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Assessment of Physical Properties of Soils of Darjeeling District, West Bengal, India

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ABSTRACT: The study was undertaken in 2020-2021 aiming to assess the physical properties of soils from Darjeeling district, West Bengal. Soil samples were collected from 9 different villages at profile depths of 0-15cm, 15-30cm and 30-45cm. The data revealed that the selected soil samples varied from brown to "yellowish brown colour in dry condition" while "dark brown colour predominated in the wet condition". "Domination of textural class, sandy clay loam" was seen in more than six villages. The value of specific gravity augmented with depth and ranged from "1.61 Mg m^{-3} to 2.57 Mg m^{-3}". The water holding capacity and pore space percentage varied from "61.53 to 76.92% and 50 to 61.1%" respectively. The values of bulk density and particle density did not show much variation with depth but significant difference was found due to site with respect to particle density. Owing to the paucity of information on layered characteristics of soil physical properties in various sites of Darjeeling region, this study will undoubtedly prove to be beneficial for the agricultural community in the small city. Armed with this information, farmers can define the quantity of fertilizers to improve the soil in the terrace farms. This is essential because fertile soils are necessary to grow healthy crops. Although the region has solely adopted organic farming from time immemorial, the disadvantages of fully adopting the organic farming system may be mitigated by the information retrieved from this study and its proper implementation when required.

Keywords: Physical properties, soil analysis, Darjeeling, bulk density, water holding capacity.

INTRODUCTION

The physical properties of soil play a great role in influencing plant growth and microbial activity, soil moisture regimes, aeration etc. which in turn affect crop production. Bulk density and total porosity can better represent the effects of soil use and management on the water and air relationships (Beutler *et al*., 2002). High bull density of soil reduces vegetative cover, exposes the soil to erosion and leads to water logging in of flat surfaces (Price, 2009). Particle density of a soil is found to increase with depth while bulk density decreases. Soil colour gives an indication of various processes going-on in the soil. The variations in the soil colour are due to organic substances, iron compounds, silica, lime and other inorganic compounds (Balasubramanian, 2017). Texture refers to the relative proportions of various sizes such as sand, silt and clay in the soil, also, soil texture and structure greatly influence water infiltration, permeability, and water holding capacity (Vega *et al*. 2012). In general, a soil is considered physically poor when it shows low rates of water infiltration, enhanced surface runoff, poor cohesion, low aeration and root density, and difficulty for mechanization (Dexter, 2004).

Agriculture being one of the main occupations of people living in rural parts of Darjeeling, makes it more important for the soil to be physically healthy and fertile so that soil can provide optimum nutrients, water, microbial activity, air, temperature etc. The region practices organic farming. Agriculture yield of major crops in the Himalayan region has been stagnant over the last few decades (Shrestha *et al*., 2017). The Darjeeling gneiss occupies a greater part of the region and is found along the higher reaches of the hills. The Darjeeling gneiss consists of garnetiferous mica-schists, quartzites, and biotite-kaolinite and sillimantic gneiss. The Darjeeling gneiss is met with traverses along Sukhia Pokhri - Maney Bhanjang – Tonglu, Sandhakphu-Phalut road and also along the Phalut-Rammam-Rimbick-Jhepi-Pulbazar-Darjeeling Road (Cajee, 2018). Various factors have been identified as the major cause for the poor productivity, which includes inadequate irrigation and improper cultivation (Joshi *et al*., 2013). The hill region of Darjeeling districts has been facing major problem of landslides especially during monsoon (Government of India, 2010).

The physical properties of the soil are very important for agricultural production and the sustainable use of soil. The amount and rate of water, oxygen and nutrient absorption by plants depend on the ability of the roots to absorb the soil solution as well as the ability of the soil to supply it to the roots. Maintenance of optimum soil physical conditions is important for sustaining plant growth and other living organisms in soils. Poor soil structure results in poor water and aeration conditions the restrict root growth, thus limiting efficient utilization of nutrients and water by plants (Almendro-

Candel *et al.*, 2018). Degradation of soil due to soil erosion, as a result of rainfall events of moderate and heavy magnitude and frequency is the major cause of concern for declining agricultural productivity in the area undertaken for study. The present study was therefore conducted owing to scarcity of information on layered physical characteristics of soil in the Darjeeling district and to serve as a database for making suitable modifications to farming practices for the enhancement of crop productivity.

MATERIALS AND METHODS

A. Soil Sampling

Soil samples were collected from agricultural fields of 9 different villages' which fall under three community development blocks viz., Rangli-Rangliot, Jorbunglow-Sukhiapokharii and Mirik. The profile depths were 0-15cm, 15-30cm, 30-45cm. Several small sampling units may yield a better representation of the whole soil than does a single large sample. In view of this, 27 samples were collected in total with 3 samples representing one village each. Soil sample collection from the edges of the field was omitted. Samples were collected using khurpi by random selection. The samples were air dried and all the unwanted materials were removed. Large clods were crushed by hand and wooden mallet and then ground using wooden mortar and pestle. Grinding was followed by sieving for which 2.0 mm sieve was used. Sieved soil samples were stored in air-tight plastic bags and tagged for estimation of physical properties.

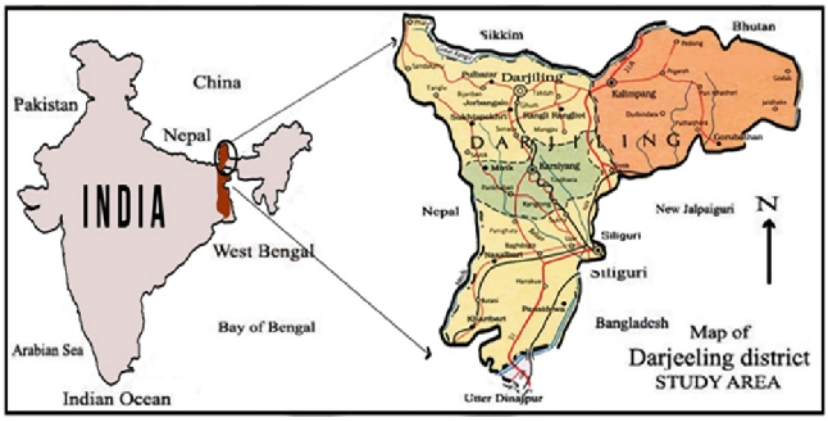


Fig. 1. Location of the study area.

B. Analysis of physical parameters

Soil textural analysis of particles less than 2 mm was performed by the Hydrometer method (Bouyoucos, 1927). The samples were matched against standard Munsell soil colour chart (Munsell, 1971) to obtain hue, value and chroma combinations for soil colour. The bulk density, particle density, pore space and water holding capacity was determined by the Graduated 100 ml Measuring Cylinder Method (Muthuvel *et al*., 1992). Specific gravity of soil was determined by the relative density bottle or pycnometer method as laid out by Black (1965).

C. Statistical Analysis

The data recorded during the course of investigation was subjected to statistical analysis by the method of analysis of variance (ANOVA) technique (Fisher, 1960). The type of ANOVA adopted for the experiment was two- factor analysis without replication. The implemented design of experiment in the analysis done was Completely Randomized Design CRD).

RESULTS AND DISCUSSION

A. Soil texture

The texture in villages one and three of the Rangli-Rangliot block was clay loam while, loam texture was seen in the second village. Similarly, in the Sandakpur-Jorbunglow block, villages one and three had clay loam texture while loam texture was found in second village. Third block Mirik, was found to have sandy clay loam texture in villages one and three while sandy loam texture dominated the second village (Table 1). The sand content in the studied soils ranges from 22.3-59.2%, silt from 17-39.5% and clay from 18-39.7%. The high content of clay in majority of these soils makes it fit for cultivation of paddy. Similar findings were reported by Majumdar *et al.*, (2014).

Bulk density (Mg m^{-3}): The bulk density values of nine villages from three community development blocks were, 1.07Mg m^{-3}, 1.07Mg m^{-3}, 1.03Mg m^{-3}, 1.07Mg m^{-3}, 1.05Mg m^{-3}, 1.07Mg m^{-3}, 1.03Mg m^{-3}, 1.08Mg m^{-3} and 1.11Mg m^{-3} respectively (Table 2). The maximum value recorded was 1.11g cm^{-3} which indicated that the soil is widely composed of clay and aggregated loams. The minimum bulk density recorded was 1 Mg m^{-3} which indicates the presence of high organic matter. Bulk density was found to increase with increase in depth in some sites due to increase in compaction. Similar findings were recorded by Wankhade *et al*., (2011).

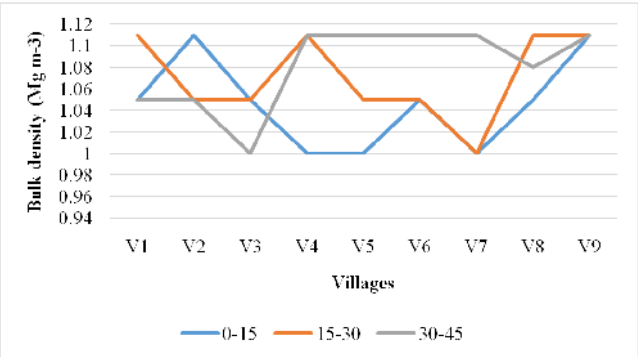
Table 1: Soil texture of different villages of Darjeeling district at 0-15cm, 15-30cm, 30-45cm depth.

Blocks	Villages	Depth(cm)	%sand	%silt	%clay	Textural class
Rangli-Rangliot	V1	0-15	25.2	36.5	38.3	Clay loam
	V1	15-30	24.4	38	37.6	Clay loam
	V1	30-45	23.6	37.5	38.9	Clay loam
	V2	0-15	34.3	42.2	23.5	Loam
	V2	15-30	36.5	39.4	24.1	Loam
	V2	30-45	37.3	41.6	21.1	Loam
	V3	0-15	26.7	34.2	39.1	Clay loam
	V3	15-30	29.7	31.8	38.5	Clay loam
	V3	30-45	28.6	34.2	37.2	Clay loam
Sandakpur-Jorbunglow	V4	0-15	51.2	18.3	30.5	Sandy clay loam
	V4	15-30	44.7	20.1	35.2	Sandy clay loam
	V4	30-45	48.6	19.3	32.1	Sandy clay loam
	V5	0-15	53.6	17	29.4	Sandy clay loam
	V5	15-30	46.9	21.9	31.2	Sandy clay loam
	V5	30-45	46.3	19	34.7	Sandy clay loam
	V6	0-15	59.2	22.3	18.5	Sandy loam
	V6	15-30	55	26.3	18.7	Sandy loam
	V6	30-45	58.4	23.6	18	Sandy loam
Mirik	V7	0-15	32.3	36.5	31.2	Clay loam
	V7	15-30	29.5	38.1	32.4	Clay loam
	V7	30-45	33.8	36	30.2	Clay loam
	V8	0-15	36.5	42.2	23.5	Loam
	V8	15-30	43.7	29.1	27.2	Loam
	V8	30-45	36.3	43	20.7	Loam
	V9	0-15	23.5	37	39.5	Clay loam
	V9	15-30	25.2	39.5	35.3	Clay loam
	V9	30-45	22.3	38	39.7	Clay loam

Table 2: Bulk density (Mg m^{-3}) of different villages of Darjeeling district at 0-15cm, 15-30cm and 30-45cm depth.

Blocks	Villages	0-15cm	15-30cm	30-45cm	Mean
Rangli-Rangliot	V1	1.05	1.11	1.05	1.07
	V2	1.11	1.05	1.05	1.07
	V3	1.05	1.05	1	1.03
Jorbunglow-Sukhiapokhri	V4	1	1.11	1.11	1.07
	V5	1	1.05	1.11	1.05
	V6	1.05	1.05	1.11	1.07
Mirik	V7	1	1	1.11	1.03
	V8	1.05	1.11	1.08	1.08
	V9	1.11	1.11	1.11	1.11
		1.05	1.07	1.07	

	F- test	SEm(±)	CD AT 5%
Due to depth	NS	0.092075	N/A
Due to site	NS	2.559196	N/A



Particle density(Mg m^{-3}): The particle density values of nine villages from three community development blocks were 2.22Mg m^{-3}, 2.27Mg m^{-3}, 2.24Mg m^{-3}, 2.31Mg m^{-3}, 2.31Mg m^{-3}, 2.5Mg m^{-3}, 2.6, Mg m^{-3} 2.65 and 2.63Mg m^{-3}, The maximum particle density (Table 3) recorded was 2.85 g cm^{-3} which indicated that the soil has low organic matter content and minimum particle density was recorded was 2.0 Mg m^{-3} indicating the presence of high organic matter, about 15 to 20%. Similar results were obtained by Barthwal *et al.*, (2019).

Soil colour: Soil colour varied from brown to yellowish brown colour in the dry condition while dark brown colour dominated in the wet condition. Dark colour corresponds to high organic matter content, and yellow colour was a result of high amount of hydrated iron oxides in the soil. The results were found in line with that of Ram *et al*., (2016) (Table 4).

Table 3: Particle density (Mg m^{-3}) of soil of Darjeeling district at 0-15cm, 15-30cm and 30-45cm depth.

Blocks	Villages	0-15	15-30	30-45	Mean
Rangli-Rangliot	V1	2.22	2.22	2.22	2.22
	V2	2.25	2.28	2.28	2.27
	V3	2.22	2.28	2.22	2.24
Jorbunglow-Sukhiapokharii	V4	2.22	2.22	2.5	2.31
	V5	2.22	2.5	2.22	2.31
	V6	2.5	2.5	2.5	2.5
Mirik	V7	2.65	2.6	2.62	2.6
	V8	2.65	2.65	2.65	2.65
	V9	2.65	2.6	2.65	2.63
		2.39	2.42	2.43	

	F- test	SEm(±)	CD AT 5%
Due to depth	NS	0.012019	N/A
Due to site	S	0.059468	4.17E-06

Table 4: Soil colour of different villages in dry and wet condition of Darjeeling district at 0- 15cm, 15-30 and 30-45cm.

BLOCKS/ VILLAGES	0-15cm		15-30cm		30-45cm	
	Dry	Wet	Dry	Wet	Dry	Wet
RANGLI-RANGLIOT						
DOKANDARA	Yellowish Brown	Brown	Yellowish brown	Dark Brown	Yellowish Brown	Brown
LABDAH	Reddish brown	Yellowish brown	Dark yellowish brown	Dark Brown	Yellowish Brown	Dark brown
RIBUNG	brown	Dark brown	Yellowish brown	Dark brown	Yellowish Brown	Dark reddish brown
JOREBUNGLOW SUKHIA-POKHARI						
SANDAKPUR	Yellowish Brown	Brown	Light yellowish brown	Dark brown	Brownish Yellow	Dark Yellowish Brown
PUBUNG	Dark brown	Dark reddish brown	Brown	Brown	Brown	Dark brown
KAIYABHIR	Very pale Brown	Olive brown	Pale brown	Dark yellowish brown	Very pale Brown	Dark yellowish brown
MIRIK						
9th MILE	Dark yellowish brown	Dark brown	Pale brown	Dark brown	Light yellowish brown	Dark brown
NAYABUSTY	Dark yellowish brown	Brown	Yellowish brown	Dark brown	Pale Yellow	Dark yellow
SOURINI	Yellowish Brown	Dark yellowish brown	Brownish yellow	Brown	Brownish Yellow	Brown

Pore space (%): The pore space values of nine villages from three community development blocks were 51.73%, 62.16%, 56.86%, 54.1%, 55.93%, 54.33%, 53.9%, 55.5% and 58.3% respectively. The range of values obtained for pore space (Table 5) was 50.0% to 68% which is indicative of clayey soils. Pore space was found to decrease with increase in depth in some of the villages. These findings were in line with that of Pandey *et al*., (2018).

Water holding capacity (%): The water holding capacity values of nine villages from three community development blocks were 69.48%, 66.9%, 60.31%, 67.4%, 70.39%, 69.85%, 70.87%, 78.16% and 71.54% respectively. The water holding capacity (Table 6) ranged from 61.53% to 82%. It indicates high clay content. The variations in water holding capacity is attributed to variation in sand, silt and clay content and organic carbon content. These findings were in line with that of Deb *et al*., (2013).

Table 5: Pore space percentage of soil of Darjeeling district at 0-15cm, 15-30cm and 30-45cm depth.

Blocks	Villages	0-15	15-30	30-45	Mean
Rangli-Rangliot	V1	52.6	50	52.6	51.73
	V2	55.5	63	68	62.16
	V3	52.6	63	55	56.86
Jorbunglow-Sukhiapokharii	V4	50	55.5	56.8	54.1
	V5	55	57.8	55	55.93
	V6	53	55	55	54.33
Mirik	V7	57.8	50	53.9	53.9
	V8	55.5	55.5	55.5	55.5
	V9	61.1	55.5	58.3	58.3
		54.78889	56.14444	56.67778	

	F- test	SEm(±)	CD AT 5%
Due to depth	NS	0.562231	N/A
Due to site	NS	1.008122	N/A

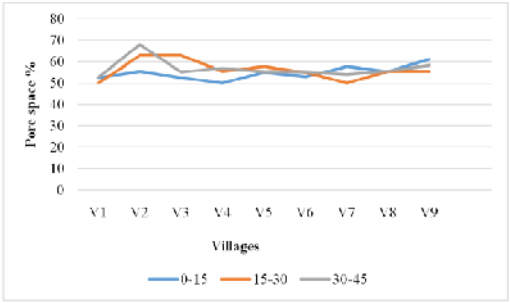
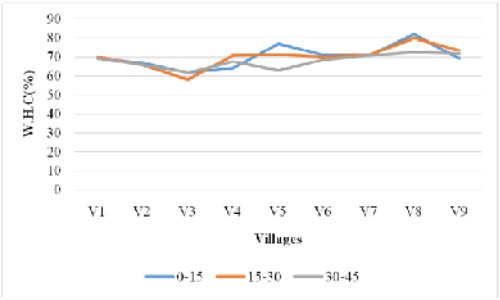


Table 6: Water holding capacity of soils of Darjeeling district at 0-15cm, 15-30cm, and 30-45cm depth.

Blocks	Villages	0-15	15-30	30-45	Mean
Rangli-Rangliot	V1	69.23	70	69.23	69.48
	V2	66.66	65.78	65.85	66.9
	V3	61.53	57.89	61.53	60.31
Jorbunglow-Sukhiapokharii	V4	64	70.8	67.4	67.4
	V5	76.92	71.42	62.85	70.39
	V6	71	70	68.57	69.85
Mirik	V7	70.7	71.05	70.87	70.87
	V8	82	80	72.5	78.16
	V9	69.23	73.62	71.79	71.54
		70.14111	70.06222	67.84333	

	F- test	SEm(±)	CD AT 5%
Due to depth	NS	0.753122	N/A
Due to site	S	1.590939	0.000707

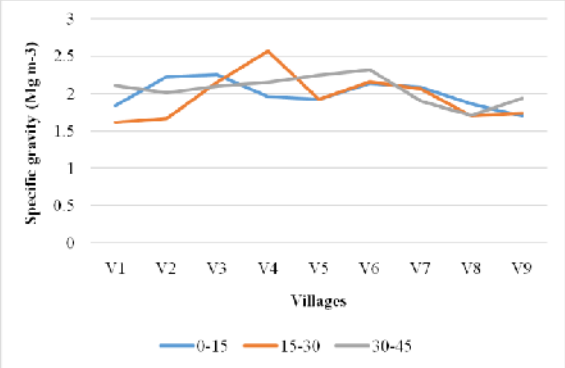


Specific gravity: The specific gravity values of nine villages from three community development blocks were 1.85, 1.96, 2.16, 2.22, 2.03, 2.2, 2.01, 1.75 and 1.79 respectively. The specific gravity (Table 7) ranged from 1.61 to 2.57 in the soils of study area which is indicative of porous particles and high organic matter content. These findings were in line with that of Sujatha *et al*., (2016).

Table 7: Specific gravity of soils of Darjeeling district at 0-15cm, 15-30cm, and 30-45cm depth.

Blocks	Villages	0-15	15-30	30-45	Mean
Rangli-Rangliot	V1	1.84	1.61	2.11	1.85
	V2	2.22	1.66	2.01	1.96
	V3	2.25	2.15	2.1	2.16
Jorbunglow-Sukhiapokharii	V4	1.96	2.57	2.15	2.22
	V5	1.92	1.92	2.25	2.03
	V6	2.13	2.16	2.32	2.2
Mirik	V7	2.08	2.06	1.9	2.01
	V8	1.86	1.7	1.71	1.75
	V9	1.7	1.74	1.94	1.79
		1.995556	1.952222	2.054444	

	F- test	SEm(±)	CD AT 5%
Due to depth	NS	0.029623	N/A
Due to site	NS	0.058494	N/A



CONCLUSION

It can be concluded that the soils of Darjeeling district have a good physical condition which favours the cultivation of most crops. Lighter soil colour was observed in the surface layer while the subsurface was characterized by darker colour. Soil texture showed high clay percentage. The bulk density values were considerably low and increased with increase in depth. The particle density also increased with depth. Low specific gravity values indicate high organic matter content. Good water holding capacity and pore space percentage is indicative of high clay content and thus makes Darjeeling terrace farms suitable for cultivation of paddy, maize, millet, ginger, buckwheat, cardamom, oranges and guava and vegetables such as cabbage, squash, spinach and a variety of other crops since these soil conditions are favorable for the growth of most crops.

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Conflict of Interest. As a Corresponding Author, I Anushka Rai, confirm that none of the others have any conflicts of interest associated with this publication.

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