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# Physico-chemical Characterization and Taxonomic Classification of Soil Profiles in a Toposequence Located in RRTTS and KVK Farm, Keonjhar, Odisha, India

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

The study investigates the physico-chemical characteristics and taxonomic classification of soil profiles along a toposequence at the RRTTS and KVK farm, Keonjhar, Odisha. Three distinct land types - upland, medium land, and lowland - were selected for the study, representing varying topographic positions. The investigation focused on soil properties such as bulk density, particle density, pH, organic carbon content, electrical conductivity, cation exchange capacity (CEC), base saturation, and available macro and micronutrients. Results indicated that bulk and particle densities were lower in upper horizons and increased with depth, while soil pH exhibited an increasing trend with increasing depth, likely due to the movement of basic cations during intensive rainfall. Organic carbon content was higher in surface horizons and declined with depth, whereas available potassium increased with depth, attributed to parent material and clay content. The exchangeable cations, primarily calcium and magnesium, dominated the soil profiles. The soils were classified into Loamy-skeletal, mixed, hyperthermic Typic Ustorthents (Pedon 1), Fine-loamy, mixed, hyperthermic Udic Haplustalfs (Pedon 2), and Fine-loamy, mixed, hyperthermic Udic Paleustalfs (Pedon 3). The study concluded that different landforms within the toposequence require specific land-use planning and conservation measures to enhance soil productivity and sustainability. Upland areas are recommended for plantation and agroforestry, medium land for crop production, and low land for paddy cultivation and pisciculture. Tailored conservation strategies, including contour cultivation and water harvesting, are essential to mitigate soil erosion and optimize land use in the region.

*Keywords: Soil characterization; taxonomic classification; toposequence; land-use planning; soil conservation; Keonjhar; Odisha; India.*

## 1. INTRODUCTION

Soil is a critical natural resource that supports agricultural productivity, sustains ecosystems and influences environmental quality. The characterization and classification of soils in different landscapes provide essential information for effective land-use planning and sustainable agricultural practices [1,2]. Understanding soil properties along a toposequence—where soils develop under varying topographic conditions—is particularly important, as these soils exhibit significant variability in their physical and chemical characteristics due to differences in elevation, drainage, and parent material.

In the context of Odisha, Keonjhar district represents a diverse topographic region with significant agricultural potential [3,4]. The district is characterized by a complex landscape, comprising upland, medium land, and lowland areas, each with distinct soil properties that influence their suitability for various agricultural practices [5]. Upland areas are often subjected to soil erosion due to their slope and poor water retention capacity, whereas lowland areas are prone to waterlogging, affecting crop productivity [1,6]. Medium lands, being moderately drained, offer a balance between the extremes of upland and lowland areas [7].

Previous studies in similar agro-ecological zones have demonstrated that the physico-chemical properties of soils, such as bulk density, particle density, pH, organic carbon content, cation exchange capacity (CEC), and base saturation, vary significantly with depth and landscape positions [8]. These properties are influenced by factors such as the movement of bases, organic matter content, and the nature of parent material, which in turn affect nutrient availability and soil fertility [9].

The present study aims to characterize the physico-chemical properties of soil profiles in a toposequence located at the Regional Research and Technology Transfer Station (RRTTS) and Krishi Vigyan Kendra (KVK) farm, Keonjhar, Odisha. The study also seeks to classify the soils taxonomically and provide recommendations for land-use planning and conservation measures tailored to the specific needs of upland, medium land, and lowland areas. This research is expected to contribute to the sustainable management of soils in the region, enhancing agricultural productivity and environmental conservation.

## 2. MATERIALS AND METHODS

### 2.1 The Study Area

The study area was RRTTS, Judia Farm, Keonjhar and KVK farm, Keonjhar located in the North Central Plateau Agro-Climatic Zone of Odisha. It is located at a distance of 211 km from the state capital Bhubaneswar. It is situated between $21^0$ 37' N latitude and $85^0$ 34' E longitude with an altitude of 480 m above Mean Sea Level. The size of the study area is 16.06 ha. The study area is situated at the foot of “Sanghagara Hills” which is covered under the Keonjhar forest range. The RRTTS and KVK farm lies along the toposequence with majorly three distinct land types comprising upland, medium land, and low land.

The soils of the study area are mainly developed from colluvial materials from the hill slope. The parent material of the study area consists of two types of rocks such as granodiorites and granites with intrusion of some basic rocks. Based on slope and elevation, the study area has been divided into three major physiographic units (Fig. 1) such as gently sloping upland (elevation of 538 feet above Mean Sea Level; slope of 2-5%), very gently sloping medium land (elevation of 496 feet above Mean Sea Level; slope of 2-3%) and nearly level low land (elevation of 335 feet above Mean Sea Level; slope of 0-1%).

The climate of the region is subtropical monsoonal type with pronounced winter, summer and rainy seasons. The summer season commences at the beginning of March and continues up to the middle of June. May is the hottest month during which, the mean maximum temperature is 39°C and the mean minimum temperature is 25°C as recorded by the local observatory. Mean annual rainfall is 1534 mm, more than half of which is received during the three months of June, July, and August. July is the rainiest month of the year. At present the total farm area is divided into 7 blocks namely Block-A to Block-G and each block consists of several plots.

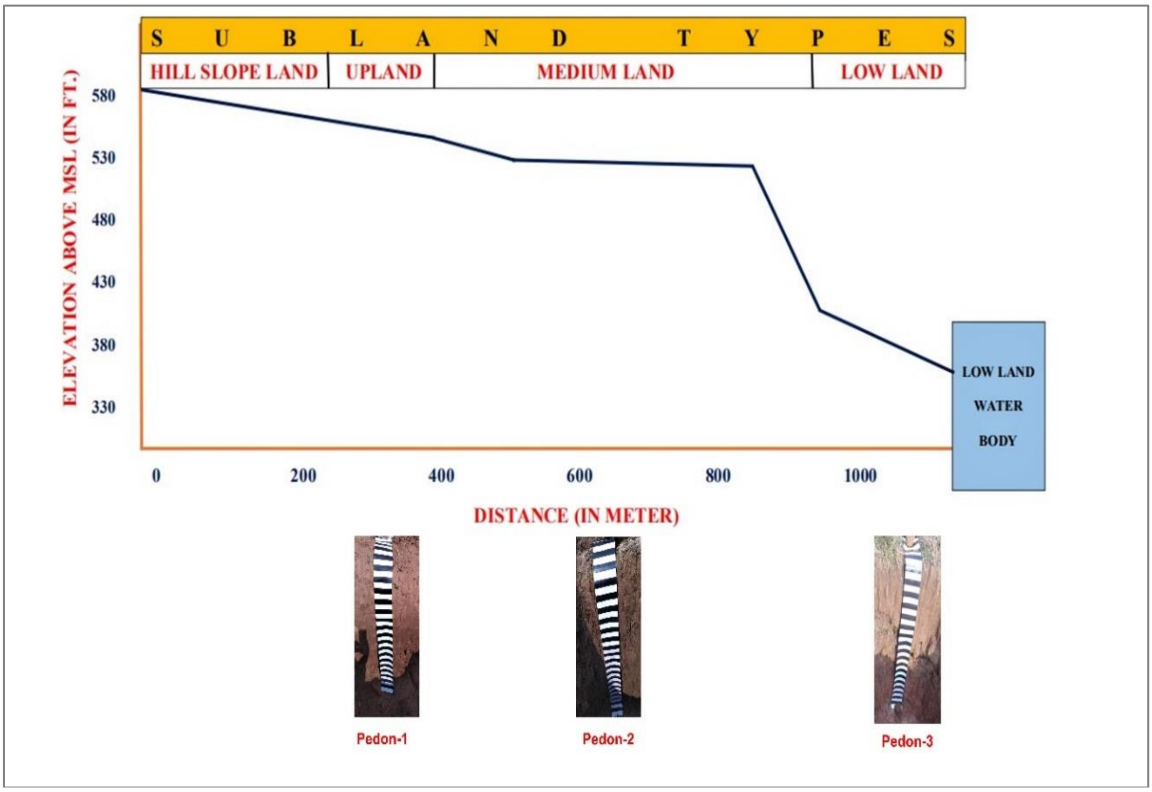


**Fig. 1. Transect study in relation to physiography of the study area**

## 2.2 Soil Sampling

The landform of the study area was determined by traversing the area and taking elevation data above Mean Sea Level (MSL) at different points using a GPS instrument (Garmin make; model: 76MAPCSx). Based on land type, three representative soil profiles of approximate size 1m x1m x 1.5 m were exposed at upland (pedon 1), medium land (pedon 2), and low land (pedon 3) of the study area (Fig. 2). The study area comes under a typical toposequence with varying topography with respect to elevation above mean sea level. The morphological features of soil pedons along the toposequence were studied and soil samples from different genetic horizons were collected for analysis of various parameters in the laboratory. The soil samples collected from the profiles were air-dried, ground with a wooden hammer, and passed through a 2 mm sieve. The samples were then preserved in plastic bottles, labelled and stored for laboratory studies.

## 2.3 Soil Analysis

The particle size analysis was carried out by the Bouyoucos Hydrometer method [10,11]. Textural classes were determined using the USDA Textural Triangular diagram. The bulk densities of the soils were analyzed by the clod method as described by Klute [12]. Particle densities of the soils were determined by a specific gravity pycnometer bottle [13]. The pH of soil samples was determined in 1:2.5 soil: water suspension using a glass electrode digital pH meter, "SYSTRONICS" (model M.K.VI). The electrical conductivity (EC) of 1:2.5 soil: water suspensions was measured using the "SYSTRONICS" conductivity meter (model 306). The organic carbon of soils was determined by the modified rapid titration method using the Ferroin indicator [14]. The cation exchange capacity (CEC) of soils was determined by leaching with I normal $NH_4OAc$ and distilling off the absorbed $NH_4^+$ into boric acid after washing out excess saturating solution by ethanol [15]. Then, it was estimated by titrating with standard acid using the Bromocresol Green-Methyl Red indicator. Exchangeable sodium and potassium of the soils present in $NH_4OAc$ leachate collected during CEC determination were determined by a "SYSTRONICS" model 128 flame photometer. Exchangeable calcium and magnesium in the above $NH_4OAc$ leachate were determined as per the procedure described by Page et al. [16]. The exchangeable $H^+$ and $Al^{+3}$ were determined by following the methods given by Thomas [17].

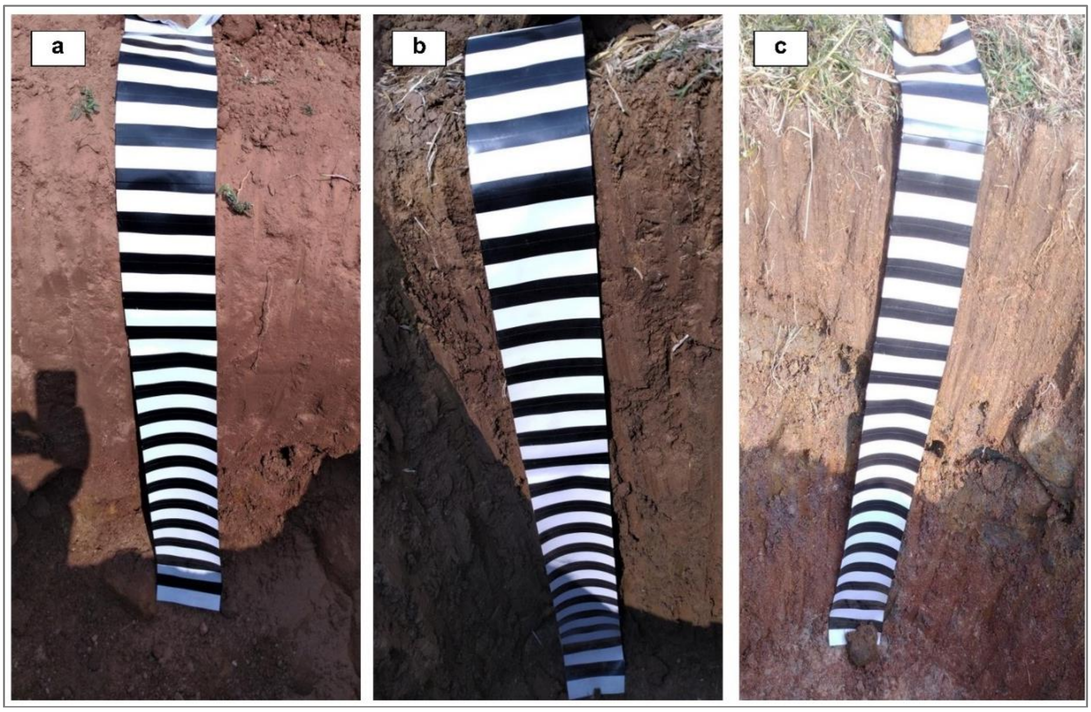


**Fig. 2. Soil profiles of (a) pedon 1-upland, (b) pedon 2-medium land, and (c) pedon 3-low land. (Note: Each black and white division of the scale represents 3 cm)**

The available nitrogen (N) content of the samples was determined by the alkaline permanganate method as outlined by Subbiah and Asija [18] by nitrogen auto-analyzer (Pelican-Classic DX). As the soil reaction was acidic, available phosphorous (P) in the soil was determined by Bray's No. 1 method [19] as outlined by Page et al. [16] and estimated colourimetrically with a SYSTRONICS spectrophotometer (model 106). Available potassium (K) was determined by extracting the soil with Neutral Normal ammonium acetate solution and was estimated by a "SYSTRONICS" digital flame photometer [20,21]. Available sulphur (S) in the soils was determined by turbidimetric method [22] using 0.15% $CaCl_2$ extractant. The colour intensity was measured at 440 nm wavelength in a Systronics Spectrophotometer (model 166). Available micronutrients (Fe, Mn, Cu and Zn) in the soil samples were determined by extracting the soil with DTPA in Perkin Elmer Atomic Absorption Spectrophotometer [23]. Available boron (B) was determined by the hot water extractable method as outlined by John et al. [24]. Then the colour intensity was measured at 450 nm wavelength in a Systronics Spectrophotometer (model 166). The taxonomic classification of the farm was done as per the USDA Soil Taxonomy [25].

## 3. RESULTS AND DISCUSSION

### 3.1 Physical Characteristics

The physical properties of pedons 1, 2, and 3 are presented in Tables 1a, 2a, and 3a, respectively.

#### 3.1.1 Particle size distribution

The particle size distribution analysis revealed distinct variations among the three pedons, reflecting their different land types and soil formation processes.

**Pedon 1 (Upland):** The sand content in Pedon 1 decreased from the surface to a depth of 91 cm, reflecting the typical profile of upland soils. The presence of coarse fragments was consistent throughout the profile, indicative of erosion processes that transport finer particles away, leaving behind coarser sands. The absence of significant eluviation, or removal of soil material from the upper layers, contributed to the lower clay content at depth. The general pattern of decreasing sand content and the presence of coarse fragments suggest ongoing erosion and sediment redistribution in this upland area.

**Pedon 2 (Medium land):** In this pedon, the sand content decreased progressively to a depth of 88 cm, then showed an increase up to 101 cm, and decreased again to 150 cm. This variability reflects a more complex soil texture influenced by both deposition and leaching processes. The clay content exhibited an increasing trend with depth, reaching a maximum at 88 cm before decreasing again. This pattern of increasing clay content with depth suggests significant eluviation of finer particles from surface layers and subsequent illuviation (deposition) in the lower horizons, which is characteristic of medium land areas with moderate relief and drainage conditions.

**Pedon 3 (Low land):** The sand content in Pedon 3 showed a decrease to 66 cm, an increase from 66 to 81 cm, and then a decrease up to 160 cm. This pattern reflects sediment accumulation and redistribution typical of low-lying areas where sedimentation processes are more pronounced. The clay content increased progressively to 112 cm and then stabilized, indicating a buildup of finer particles in the lower horizons. The observed increase in clay content with depth in lowland areas is often attributed to the gradual accumulation of finer sediments and reduced erosion compared to upland areas. Overall higher clay per cent in medium and lowlands suggests clay migration from uplands to medium and lowlands through surface and internal drainage along with flowing water. Similar observations were recorded by Dash et al. [1,3,6].

#### 3.1.2 Bulk density

Bulk density values were highest in the lower horizons of all pedons. In Pedon 1, bulk density values ranged from 1.28 to 1.58 $Mg/m^3$, with higher values in deeper layers due to increased sand content, lower clay content, and reduced organic carbon in these horizons. Similarly, Pedon 2 showed bulk density values ranging from 1.25 to 1.63 $Mg/m^3$, with the highest values observed in lower horizons, reflecting compaction effects associated with higher sand content and lower organic matter. Pedon 3 exhibited bulk density values from 1.32 to 1.63 $Mg/m^3$, also showing increased compaction in deeper horizons due to the accumulation of finer particles and reduced organic matter. These findings align with those of Mishra [26], indicating that increased bulk density in deeper horizons is a common feature in soils with higher sand content and lower organic carbon.

**Table 1a. Physical characteristics of Pedon 1 (Upland)**

| Horizon | Depth (cm) | Sand | Silt | Clay | Bulk Density | Particle Density | Porosity |
|---|---|---|---|---|---|---|---|
| | | (%) | | | (Mg $m^{-3}$) | | (%) |
| Ap | 0-18 | 87.8 | 2.2 | 10 | 1.28 | 2.38 | 46.3 |
| C1 | 18-51 | 85.3 | 3.4 | 11.3 | 1.34 | 2.40 | 44.2 |
| C2 | 51-91 | 79.0 | 6.5 | 14.5 | 1.48 | 2.60 | 43.1 |
| C3 | 91-100 | 85.3 | 2.2 | 12.5 | 1.58 | 2.68 | 41.0 |

**Table 1b. Chemical characteristics of Pedon 1 (Upland)**

| Horizon | Depth (cm) | pH (1:2.5) | EC (1:2.5) $dSm^{-1}$ | Organic Carbon (g $kg^{-1}$) | Exchangeable cations [cmol($p^+$) $kg^{-1}$] | | | | | Exchangeable Acidity ($H^+$) [cmol($p^+$) $kg^{-1}$] | Cation Exchange Capacity [cmol($p^+$) $kg^{-1}$] | Base Saturation (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | Sum | | | |
| Ap | 0-18 | 6.04 | 0.20 | 8.1 | 11.6 | 1.7 | 0.25 | 1.77 | 15.32 | 2.8 | 18.5 | 82.81 |
| C1 | 18-51 | 6.16 | 0.18 | 7.5 | 11.9 | 1.9 | 0.26 | 1.96 | 16.02 | 2.5 | 18.9 | 84.76 |
| C2 | 51-91 | 6.44 | 0.19 | 6.9 | 12.6 | 2.4 | 0.35 | 2.32 | 17.67 | 1.9 | 19.8 | 89.20 |
| C3 | 91-100 | 6.64 | 0.10 | 2.3 | 13.3 | 2.5 | 0.39 | 2.37 | 18.56 | 1.6 | 20.5 | 90.53 |

**Table 2a. Physical characteristics of Pedon 2 (Medium land)**

| Horizon | Depth (cm) | Sand | Silt | Clay | Bulk Density | Particle Density | Porosity |
|---|---|---|---|---|---|---|---|
| | | (%) | | | (Mg $m^{-3}$) | | (%) |
| Ap | 0-15 | 73.2 | 6.1 | 20.7 | 1.25 | 2.36 | 47.0 |
| Bt1 | 15-24 | 66.7 | 7.3 | 26.0 | 1.34 | 2.54 | 47.2 |
| Bt21 | 24-39 | 65.2 | 7.6 | 27.2 | 1.39 | 2.58 | 46.1 |
| Bt22 | 39-54 | 64.2 | 7.6 | 28.2 | 1.46 | 2.59 | 43.6 |
| Bt23 | 54-88 | 60.4 | 8.4 | 31.0 | 1.52 | 2.61 | 41.7 |
| BC | 88-101 | 69.3 | 3.5 | 27.2 | 1.58 | 2.67 | 40.8 |
| C | 101-150 | 66.7 | 8.5 | 24.8 | 1.63 | 2.69 | 39.4 |

**Table 2b. Chemical characteristics of Pedon 2 (Medium land)**

| Horizon | Depth (cm) | pH (1:2.5) | EC (1:2.5) $dSm^{-1}$ | Organic Carbon ($g\ kg^{-1}$) | Exchangeable cations [$cmol(p^+)\ kg^{-1}$] | | | | | Exchangeable Acidity ($H^+$) [$cmol(p^+)\ kg^{-1}$] | Cation Exchange Capacity [$cmol(p^+)\ kg^{-1}$] | Base Saturation (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | Sum | | | |
| Ap | 0-15 | 6.01 | 0.57 | 10.3 | 13.2 | 2.9 | 0.42 | 2.56 | 19.08 | 3.2 | 23.8 | 80.16 |
| Bt1 | 15-24 | 6.13 | 0.62 | 9.7 | 15.9 | 3.1 | 0.48 | 2.85 | 22.33 | 2.8 | 26.7 | 83.63 |
| Bt21 | 24-39 | 6.18 | 0.69 | 8.8 | 16.1 | 3.2 | 0.48 | 2.85 | 22.63 | 2.7 | 26.9 | 84.10 |
| Bt22 | 39-54 | 6.36 | 0.72 | 8.6 | 16.3 | 3.4 | 0.50 | 2.87 | 23.07 | 2.6 | 27.2 | 84.80 |
| Bt23 | 54-88 | 6.58 | 0.75 | 8.6 | 16.4 | 3.7 | 0.52 | 2.88 | 23.50 | 2.3 | 27.5 | 85.40 |
| BC | 88-101 | 6.64 | 0.80 | 2.4 | 14.3 | 2.4 | 0.21 | 2.37 | 19.28 | 1.9 | 21.7 | 88.84 |
| C | 101-150 | 6.74 | 0.84 | 2.2 | 13.2 | 2.4 | 0.21 | 2.32 | 18.13 | 1.5 | 20.2 | 89.75 |

**Table 3a. Physical characteristics of Pedon 3 (Low land)**

| Horizon | Depth (cm) | Sand | Silt | Clay | Bulk Density | Particle Density | Porosity |
|---|---|---|---|---|---|---|---|
| | | (%) | | | ($Mg\ m^{-3}$) | | (%) |
| Ap | 0-12 | 86.9 | 3.2 | 9.9 | 1.24 | 2.34 | 47.0 |
| Bt1 | 12-21 | 79.4 | 5.7 | 14.9 | 1.37 | 2.40 | 42.9 |
| Bt21 | 21-31 | 79 | 6.0 | 15 | 1.39 | 2.43 | 42.8 |
| Bt22 | 31-45 | 78.2 | 4.4 | 17.4 | 1.45 | 2.51 | 42.1 |
| Bt23 | 45-66 | 66.9 | 8.2 | 24.9 | 1.48 | 2.55 | 42.0 |
| Bt24 | 66-81 | 67.4 | 5.6 | 27 | 1.54 | 2.62 | 41.2 |
| BC | 81-112 | 66.9 | 5.6 | 27.5 | 1.57 | 2.65 | 40.7 |
| C | 112-160 | 66.9 | 5.6 | 27.5 | 1.63 | 2.70 | 39.6 |

**Table 3b. Chemical characteristics of Pedon 3 (Low land)**

| Horizon | Depth (cm) | pH (1:2.5) | EC (1:2.5) $dSm^{-1}$ | Organic Carbon ($g\ kg^{-1}$) | Exchangeable cations [$cmol(p^+)\ kg^{-1}$] | | | | | Exchangeable Acidity ($H^+$) [$cmol(p^+)\ kg^{-1}$] | Cation Exchange Capacity [$cmol(p^+)\ kg^{-1}$] | Base Saturation (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | Sum | | | |
| Ap | 0-12 | 6.74 | 0.65 | 14.6 | 12.9 | 2.7 | 0.37 | 2.19 | 18.16 | 3.4 | 22.1 | 82.17 |
| Bt1 | 12-21 | 6.80 | 0.67 | 9.6 | 13.8 | 2.8 | 0.39 | 2.25 | 19.24 | 3.1 | 22.8 | 84.38 |
| Bt21 | 21-31 | 6.79 | 0.69 | 8.6 | 14.1 | 2.8 | 0.42 | 2.26 | 19.58 | 2.8 | 23.1 | 84.76 |
| Bt22 | 31-45 | 6.96 | 0.71 | 7.6 | 14.3 | 3.1 | 0.45 | 2.30 | 20.15 | 2.5 | 23.5 | 85.74 |
| Bt23 | 45-66 | 7.05 | 0.74 | 6.9 | 14.5 | 3.2 | 0.49 | 2.35 | 20.54 | 2.4 | 23.6 | 87.03 |
| Bt24 | 66-81 | 7.13 | 0.75 | 6.7 | 14.6 | 3.2 | 0.51 | 2.37 | 20.68 | 2.1 | 23.7 | 87.25 |
| BC | 81-112 | 7.26 | 0.79 | 6.3 | 14.8 | 3.4 | 0.52 | 2.39 | 21.11 | 1.9 | 24.1 | 87.59 |
| C | 112-160 | 7.3 | 0.81 | 5.9 | 14.8 | 3.4 | 0.52 | 2.41 | 21.13 | 1.7 | 24.1 | 87.67 |

**Table 4. Depth-wise distribution of available nutrients in representative pedons of the study area**

| Horizon | Depth (cm) | N | P | K | S | Fe | Mn | Cu | Zn | B |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $kg\ ha^{-1}$ | | | | $mg\ kg^{-1}$ | | | | |
| **Pedon-1 (Upland)** | | | | | | | | | | |
| Ap | 0-18 | 137.5 | 15 | 225 | 5.3 | 36.8 | 17.1 | 1.4 | 1.1 | 0.76 |
| $C_1$ | 18-51 | 100.0 | 9 | 231 | 4.6 | 35.6 | 16.3 | 1.1 | 0.9 | 0.74 |
| $C_2$ | 51-91 | 87.5 | 5 | 306 | 3.5 | 30.6 | 12.2 | 0.7 | 0.5 | 0.65 |
| $C_3$ | 91-100 | 75.0 | 2 | 431 | 2.9 | 23.5 | 9.8 | 0.3 | 0.2 | 0.58 |
| **Pedon 2 (medium land)** | | | | | | | | | | |
| Ap | 0-15 | 137.5 | 34 | 381 | 8.1 | 69.6 | 36.5 | 2.5 | 1.5 | 1.03 |
| Bt1 | 15-24 | 87.5 | 25 | 505 | 6.6 | 59.5 | 26.8 | 1.7 | 1.3 | 0.95 |
| Bt21 | 24-39 | 87.5 | 23 | 519 | 5.9 | 56.3 | 24.8 | 1.5 | 1.1 | 0.87 |
| Bt22 | 39-54 | 87.5 | 18 | 532 | 5.4 | 51.8 | 22.1 | 1.3 | 0.8 | 0.81 |
| Bt23 | 54-88 | 75.0 | 15 | 540 | 4.3 | 43.7 | 21.5 | 1.2 | 0.7 | 0.65 |
| BC | 88-101 | 75.0 | 14 | 552 | 3.9 | 41.1 | 19.6 | 1.1 | 0.7 | 0.59 |
| C | 101-150 | 62.5 | 14 | 576 | 3.8 | 37.2 | 19.5 | 1.1 | 0.5 | 0.54 |
| **Pedon 3 (low land)** | | | | | | | | | | |
| Ap | 0-12 | 150.0 | 48 | 374 | 15.5 | 87.9 | 41.2 | 2.9 | 1.5 | 1.29 |
| Bt1 | 12-21 | 100.0 | 44 | 381 | 13.3 | 81.4 | 37.6 | 2.4 | 1.4 | 1.17 |

| Horizon | Depth (cm) | N | P | K | S | Fe | Mn | Cu | Zn | B |
|---|---|---|---|---|---|---|---|---|---|---|
| | | kg ha$^{-1}$ | | | mg kg$^{-1}$ | | | | | |
| Bt21 | 21-31 | 100.0 | 41 | 388 | 13.3 | 75.7 | 35.5 | 1.9 | 1.2 | 0.97 |
| Bt22 | 31-45 | 87.5 | 35 | 397 | 12.6 | 71.6 | 34.8 | 1.7 | 1.2 | 0.78 |
| Bt23 | 45-66 | 87.5 | 32 | 405 | 12.4 | 58.5 | 31.2 | 0.9 | 1.1 | 0.62 |
| Bt24 | 66-81 | 87.5 | 23 | 416 | 11.6 | 49.7 | 28.5 | 0.7 | 0.8 | 0.58 |
| BC | 81-112 | 75.0 | 17 | 432 | 10.1 | 41.3 | 27.3 | 0.5 | 0.6 | 0.52 |
| C | 112-160 | 75.0 | 14 | 439 | 9.2 | 35.5 | 24.9 | 0.3 | 0.6 | 0.49 |

**Table 5. Taxonomic classification of soils of the study area**

| | Pedon-1 (Upland) | Pedon-2 (Medium land) | Pedon-3 (Low land) |
|---|---|---|---|
| Order | *Entisols* | *Alfisols* | *Alfisols* |
| Sub Order | *Orthents* | *Ustalfs* | *Ustalfs* |
| Great group | *Ustorthents* | *Haplustalfs* | *Paleustalfs* |
| Subgroup | *Typic Ustorthents* | *Udic Haplustalfs* | *Udic Paleustalfs* |
| Family | Loamy-skeletal, mixed, hyperthermic | Fine- loamy, mixed, hyperthermic | Fine- loamy, mixed, hyperthermic |

#### 3.1.3 Particle density

Particle density values in all pedons increased with depth, ranging from 2.38 to 2.68 Mg/m³ in Pedon 1, 2.36 to 2.69 Mg/m³ in Pedon 2, and 2.34 to 2.70 Mg/m³ in Pedon 3. The increase in particle density with depth can be attributed to the lower organic carbon content in deeper horizons, which leads to higher mineral content and greater particle density.

#### 3.1.4 Total porosity

Total porosity generally decreased with depth in all pedons. In Pedon 1, total porosity ranged from 42.8% to 46.3%, reflecting increased compaction and reduced pore space in deeper horizons. Pedon 2 showed total porosity values ranging from 39.4% to 47.2%, with a similar decrease in depth. In Pedon 3, total porosity ranged from 39.6% to 43.5%, indicating reduced pore space in deeper layers. The decrease in total porosity with depth is consistent with the observed increase in bulk density and the accumulation of finer particles in lower horizons, which contribute to soil compaction and reduced pore space.

### 3.2 Chemical Characteristics

The chemical properties of pedons 1, 2, and 3 are presented in Tables 1b, 2b, and 3b, respectively.

#### 3.2.1 Soil reaction

Soil pH values increased with depth across all pedons, moving from moderately acidic to neutral. In Pedon 1, pH increased from 6.04 at the surface to 6.64 at a depth of 91 cm, likely due to the leaching of basic cations and accumulation of acidic ions in the upper layers. Pedon 2 exhibited a similar trend, with pH values increasing from 6.01 at the surface to 6.74 at 101 cm. Pedon 3 had a surface pH of 6.74, increasing to 7.30 at 160 cm, reflecting less leaching and greater accumulation of basic cations in lower horizons. This trend of increasing pH with depth is supported by similar observations from Kumar et al. [27] and Rajeswar and Ramulu [28], who noted that leaching can lead to increased pH in deeper horizons.

#### 3.2.2 Electrical Conductivity

EC values remained below 1 dS/m across all pedons, indicating low salinity levels. This low EC is likely due to the leaching of soluble salts through intensive rainfall, which flushes out soluble ions and maintains low salinity levels in the soil. This finding is consistent with Mishra [25], who reported similar low salinity levels in soils subjected to high rainfall.

#### 3.2.3 Organic carbon

Organic carbon content was highest in the surface horizons of all pedons and decreased with depth. In Pedon 1, organic carbon content ranged from 8.1 g/kg at the surface to 2.3 g/kg at lower levels of depth. Pedon 2 showed a surface organic carbon content of 10.3 g/kg, decreasing with depth. Pedon 3 had the highest surface organic carbon content of 14.6 g/kg, with a similar decreasing trend. The higher organic carbon levels in surface horizons are attributed to recent crop residue decomposition and accumulation of organic matter. This trend is supported by findings from Dorji et al. [29], Kumar et al. [27], and Khanday et al. [30], who observed that organic carbon content tends to decrease with depth due to reduced decomposition and accumulation of organic materials in deeper soil layers. Moreover, higher soil organic carbon in the lower most topographic position i.e., lowland reflects lower soil organic carbon decomposition in the lowlands, possibly due to higher soil moisture status.

#### 3.2.4 Exchangeable bases

The distribution of exchangeable bases varied across pedons. **Pedon 1:** Exchangeable calcium and magnesium increased with depth, reflecting the movement and accumulation of these bases in lower horizons. Exchangeable sodium and potassium values were relatively stable with depth, with potassium showing a slight increase in deeper layers. **Pedon 2:** Exchangeable calcium and magnesium showed an initial increase with depth, reaching a peak and then decreasing. This pattern suggests that basic cations are leached from the surface layers and accumulate in lower horizons before being depleted. Exchangeable sodium and potassium values varied, with potassium generally increasing with depth. **Pedon 3:** Exchangeable calcium and magnesium increased with depth, indicating the accumulation of these bases in lower horizons. Exchangeable sodium and potassium also varied, with potassium showing a general increase with depth. This pattern of increasing exchangeable bases with depth is consistent with findings from Mishra et al. [31], who reported similar trends in soils with varying land use and management practices.

#### 3.2.5 Exchangeable acidity

Exchangeable acidity ($H^+$) decreased with depth in all pedons, reflecting the increased saturation of exchange sites by other cations. This pattern indicates that as basic cations accumulate in deeper horizons, the exchangeable acidity is reduced. These findings are similar to the observations by Pattnaik [32], who noted that exchangeable acidity tends to decrease with depth as other cations occupy the exchange sites.

#### 3.2.6 Cation exchange capacity (CEC)

CEC values increased with depth in Pedons 1 and 3, reflecting the higher clay content and organic matter in deeper horizons, which contribute to greater cation exchange capacity. In Pedon 2, CEC values increased up to 88 cm before decreasing, indicating a complex interplay of soil formation processes and leaching effects.

#### 3.2.7 Base saturation

Base saturation percentages were higher in lower horizons across all pedons and increased with soil pH. This trend indicates that as soil pH increases and more basic cations are present, the base saturation increases. Thus, higher base saturation in lower horizons reflects the accumulation of base cations in these layers.

### 3.3 Depth-wise Vertical Distribution of Available Macro and Micronutrients

Evaluation of soil fertility status is essential for optimizing crop production and productivity by precise nutrient management [6,33,34]. Previously, Digal et al. [35], Sethy et al. [36], Swain et al. [37], Lokya et al. [38], and Singh et al. [39] have worked on soil fertility status of the surface soils in different locations of Odisha, India. However, knowledge of the vertical distribution of plant nutrients in the soil is also useful as the roots of many crop plants go beyond the surface layer and draw part of their nutrient requirements from the sub-surface layers of the soil [7]. Therefore, the vertical distribution of available plant nutrients is evaluated in the pedons under consideration.

#### 3.3.1 Available macronutrients

Available nitrogen (N), phosphorus (P), and sulfur (S) generally decreased with depth across all pedons (Table 4). This reduction is attributed to the higher availability of these nutrients in the surface horizons due to recent crop residue decomposition and nutrient cycling [7, 8, 40]. Potassium (K) exhibited an increase with depth, reaching maximum levels in the deeper layers. This pattern suggests that potassium is less mobile and accumulates in lower horizons. These findings are consistent with results from Kishore et al. [41], who observed similar nutrient distribution patterns in soil profiles of Karaikal, Puducherry, India.

#### 3.3.2 Available micronutrients

Available micronutrients, including iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), and boron (B), also decreased with depth (Table 4). This decrease is related to the reduction in organic matter and changes in soil chemical properties in lower horizons, which affect the availability of micronutrients.

### 3.4 Taxonomic Classification of the Soils

#### 3.4.1 The epipedon

All soils exhibited an Ochric epipedon with Munsell colour values ≥6, indicating a surface horizon characterized by a lighter colour and less organic matter accumulation. This classification aligns with the typical characteristics of Ochric epipedons, which are commonly found in soils with relatively low organic content and high mineral content.

#### 3.4.2 The Endopedon

**Pedon 1:** This pedon was classified under the soil subgroup *Typic Ustorthents* under soil order *Entisols* (Table 5), due to its coarse fragments, lack of distinct horizons, and the influence of erosion processes. The classification reflects the young and relatively undeveloped nature of the soil. **Pedon 2:** This pedon was classified as *Udic Haplustalfs* at the subgroup level under the soil order *Alfisols,* due to the presence of argillic horizon and moderate clay content. The classification reflects the well-developed nature of the soil with significant clay accumulation. **Pedon 3:** This pedon was classified as *Udic Paleustalfs* under the soil order *Alfisols*, based on its argillic horizon, clay content, and the presence of less developed characteristics compared to Pedon 2. This classification aligns with previous studies by Sharma and Jassal [42], who reported similar soil types and classifications in the region [43].

## 4. CONCLUSION

The study of soil profiles along the toposequence in RRTTS and KVK farm, Keonjhar reveals distinct variations in physico-chemical properties with soil depth. Bulk and particle densities increased with depth across all pedons, indicating higher compaction in lower horizons. Soil pH showed a gradual increase with depth, likely due to the movement of base cations. Organic carbon content decreased significantly from the surface to deeper layers, reflecting reduced organic matter with depth. Electrical conductivity remained low, suggesting minimal salinity issues. CEC generally increased with depth in most pedons, while available nutrients such as nitrogen, phosphorus, and sulfur decreased with depth. In contrast, available potassium increased with depth, which may be due to higher clay content in lower horizons. Micronutrients also decreased with depth, correlating with lower organic matter levels. These findings underscore the need for tailored land-use and soil management practices. Upland areas should focus on erosion control and organic matter addition, medium lands on contour cultivation to manage runoff and maintain fertility, and lowlands on effective water management to support paddy cultivation and prevent waterlogging. Such targeted strategies will enhance soil productivity and sustainability across different topographic positions.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Dash PK, Mishra A, Saren S. Characterization and taxonomic classification of soils under a toposequence located in Eastern India. Environment and Ecology. 2019a; 37(4):1240-1249.
2. Dash PK, Mishra A, Saren S. Vertical distribution of available nutrients in an Eastern Indian Catena. Annals of Plant and Soil Research. 2019b; 21:320—325.
3. Dash PK, Mishra A, Patro H, Nayak RK, Jena B, Satapathy M. Soil characterization along a toposequence located in North-Central Plateau Agro-climatic zone of Odisha. Ecology Environment and Conservation. 2022a; 28 (October Suppl. Issue), 471- 476.
4. Dash PK, Mishra A, Patro H, Patra RK, Sahoo BC, Panda RK, Saren S. Morphological Characterization of Soil Profiles in a Toposequence Located in the North-Eastern Coastal Plains Agroclimatic Zone of Odisha. Environment and Ecology. 2022b;40(3C):1762-1772.
5. Patra SR. Preparation of GIS and GPS based soil fertility maps and identification of soil related crop production constraints of KVK farm and RRTTS, Keonjhar, M.Sc. Thesis, Department of Soil Science and Agricultural Chemistry, College of Agriculture, OUAT, Bhubaneswar; 2019.
6. Dash PK, Mishra A, Saren S, Revathi B and Sethy SK. Preparation of GPS and GIS based soil fertility maps and identification of soil related crop production constraints of RRTTS and KVK farm, Dhenkanal located in the mid central table land agro-climatic zone of Odisha, India, International Journal of Chemical Studies. 2018;6(5):934-943.
7. Pattnaik T, Dash PK, Mishra A, Saren S, Phonglosa A, Kishore MA. Vertical distribution of available plant nutrients in soils of mid-central tableland agro-climatic zone of Odisha, India, Environment and Ecology. 2023;41(4D): 2982-2988
8. Kishore MA, Panda, N, Dash PK, Saren S, Mishra A. Vertical distribution of major, micronutrients and sulfur nutrients in Kantamal Block of Boudh District Catena, Environment and Ecology. 2023;41(4C): 2943-2946.
9. Dash PK, Nayak B, Mishra A, Saren S. Geomorphological characterization of soils under a toposequence located in Eastern

India. Environment and Ecology. 2019c; 37 (4A): 1349—1359
10. Bouyoucos GJ. Hydrometer method improved for making particle size analysis of soils, Agronomy Journal. 1962;54:464.
11. Piper CS. Soil and Plant Analysis, University of Adelaide, Proceedings of Soil Science Society of America. 1950; 14:149-51.
12. Klute. Methods of Soil Analysis, part I, American Society of Agronomy, Soil and Society of America. 1986;371-373.
13. Chopra SL and Kanwar JS. Analytical agricultural chemistry, Kalyani Publishers, New Delhi; 1986.
14. Walkley AJ and Black CA. Estimation of soil organic carbon by the chromic acid titration method, Soil Science. 1934;37: 29-38.
15. Chapman HD. Methods of Soil Analysis, Part-II, American Society of Agronomy. Inc. Wisconsin, USA. 1965;891-900.
16. Page AL, Miller RH, Keeney DR. Methods of Soil Analysis, part-2 (Edn.), Monograph no-9, American Society of Agronomy, Agronomy series ASA SSA, Publishers, Madison, Wisconsin, USA. 1982;621-622.
17. Thomas GW. Soil pH and soil acidity. In Sparks D.L.ed., Methods of soil analysis, part 3, chemical methods Madison, WI, Soil Science Society of America, American Society of Agronomy. 1996; 475-490.
18. Subbiah BV and Asija GL. A rapid procedure for the determination of available nitrogen in soils, Current Science. 1956; 25:259-25260.
19. Bray RH and Kurtz Lt. Determination of total, organic and available forms in soils, Soil Science. 1945; 59: 39-45.
20. Hanway JJ and Heidel H. Soil analysis methods as used in Iowa State College, Soil Testing Laboratory, Iowa State College Bulletin. 1952; 57:1-31.
21. Jackson ML. Soil Chemical Analysis, Prentice Hall of India. Private Limited, New Delhi; 1973.
22. Chesnin L and Yien CH. 1950. Turbidimetric determination of available sulphates, Proc Soil Sci Soc Am. 1950;14: 149-151.
23. Lindsay WL, Norvell W. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci Soc Am J. 1978; 42(3):421-428.
24. John MK, Chuah HH, Ndufeld JH. Application of improved azomethine-H method to the determination of boron in soils and plants. Analytical Letters. 1975; 8: 559-568.
25. Soil Survey Staff Keys to Soil Taxonomy. 12th (edn). USDA, Natural Resource Conservation Service, Washington, DC; 2014.
26. Mishra A. Characterisation, fertility status and taxonomic classification of some soils of West Central Table Land Agro-Climatic Zone of Odisha, Ph.D. Thesis, Department of Soil Science and Agricultural Chemistry, OUAT, Bhubaneswar; 2005.
27. Kumar R, Rawat KS and Yadav B. Vertical distribution of physico- chemical properties under different toposequence in soils of Jharkhand, Journal of Agricultural Physics. 2012; 12(1):63 -69.
28. Rajeswar M and Ramulu V. Vertical distribution of available macro and micronutrients in soil profiles of Ganapavaram pilot area of Nagarjuna Sagar left canal command area of Andhra Pradesh, Asian Journal of Soil Science. 2016;11(1):202-206.
29. Dorji T, Odeh IOA, Field DJ. Vertical distribution of soil organic carbon density in relation to land use cover, altitude and slope aspect in the Eastern Himalayas, Land. 2014; 3:1232-1250.
30. Khanday M, Wani JA, Ram D, Kumar S. Depth wise distribution of available nutrients of soils of horticulture growing areas of Ganderbal District of Kashmir valley, Journal of Pharmacognosy and Phytochemistry. 2018; 7(1):19-22.
31. Mishra A, Pattnayak T, Das D, Das M. Vertical distribution of available plant nutrients in soils of Mid Central Valley at Odisha Zone, India, American Journal of Experimental Agriculture. 2015; 7(4):214-221.
32. Pattnaik T. Preparation of GPS-based soil fertility maps and identification of soil-related crop production constraints for Dhenkanal District, Odisha (PhD thesis). Department of chemistry, institute of technical education and Research, Siksha 'O' Anusandhan University, Bhubaneswar; 2016.
33. Dash PK, Panigrahi N, Mishra A. Identifying opportunities to improve digital soil mapping in India: A systematic review.

Geoderma Regional. 2022c; 28, e00478. https://doi.org/10.1016/j.geodrs.2021.e00478

34. Revathi B, Saren S, Dash, PK, Mishra A, Sethy SK, Patnaik T, Dey P. Optimizing nutrient recommendations for bottle gourd crop by formulation of targeted yield equations in an *Inceptisol* of Odisha, India, Asian Journal of Soil Science and Plant Nutrition. 2024;10 (2):223-235.
35. Digal M, Saren S, Mishra A, Dash PK, Swain N, Acharya BP. Soil fertility status of some villages in Phiringia Block of Kandhamal District under North-Eastern Ghat Agro-Climatic Zone of Odisha, India. Journal of Pharmacognosy and Phytochemistry. 2018;7 (6):659-662.
36. Sethy SK, Mishra A, Dash PK, Sraen S, Dey P. Geo-Information based soil fertility status of Deogarh district of Odisha. India. International Journal of Current Microbiology and Applied Sciences. 2019;8 (12):255-262.
37. Swain N, Mishra A, Saren S, Dash PK, Digal M, Mishra BB. Soil fertility status of some villages in Khordha and Bhubaneswar block of Khordha district under Northeastern Ghat agro-climatic zone of Odisha, India. International Journal of Current Microbiology and Applied Sciences. 2019;8 (1): 415-423.
38. Lokya T, Mishra A, Saren S, Dash PK. GPS and GIS-based soil Fertility maps of KVK farm, Nayagarh located in the North-Eastern Ghat Agro-Climatic zone of Odisha. India. Journal of Pharmacognosy and Phytochemistry . 2020; 9(4):599-605.
39. Singh RP, Mishra A, Dash PK, Saren S, Mallik H, Mishra BB. Soil fertility assessment of some villages in Kankadahad block of Odisha. Environment and Ecology. 2021;39(1A):250-255.
40. Kishore MA, Mishra A, Dash PK, Saren S, Das TK, Priyadarsini S, Sethy H, Sardar MS. 2022. Vertical distribution of available nutrients in Boudh Block of Boudh District Catena. International Journal of Plant & Soil Science. 2022; 34:1681-1686.
41. Kishore M, Baskar A, Dash PK, Bagavathi AU, Mishra A, Saren S. Distribution of different potassium fractions in the soil profiles of Karaikal, Puducherry. International Journal of Chemical Studies. 2020;8(2): 01-05.
42. Sharma BD, Jassal HS. Study of a toposequence for variability in micronutrients from the Moist Sub Humid Siwalik agro-ecological sub region of Punjab, Archives of Agronomy and Soil Science. 2013; 59(4):573-591
43. Dash PK. Chapter 22 - Remote sensing as a potential tool for advancing digital soil mapping, In: Dharumarajan, S., Kaliraj, S., Adhikari K, Lalitha M, Kumar N. (Eds.), Remote Sensing of Soils. Elsevier. 2024;357-370.



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