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Soil properties of landslide affected areas in Kodagu district

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Abstract
Kodagu district in Karnataka, India is located on the eastern slope of Western Ghats with high range hills and abundance of forest wealth. However, Kodagu district has witnessed many natural hazards including landslide and floods and the area is becoming more susceptible for soil erosion. This study was aimed to establish a relationship between soil physical properties and relief in landslide affected areas of Kodagu district. The soil physical properties such as soil texture, bulk density, particle density, porosity and infiltration rate were estimated by using standard methods. Thematic maps were generated to assess the soil depth, slope and elevation. It was observed that the landslide affected areas were predominant with sandy clay loam soils which was more vulnerable for land slide.

Keywords: Kodagu, landslide, soil properties, soil conservation and Western Ghats

1. Introduction

Kodagu district lies in the south western part of Karnataka, India with distinctive geomorphological, geological, hydrological and meteorological characteristics. This district along with its scenic beauty and pleasant climatic conditions is also becoming prone to natural hazards such floods and landslides as a result of infrastructure development projects in response to growing population and tourist. With every passing monsoon, the Coorg district witnesses several landslides as a result of infrastructure development projects in response to growing population and tourist. Infrastructure development, such as the construction of new roads and the enlargement of existing highways, includes the alteration of slopes, compromising the natural equilibrium. Introduced human assets are vulnerable to natural processes, resulting in natural hazards. In the year 2018-19, Kodagu district witnessed multiple landslides causing huge damage to life and property. Apart from depletion of fertile soil, erosion results in the loss of plant nutrients and organic matter, siltation of reservoirs and riverbeds thereby adversely affecting irrigation and power potential. It is also evident that, landslides affect agricultural production, forest stand and availability of water both for irrigation and drinking besides bringing about a disturbance in the ecological balance. To understand the susceptibility of landforms to landslides, it is essential to study the relationship between soil physical properties and topographical features in the landslide affected areas. Infiltration and storage capacity of the soil is influenced by the soil physical properties and topographical features which contribute to the occurrence of landslides in landslide prone areas. In comparison to clayey and sandy soils, silty soils are more vulnerable to erosion (Sadeghi *et al.*, 2012) [8]. The interaction between the soil structure and hydraulic behaviour of soil in landslide affected areas can be evaluated based on its soil physical properties (Bogner *et al.*, 2014) [3]. Remote Sensing and GIS techniques have emerged as effective and powerful tools for generating spatial information on soil inventory, land use land cover, land suitability water resource assessment (Ravikumar and Govindraju, 2019) [7].

Therefore, this study was undertaken to determine the soil physical properties in landslide affected areas of Kodagu district which will be helpful in modelling the soil physical properties and spatial features for landslide vulnerability

2. Materials and Methods

The study was carried out in the landslide affected areas of Kodagu district, Karnataka, India. The total geographical area of Kodagu is 4102 sq. km with an average rainfall of 2607mm. It lies between the latitudes 11°55′00″ to 12°50′00″ N and 75°22′00″ to 76°11′00″E longitudes. The altitude ranges from 800–1700 m above MSL.

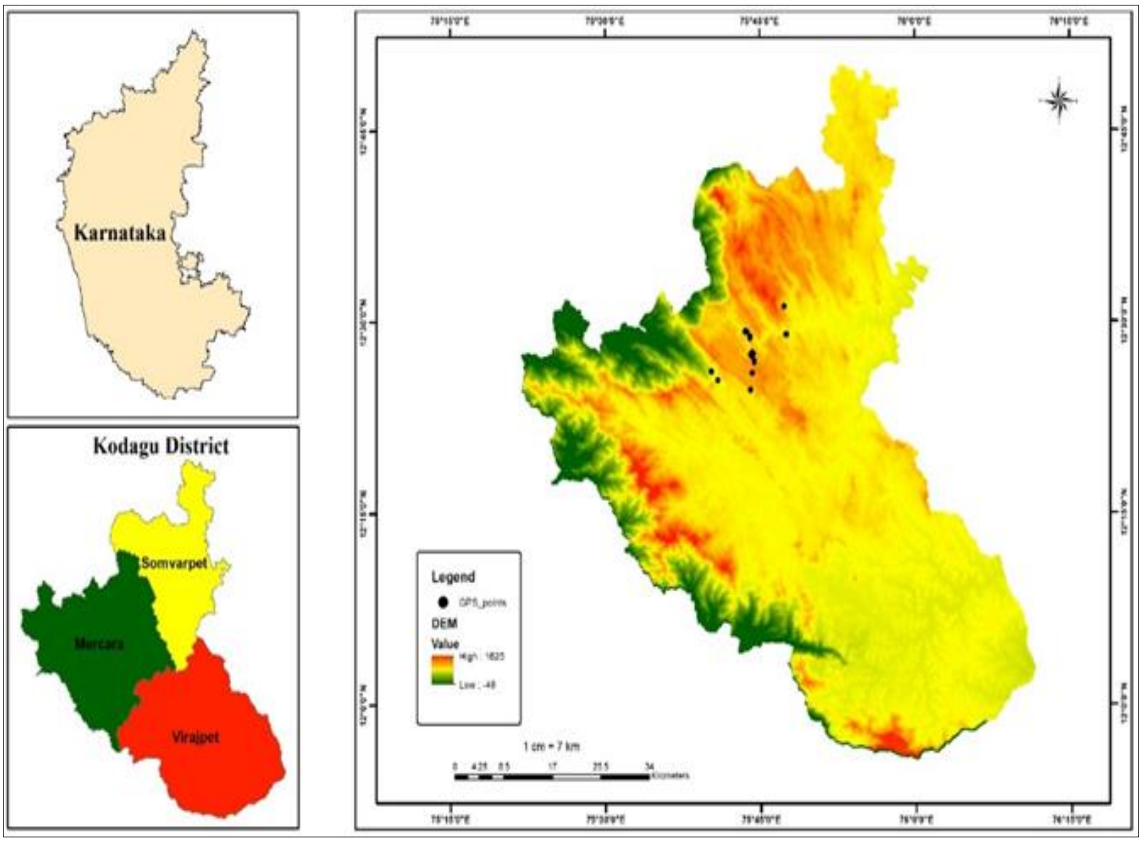

Fig 1: Study Area

2.1 Soil collection and processing

The sampling points were digitally localised in ArcGIS 10.5. The sample points were inserted with their respective coordinates in the GPS. On locating the sample points on the ground, the soil samples were collected using soil auger from the rhizosphere depth of 0-20 cm in landslide affected areas at Hebettageri, Kaloor, Anjanageri Bettageri, Hattihole and Makkanduru villages. Representative soil samples of 500 g were collected from all the sites and stored in a plastic bag with proper labeling for laboratory analysis.

The collected soil samples were shade dried, pounded and sieved through a 2 mm sieve to remove gravel, small stones and coarse roots.

2.2 Laboratory Analysis

Soils samples were analyzed for various physico-chemical properties such as texture, bulk density (BD), particle density (PD), porosity, infiltration rate, soil reaction, EC, SOC, major and minor nutrients.

The International Pipette Method was adopted for analyzing soil separates using sodium hydroxide as a dispersing agent to determine the relative proportion of sand, silt and clay fractions in soils as described by Black (1965) [1]. The bulk density and particle density was determined by volumetric flask method (Gupta *et al.*, 2007) [5]. Infiltration rate of the soil adjoining the landslide affected areas was determined using double ring infiltrometer.

The soil chemical properties at landslides affected areas were determined using standard laboratory procedures.

2.3 Pedotransfer function

Pedotransfer functions is a multiple regression equation used to determine the soil hydraulic conductivity from other independent soil properties such as clay, bulk density and porosity (Medeiros *et al.*, 2014) [6]. The data for the were significant in the regression results in equation (1)

$$K_0 = -6.74 * BD + 51.74 * Macro + 0.01 * Clay$$

Because the data of hydraulic conductivity (K0) were not spatially adjusted, the relationship between the soil physical characteristics and K0 was tested by multiple linear regressions with program R. When the variables are soil properties, these regressions are called pedotransfer functions. The equation showed the best values of the multiple linear regression fitting, with $r^2 = 0.6$ and p-value = 2.9 10-8. Therefore, K0 was mapped in the area of the sub-basin using the equation established, performing operations between images consisting of a cell matrix (rasters).

3. Results and Discussion

3.1 Soil physical properties

The statistical data of soil physical properties in landslide affected areas of Kodagu district is given in Table 1. It was observed that the sandy clay loam was the predominant soil texture in the study area. Since soil containing more than 50 percent of sand, which create instability and have low binding capacity. Similar results were observed by Zaruba and Mincl (1969), Varnes (1978), Verma (1982a), Wieckzorek *et al.* (1988), Waltham (1994) which showed that the predominance of sand as an augmenting factor for landslides. The interflow of water has a tendency to avoid the clay layer and to pass through such layers having more intergranular voids. As a result, the clay layer, when underlain by other relatively more porous layers, like sandy loam and loam, becomes unstable on steep slopes, and moves down as landslides. Thus, preponderance of sand and other coarse textured fragments in soils give way to landslides due to its less cohesive nature.

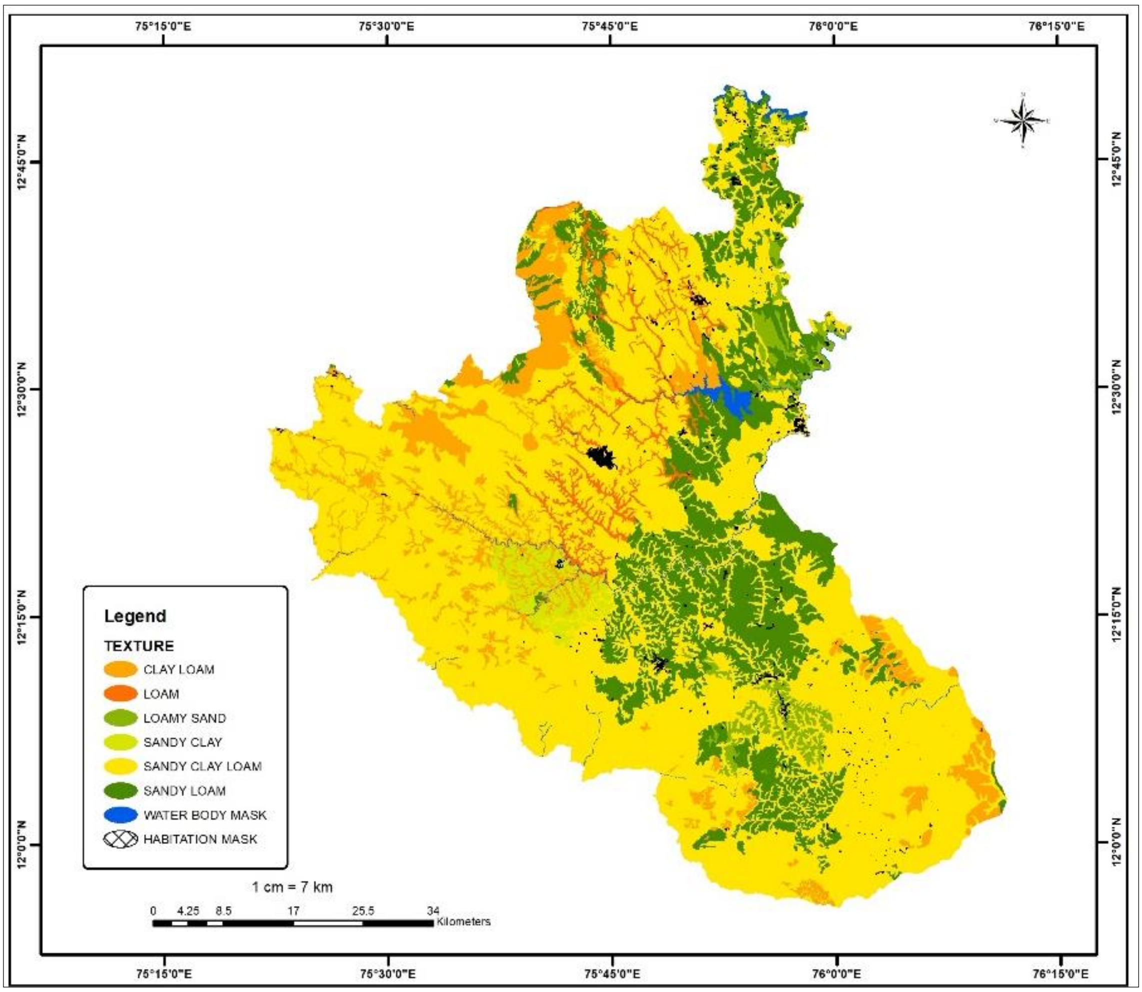

Fig 2: Soil texture map of study area

The bulk density of soil in the adjoining areas of landslide affected site ranged from 1.82-2.23 g/cc. It was observed that the higher soil bulk density was due to the destruction of the soil structure during landslide process. The higher value of soil bulk density influenced the drainage, water-holding capacity and aeration. It was observed that the porosity of soil in the study area ranged from 37.88-50.81%. The poor porous condition can be attributed to the clogging of soil pores due to landslides.

3.2 Infiltation rate

Kaolinite is the dominant soil mineral in the district which has 1:1 type of clay mineral and is therefore unable to expand. Under the circumstances, when run-off begins to infiltrate into the soil mass it tends to move down slope. For permeable soils, the slope and infiltration capacity are inversely related. The infiltration rate is the rate at which water moves through the soil. The depth (in cm) of the water layer that can reach the soil in one hour is commonly used to calculate infiltration rate. The mean infiltration rate was 1.12 (cm/hr) which shows soil is at or near saturation point. In the study area rainfall intensity was greater than infiltration capacity which results in surface runoff.

3.3 Soil chemical properties

The statistical data of soil chemical properties is given in Table. 2. It was observed that soil pH in the landslide affected area was strongly acidic to slightly acidic. The acidic nature of the soil is mainly due to heavy rainfall which causes leaching and also nature of parent material. The soil fertility study showed that soil organic carbon (SOC) ranged from 0.12 to 0.63 i,e low to medium. The low SOC in the landslide affected areas is due to the deposition of debris on the surface and removal of surface soil horizons. Similar results were reported by Singh *et al.* (2001) [10] and Sparling *et al.* (2003) [11].

The primary nutrients i.e., available Nitrogen and available Phosphorus content and available potassium ranged from 68.99-188.16, 5.95 to 60.00 and 63.97 to 247.70 kg/ha respectively. It was observed that the available nitrogen and available phosphorous was low in the landslide affected areas whereas, Potassium content varied from low to medium. Similar results were reported by other researchers. The secondary nutrients and the micronutrients status were found to be sufficient except the available Sulphur content.

Table 1: Statistical analysis of soil physical properties

Property	N	Min	Max	Mean	CV	SD
Bulk Density(g/cc)	25	1.82	2.23	2.01	4.27	0.06
Particle density(g/cc)	25	2.21	2.49	2.36	3.26	0.08
Porosity(%)	25	37.88	50.81	44.52	6.16	2.74
Infiltration rate(cm/hr)	25	0.60	1.85	1.12	45.39	0.51
sand	25	50.00	65.00	54.72	6.43	3.52
silt	25	20.00	33.00	24.36	14.21	3.46
clay	25	15.00	26.00	20.92	15.79	3.30

Table 2: Statistical analysis of soil chemical properties

Parameters	N	Min	Max	Mean	CV	SD
Ph	25	5.20	7.71	5.89	11.06	0.65
EC	25	0.01	0.08	0.04	45.58	0.02
OC	25	0.12	0.63	0.43	42.11	0.18
N	25	68.99	188.16	128.05	35.35	45.27
P	25	5.95	60.00	16.07	93.04	14.95
K	25	63.97	247.70	148.07	45.40	67.22
Ca	25	3.25	4.75	4.04	11.45	0.46
Mg	25	1.75	3.75	2.65	21.87	0.58
S	25	12.03	20.08	15.58	14.71	2.29
Zn	25	0.36	2.02	0.95	61.07	0.58
Fe	25	1.89	23.14	12.57	52.46	6.59
Mn	25	1.32	16.70	10.09	44.57	4.50
Cu	25	0.89	2.48	1.38	32.92	0.45

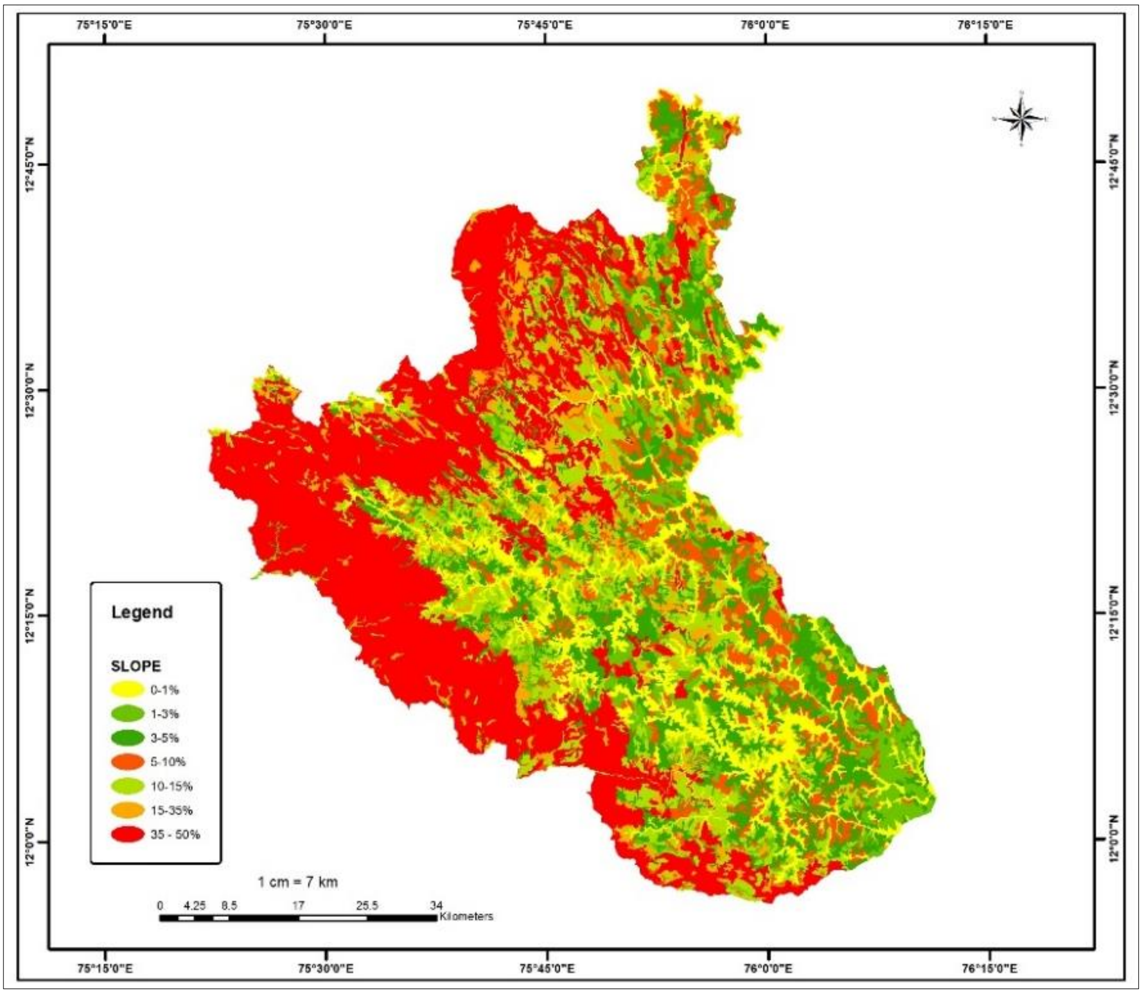

Fig 3: Slope map of the study area

4. Conclusion

Sandy clay loam soil was found to be problematic soil and is more vulnerable for land slide. The higher bulk density, poor porosity, saturated soil and poor drainage due to blockages are contributing factors for landslide.

As SOC and total nitrogen content is crucial in soil fertility, such decreases may serve as a profound influence on vegetation growth, stand development, biodiversity, and net primary productivity in landslide areas (Blaschke *et al.*, 1992; Walker *et al*., 1996; Dislich and Huth, 2012) [2, 14, 4]. SOC and total nitrogen content was found to be deficit so, the soil must be replenished with organic manure and vegetation in order to return to its normal cultivable range by cultivating reclamation crops that can add a significant amount of organic matter.

Sowing or planting some legumes (Mucuna, lemon grass, Vetriver grass) and Bamboo for in-situ soil and water conservation in the affected area will progressively contribute organic matter to soil for increasing soil property and soil organic matter content.

It is imperative to desilt bodies of water and unclog drainage systems immediately. Bench terracing is required to stabilise slopes that are steeper than 30%. In landslide affected and vulnerable regions, there is a need to encourage the production of deeply rooted indigenous plants. Immediate effort towards conservation is required because if the impacted and sensitive regions are left unprotected, there would be a substantial risk of soil erosion.

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