors may lead to differences in spatial variability among soil physical properties.

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