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Characterization and Classification of Soils of Chamba Block of Tehri Garhwal District of Uttarakhand, India: A Case Study from Lesser Himalayas

Vikas Joon [a++*], Rajesh Kumar Meena [a#], Ritu Nagdev [a++] and Jaya N. Surya [a†]

[a] *ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Center, Delhi-110012, India.*

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

In the present study, an attempt was made to characterize and classify the soils occurring on different topography in the Chamba block of Tehri Garhwal district of Uttarakhand. A detailed soil survey was carried out by simple random sampling and studying master profiles using Landscape Ecological Unit's map on 1:10000 scale to study the soils. The high-resolution remote sensing data product derived from the IRS-R2, specifically the LISS-IV data and GIS approaches were used. Nine representative pedons (covering all the soil types) were studied for their morphological, physical and chemical properties. These soils were very shallow to deep, dark grayish brown to

[++] *Scientist;*
[#] *Senior Scientist;*
[†] *Head & Principal Scientist;*
**Corresponding author: Email: vikashhau@gmail.com;*

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dark brown/dark yellowish brown, brown to dark yellowish brown, dark grayish brown to olive brown and very dark grayish brown to dark yellowish brown in colour. Structure of the surface soils varied from sub-angular blocky to disturbed to single grain.Soil texture varied fromsandy loam to sandy loam, sandy loam to loam, loamy sand to sand and loam to clay loam in texture, strongly acidic to acidic (<5.5-6.5) and neutral (6.5-7.5) in reaction. The electric conductivity exhibited a range from 0.17 to 1.83 dS m-1 within surface horizons and from 0.02 to 0.80 dS m-1 within the sub-surface horizons, accompanied by organic carbon content categorized as medium (0.50-0.75%) to high (>0.75%). The exchangeable cations, specifically Ca2+, Mg2+, Na+, and K+, demonstrated variability ranging from 4.90 to 10.40, 1.30 to 4.00, 0.39 to 1.01, and 0.44 to 1.27 cmol p+kg-1, respectively, in surface horizons. Base saturation (BS) varied from 80 to 92% in surface horizons and from 68 to 91% in the sub-surface horizons. The cation exchange capacity (CEC) varied between 8.6 to 19.9 cmol p+kg-1 in surface horizons and from 2.7 to 17.2 cmol p+kg-1 in the sub-surface horizons. The soils were classified within the *Entisols* and *Inceptisols* orders. To ensure sustainable agricultural production within these soils, it is imperative to implement appropriate management strategies to mitigate the impacts of soil degradation.

Keywords: Landforms, soil characterization; soil classifications; soil physico-chemical properties; western Himalayas.

1. INTRODUCTION

Soil is one of the vital natural resources as it produces food, fodder, fiber and fuel for burgeoning population of human and animals. In hilly areas, the cultivated area is limited for biomass production. At the same time, this biomass production is constrained by spatial physico-chemical properties such as depth, drainage, soil reaction (pH) and so on. The existing soil degradation in the regionis further aggravated by susceptible geology, topography, inappropriate agricultural practices; indiscriminate deforestation and climate change [1,2]. The lesser Himalayas characterized by varying elevations, slopes, climatic conditions and they influence the soil properties and its uses. Such variations in soil properties have different suited uses such as agriculture,forestry, horticulture and grasslands. A comprehensive investigation was conducted to evaluate the soil resources within the region characterized by the warm humid lesser western Himalayas. The findings of the research indicate that the region predominantly features steep to very steep terrain, rendering it susceptible to severe to very severe soil erosion [3]. It can be inferred the physicochemical properties of the soil exhibit variability corresponding to alterations in the vegetation composition (forest types) at varying elevations in the Western Himalaya [4]. An empirical study was executed in the mid-Himalayan region to ascertain the influence of altitude on various soil properties. The results of this investigation demonstrated that the chemical and physical characteristics of the soils were differentially influenced by altitudinal changes, serving as a critical foundation for the initiation of scientifically informed management of soil resources in the region [5,6]. Due to inherent bio-physical constraints in production ecosystem in hilly region makes them susceptible to high risk and have low resilience against climate change [7,8]. In addition, increasing agriculture moisture stress is likely due to erratic and intense rainfall in the rainfed production system of hilly regions. In such a scenario, reorientation of rainfed agriculture by soil and water conservation, rainwater harvesting, crop diversification, and adopting eco-sustainable agriculture practices has been suggested against climate change [9]. Therefore, adetailed scientific appraisal of soil resources is essential to know their constraints, potentials, capabilities and suitability for various uses [10,11,12]. Such a detailed database will help to understand soil capabilities for developing scientific land use plans, resource conservation planning, optimizing economic returns and adoption site-specific climate resilient practices, technologies for sustainable production and management of soil resources in the ecologically fragile and socio-economically backward region of Himalaya. In view of the above, a detailed soil survey of Chamba block of Tehri Garhwal district, Uttarakhand was conducted using the latest geospatial technology to generate a soil resource database.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was carried out in Chamba block (30º8′52′′N to 30º24′32′′N and 78º15′22′′E to

78º36′21′′E, TGA:16256 ha) of Tehri Garhwal district in Uttarakhand state, located on the outer ranges of the mid-Himalayas. It falls in warm, moist dry sub-humid agro-ecological sub-region (AESR) No. 14.2 [13]. The physiography of the block is characterized by high mountain peaks, deep gorges and valleys. Geology of the block is very complex due to the repeated tectonic disturbances caused by different orogenic cycles. A group of regionally metamorphosed rocks known as Central Crystalline are exposed in the Central Himalayas. Major rock types of Central Crystalline are migmatites, psammitic and mica gneiss, calc gneiss, quartzite, marble mica schist and amphibolites. Granites of different ages ranging from Paleoproterozoic to Mesozoic- Tertiary intrude the Central Crystalline [14].

The climate varies from cold temperate, tropical to sub-tropical. January is the coldest month andthe temperature becomes highest usually during June. Relative humidity in the area increases rapidly with the onset of monsoon and reaches maximum (85%) during August. The average annual rainfall of the area is 1894.2 mm and it varied from 449.9 mm to 1388.1 mm. The soil moisture control section (SMCS) does not remain dry in any part of it for as long as 90 cumulative days in a year or any part of it does not remain dry for as long as 45 consecutive days after summer solstice suggesting udic soil moisture regime in the area [13,15]. During the summer the average temperature is 20°C, varying between 13.6 and 25.2°C, whereas, in winter the average mean temperature is 16.3°C, varying between 11.1 and 19°C, thus the area qualifies for thermic temperature regime [15,16]. The principal kharif crops grown in the area are maize, rice and finger-millets while during the rabi season, wheat, barley and vegetables crops are the main crops. The natural vegetation consists of trees of pine, conifers, sal, deodar, rhododendron, birch, alder and various types of fruit tree like the cornel, figs, jaiphal, mulberry, apples, pears, apricots, plums, peaches, oranges and limes are found in the block besides a variety of herbal plants bushes, shrubs, grass and weeds.

2.2 Remote Sensing Data

The high-resolution remote sensing data product derived from the IRS-R2, specifically the LISS-IV, possesses a swath width of 23 km, and includes geocoded data in the form of a stereo pair of Cartosat-1 digital merged datasets, in conjunction with toposheets numbered 53J and 53N at a scale of 1:50,000, which were subsequently enlarged to a scale of 1:10,000. The remote sensing data underwent both digital and visual interpretation, utilizing various photomorphic characteristics such as tone, texture, dimensionality, and morphological variations to facilitate the identification of diverse landforms and other surface features. Google Earth data, also at a scale of 1:10,000, was employed to ascertain land use and land cover information across different landform units. The interpretation of satellite data was conducted to perform terrain analysis, delineating terrain attributes including relief, contour lines, elevation, drainage patterns, slope, landform characteristics, and land use/land cover, culminating in the generation of corresponding maps. An automated procedure for the delineation of landforms and Landscape Ecological Units (LEUs) has been established through the utilization of terrain attributes. The base map was meticulously prepared by transcribing the details from Survey of India toposheets, which were then reduced to a scale of 1:10,000 without any simplification. This layer of information was subsequently superimposed onto the LEU map, thereby producing the final base map intended for field work.

2.3 Soil Survey and Soil Sampling Techniques

A detailed soil survey was carried out by simple random sampling and studying master profiles using Landscape Ecological Unit's map on 1:10000 scale to study the soils [17]. Representative pedons were meticulously analyzed within each Landscape Ecological Unit. Through a comprehensive examination of the soil profiles, the soils were delineated according to their morphological and physico-chemical properties. In consideration of the soil-site characteristics, the soils were classified into distinct soil series (a soil series represents the most uniform unit exhibiting analogous horizons and properties, which demonstrate similar behavior under a specified level of management). The principal distinguishing characteristics of the soil series identified within the region included soil depth, texture, coloration, calcareousness, salinity presence, and horizon sequence. Nine typical pedons, covering all the major landforms (Table 1) were selected for characterization of soils and soil samples were collected from all the horizons of the selected pedons.

2.4 Physico-Chemical Characterization of Soil Samples

The horizon wise soil samples of the representative pedons were air-dried and the fine fraction (2mm) was analyzed for various physical and chemical properties such as particle size distribution, pH, EC, organic carbon, cation exchange capacity, exchangeable bases as per the standard laboratory procedures [18,19,20]. The horizon-wise morphological properties including depth, color, structure, texture, gravels, consistence, and occurrence of nodules were described using soil description guidelines [21]. The soils were classified as per Keys to Soil Taxonomy [22].

3. RESULTS AND DISCUSSION

3.1 Morphological Characteristics

Pedons P7 and P9 were deep with more than 100 cm depth, and the pedons P6 and P8 were moderately deep, and P3 and P5 were moderately shallow, while, P1, P2 and P4 were shallow (Table 2). The variation in the depth could be attributed to the variation in elevation of the different landforms, slope, topography and earlier geomorphic processes of sub-humid regions. Soils with similar depth variation occur in various landforms in the sub-humid regions of Almora district [23].

The colour of the pedon P7 was dark yellowish brown to brown to dark yellowish brown (10YR4/4, 3/4, 4/6) while pedon P9 was very dark grayish brown to dark yellowish brown (10YR3/2, 3/3, 3/4). The pedon P6 has colour varying from very dark grayish brown to dark yellowish brown and brown to dark yellowish brown (10YR4/3, 3/4) while P8 has colour varying from dark grayish brown to olive brown (2.5Y4/3, 4/4, 4/3). The pedons P3 and P5 were brown to dark brown to dark yellowish brown (10YR4/4, 3/3, 3/4) to brown to dark yellowish brown (10YR4/3, 4/4) in colour. The pedons P1, P2 and P4 were dark yellowish brown (10YR4/4) to dark grayish brown (10YR4/2) to brown to dark yellowish brown (10YR4/3, 4/4). The variation in the colour of surface and sub-surface horizons appears to be the function of chemical and mineralogical composition of soils [24]. The 10YR hue observed in the pedons P1, P2, P3, P4, P5, P6, P7 and P9 could be due to moderate weathering of basaltic parent material [25].

The size of the structure varied from 0 to 2 and strength of the structure varied from moderate to fine to weak and the structure of the surface soils varied from sub-angular blocky (P9) to single grain (P1, P2, P3, P4, P5, P6, P7 and P8). There is not so much variation in the structure of the surface horizons due to slopes, organic matter content and erosion in the region.

3.2 Physical Characteristics

The data of the physical properties of the nine pedons is presented in Table 3. Sand content varied from 49.8 to 85% in surface horizons and from 37.7 to 91.5% in the sub-surface horizons. The sand content showed irregular distribution with depth in all the pedons. Silt content varied from 9.5 to 37.7% in surface horizons and from 5.5 to 38% in the sub-surface horizons. The silt content also showed irregular trend with depth in the pedons, except in P1, P2, P5 and P7 where, it increased with depth. Clay content varied from 5.5 to 17.5% in surface horizons and from 2.25 to 29% in the sub-surface horizons. The clay content of the sub-surface horizons was higher than the surface horizons in the pedons, except in P2, P4 and P8 where in, it decreased with depth.

Soil texture varied from sandy loam (P1, P2, P3, P4, P5, P6 and P7) to loam (P9) to loamy sand (P8) in surface horizons and from sandy loam to sandy loam (P1, P2, P3, P4, P5 and P6), sandy loam to loam (P7), loamy sand to sand (P8) and loam to clay loam (P9) in the sub-surface horizons. As observed in the present study, the loamy, loamy skeletal and fine loamy soils are common in the sub-humid region. Similar soils were also reported in previous studies of sub-humid region [15,23].

3.3 Chemical Characteristics

Soil reaction (pH) varied from 3.8 to 6.98 in surface horizons and from 3.4 to 7.61 in the sub-surface horizons (Table 4). The pH ranges from 5.5 to 6.5 indicates that pedons P3, P4, P6 and P7 are acidic in nature while pedons P1, P2 and P5 has pH less than 5.5 are grouped as strongly acidic in nature and remained pedons P8 and P9 are neutral (Table 4). The most of the soils are acidic in reaction, non-calcareous, mixed in mineralogy and have thermic soil temperature and udic soil moisture regimes [26]. EC varied from 0.17 to 1.83 dS m^{-1} in surface horizons and from 0.02 to 0.80 dS m^{-1} in the sub-surface horizons. The EC, generally, increased with depth (P1) but in this study EC decreased with depth, where the surface horizons had higher EC than their sub-surface horizons (Table 4). However, the soils were, generally, non-saline.

Table 1. Site characteristics and land use of studied pedons

Pedon	Landform	Elevation (m)	Slope (%)	Drainage	Run-off	Erosion	Present land use
P1	Upper hillside slopes	1514	33-50	excessive	very rapid	severe	wheat
P2	Upper hillside slopes	1302	25-33	excessive	very rapid	severe	Arhar, wheat
P3	Upper hillside slopes	1897	25-33	somewhat excessive	rapid	severe	Potato, wheat, pea, barley, mandua
P4	Lower hillside slopes	1169	10-15	well	medium	moderate	Wheat, mandua
P5	Lower hillside slopes	1680	15-25	well	rapid	moderate	Paddy, Jhangora, wheat, pea
P6	Lower hillside slopes	1521	25-33	excessive	rapid	severe	Wheat, mandua, arhar, rajma
P7	Lower hillside slopes	1662	15-25	well	rapid	moderate	Wheat, pea, arhar, rajma
P8	River terraces	1092	3-5	somewhat excessive	medium	moderate	Wheat, paddy, tomato
P9	River terraces	1086	3-5	moderately well	medium	moderate	Wheat, paddy, tomato, pea

Table 2. Morphological characteristics of the studied pedons

Pedon	Depth (cm)	Horizon	Boundary	Munsell Colour (Moist)	Structure	Gravel (%)	Plasticity	Roots
P1	0-17	Ap	c s	10YR 4/4	f 0 sg	60	p0	m vf f
	17-25	AC		10YR 4/4	massive	>80	p0	vf c
P2	0-16	Ap	c s	10YR 4/2	f 0 sg	70	p0	m vf f
	16-36	AC		10YR 4/2	massive	>80	p0	m vf
P3	0-12	Ap	c s	10YR 4/4	f 1 sg	60	p0	vf f c
	12-34	C1	g s	10YR 3/3	f 0 sg	70	sp	vff
	34-61	C2		10YR 3/4	f 0 sg	>90	sp	vff
P4	0-11	Ap	c s	10YR 4/3	f 0 sg	50	p0	vf f c
	11-29	AC		10YR 4/4	massive	>70	sp	vf c
P5	0-15	Ap	c s	10YR 4/3	f 0 sg	45	p0	vf f c
	15-29	AC	c s	10YR 4/4	f 1 sbk	50	sp	vf f c
	29-37	C1	g s	10YR 4/4	f 0 sg	50	sp	vff
	37-55	C2		10YR 4/4	f 0 sg	>80	p0	-
P6	0-18	Ap	c s	10YR 4/3	f 0 sg	50	p0	vf f c
	18-44	AC	g s	10YR 3/4	f 0 sg	50	p0	vff
	44-59	C1	g s	10YR 3/4	f 0 sg	70	p0	vff
	59-75	C2		10YR 3/4	f 0 sg	>90	sp	-
P7	0-17	Ap	c s	10YR 4/4	f 0 sg	20	sp	m vf f
	17-46	Bw1	c w	10YR 3/4	m 2 sbk	20	sp	vf f c
	46-74	Bw2	c s	10YR 4/4	m 2 sbk	20	sp	vff
	74-98	BC	g s	10YR 4/6	m 1 sbk	40	sp	-
	98-127	C		10YR 4/6	m 1 sbk	>80	sp	-
P8	0-15	Ap	c s	2.5Y 4/3	f 0 sg	15	p0	m vf f
	15-31	1C1	c s	2.5Y 4/4	f 0 sg	50	p0	vf f c
	31-50	1C2	c s	2.5Y 4/3	f 0 sg	60	p0	vff
	50-71	2C3	g s	2.5Y 4/3	f 0 sg	60	p0	vff
	71-88	2C4		2.5Y 4/3	f 0 sg	>80	p0	vff
P9	0-19	Ap	c s	10YR 3/2	f 1 sbk	15	sp	vf f c
	19-34	Bw1	c s	10YR 3/2	m 1 sbk	50	sp	vff
	34-48	Bw2	g s	10YR 3/2	m 1 sbk	70	sp	vff
	48-77	Bw3	g s	10YR 3/3	m 1 sbk	40	sp	-
	77-91	Bw4	g s	10YR 3/4	m 1 sbk	40	sp	-
	91-111	C		10YR 3/4	massive	60	sp	-

Organic carbon (OC) contents varied from 0.76 to 3.16% in surface and from 0.16 to 3.06% in the sub-surface soils. Most of the soils fall in high level of organic carbon due to dense vegetation cover and slow decomposition followed by medium in organic carbon which includes mostly very severely eroded soil and intensively cultivated land [15].

The exchangeable cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} varied from 4.90 to 10.40, 1.30 to 4.00, 0.39 to 1.01 and 0.44 to 1.27 cmol $p^{+}kg^{-1}$, respectively, in surface horizons. In the sub-surface horizons, the bases varied from 1.00 to 8.50, 0.30 to 3.90, 0.20 to 0.69 and 0.15 to 0.65 cmol $p^{+}kg^{-1}$ in the same order. Base saturation (BS) varied from 80 to 92% in surface and from 68 to 91% in the sub-surface.

The cation exchange capacity (CEC) varied from 8.6 to 19.9 cmol $p^{+}kg^{-1}$ in surface and from 2.7 to 17.2 cmol $p^{+}kg^{-1}$ in the sub-surface. Nutrient holding capacity of pedons P1, P2, P3, P4, P5, P6 and P8 soils was very low to medium as revealed from cation exchange capacity (CEC) which ranged from 2.70 to 19.90 cmol$p^{+}kg^{-1}$. This is due to coarse texture having very less clay content. The higher CEC value of surface soils in comparison to clay content is due to higher organic matter content in top soils. The pedons P7 and P8 exhibited medium nutrient holding capacity as reflected in their CEC values which ranged from 9.80 to 14.40 cmol $p^{+}kg^{-1}$, as these soils are loam to clay loam in texture and have comparatively high clay content.

Table 3. Physical characteristics of the studied pedons

Pedon	Depth (cm)	Horizon	Sand (%)	Silt (%)	Clay (%)	Texture
P1	0-17	Ap	59.95	26.55	13.00	Sandy loam
	17-25	AC	57.70	29.30	13.50	Sandy loam
P2	0-16	Ap	53.70	30.80	15.50	Sandy loam
	16-36	AC	52.65	32.85	14.50	Sandy loam
P3	0-12	Ap	53.05	31.95	15.00	Sandy loam
	12-34	C1	53.15	29.35	17.50	Sandy loam
	34-61	C2	53.55	23.95	22.50	Sandy loam
P4	0-11	Ap	56.95	25.55	17.50	Sandy loam
	11-29	AC	58.10	25.65	16.25	Sandy loam
P5	0-15	Ap	55.85	27.65	16.50	Sandy loam
	15-29	AC	54.50	30.50	15.00	Sandy loam
	29-37	C1	53.10	28.40	18.50	Sandy loam
	37-55	C2	53.05	24.45	22.50	Sandy loam
P6	0-18	Ap	54.05	28.45	17.50	Sandy loam
	18-44	AC	55.05	27.70	17.25	Sandy loam
	44-59	C1	55.40	27.10	17.50	Sandy loam
	59-75	C2	54.50	28.00	17.50	Sandy loam
P7	0-17	Ap	53.50	29.00	17.50	Sandy loam
	17-46	Bw1	41.75	38.00	20.25	Loam
	46-74	Bw2	44.45	37.30	18.25	Loam
	74-98	BC	44.25	36.00	19.75	Loam
	98-127	C	43.25	36.50	20.25	Loam
P8	0-15	Ap	85.00	9.50	5.50	Loamy sand
	15-31	1C1	91.50	6.00	2.50	Sand
	31-50	1C2	90.00	5.50	4.50	Sand
	50-71	2C3	91.00	6.50	2.50	Sand
	71-88	2C4	91.00	6.75	2.25	Sand
P9	0-19	Ap	49.80	37.70	12.50	Loam
	19-34	Bw1	50.00	30.00	20.00	Loam
	34-48	Bw2	39.00	32.50	28.50	Clay loam
	48-77	Bw3	39.40	31.85	28.75	Clay loam
	77-91	Bw4	37.85	33.15	29.00	Clay loam
	91-111	C	37.75	33.50	28.75	Clay loam

Table 4. Chemical characteristics of the studied pedons

Pedon	Depth (cm)	Horizon	pH	EC (dS m^{-1})	OC (%)	Exch. Ca	Exch. Mg	Exch. Na	Exch. K	CEC	BS (%)
						------------------c mol p^+kg^{-1}-------------------					
P1	0-17	Ap	3.8	0.50	2.83	5.20	1.30	0.51	0.80	8.60	91
	17-25	AC	3.4	0.78	1.22	3.80	1.80	0.35	0.34	8.00	79
P2	0-16	Ap	5.18	0.66	2.18	7.90	2.80	0.61	0.96	14.80	83
	16-36	AC	4.74	0.21	1.34	5.10	2.60	0.46	0.45	11.50	75
P3	0-12	Ap	5.91	0.17	3.06	10.40	4.00	0.76	1.27	19.90	83
	12-34	C1	6.31	0.05	2.98	8.50	3.90	0.44	0.40	17.20	77
	34-61	C2	6.25	0.07	0.88	7.50	2.50	0.69	0.52	12.60	89
P4	0-11	Ap	5.72	0.63	0.57	6.50	2.80	0.52	0.76	11.60	91
	11-29	AC	6.02	0.15	0.42	5.40	2.50	0.43	0.47	10.40	85
P5	0-15	Ap	3.9	1.83	0.99	6.20	2.10	0.42	0.44	10.00	92
	15-29	AC	4.6	0.22	0.53	5.00	1.50	0.36	0.32	9.00	80
	29-37	C1	5.2	0.8	0.50	7.00	2.60	0.40	0.39	12.10	86
	37-55	C2	5.1	0.6	0.42	4.90	1.80	0.40	0.39	9.30	81
P6	0-18	Ap	5.95	0.43	0.76	7.60	3.60	0.39	0.45	14.00	86

Pedon	Depth (cm)	Horizon	pH	EC (dS m^{-1})	OC (%)	Exch. Ca	Exch. Mg	Exch. Na	Exch. K	CEC	BS (%)
						------------------c mol p^+kg^{-1}-------------------					
	18-44	AC	5.81	0.06	0.57	2.90	0.90	0.48	0.65	6.00	82
	44-59	C1	6.05	0.04	0.38	3.50	1.10	0.40	0.34	6.90	77
	59-75	C2	6.03	0.05	0.19	3.80	2.00	0.36	0.34	7.40	88
P7	0-17	Ap	5.70	0.17	1.63	7.70	2.70	0.47	0.52	14.30	80
	17-46	Bw1	5.92	0.07	1.31	7.60	2.60	0.42	0.42	13.10	84
	46-74	Bw2	5.90	0.06	1.23	7.80	2.70	0.42	0.64	13.30	87
	74-98	BC	6.13	0.08	0.56	6.90	2.70	0.46	0.45	12.50	84
	98-127	C	6.17	0.02	0.44	6.30	2.30	0.50	0.43	11.50	83
P8	0-15	Ap	5.11	0.39	1.59	4.90	2.00	0.59	0.62	9.80	83
	15-31	1C1	6.33	0.04	0.56	1.80	0.50	0.49	0.26	4.10	74
	31-50	1C2	6.62	0.03	0.28	1.10	0.50	0.48	0.15	3.10	72
	50-71	2C3	6.63	0.02	0.16	1.30	0.30	0.20	0.17	2.90	68
	71-88	2C4	6.61	0.03	0.16	1.00	0.40	0.45	0.30	2.70	80
P9	0-19	Ap	6.98	0.55	3.16	7.20	3.40	1.01	0.76	13.50	92
	19-34	Bw1	7.61	0.13	3.06	5.20	2.70	0.57	0.35	10.10	87
	34-48	Bw2	7.53	0.11	0.80	6.40	2.80	0.42	0.47	11.10	91
	48-77	Bw3	7.46	0.08	0.72	7.20	3.00	0.65	0.59	12.90	89
	77-91	Bw4	7.41	0.09	0.68	7.00	2.30	0.64	0.58	11.90	88
	91-111	C	7.32	0.08	0.60	8.20	2.90	0.60	0.58	14.40	85

3.4 Soil Classification

The study area belongs to udic soil moisture regime and the soils were classified into two orders viz. Entisols and Inceptisols. The pedons P1, P2 and P4 were classified as loamy-skeletal, mixed, thermic lithic udorthents. The pedon P3 classified as loamy, mixed, thermic typic udorthents. The pedon P5 classified as fine-loamy, mixed, thermic typic udorthents. The pedons P6 and P7 were classified as fine-loamy, mixed, thermic dystric eutrudepts. The pedon P8 was classified as sandy-skeletal, mixed, thermic typic udifluvents and the pedon P9 was classified as fine-loamy, mixed, thermic mollic udifluvents.

4. CONCLUSION

Nine pedons from the sub-humid region of Chamba block of Tehri Garhwal district, Uttarakhand were characterized for their morphological, physical, and chemical properties. The variation in depth of the soils indicates that the soil formation was influenced by variation in elevation of the different landforms, slope, and earlier geomorphic processes of sub-humid regions. The loamy-skeletal texture of the soils indicates that erosion and fluvial activity were the common processes in the study area. For sustainable crop production in these soils, suitable management measures need to be implemented to prevent the effects of soil degradation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declared that NO generative AI technologies such as Large Language Models (Chat GPT, COPILOT, etc.) and text-to-image generators have not been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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