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SOIL PHYSICAL PROPERTIES UNDER DIFFERENT LAND USE SYSTEMS IN EASTERN DISTRICTS OF HARYANA

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ABSTRACT

The present investigation aimed to compare the physical properties of soils with different textures under four land use systems (agriculture, horticulture, agro-forestry, and forestry) across various locations. A total of 180 soil samples were analyzed for bulk density, aggregate size distribution, and moisture retention characteristics. Results revealed that the highest bulk density (BD) was observed in soils under agriculture (1.41 Mg m^{-3}), while the lowest (1.34 Mg m^{-3}) was in forest soils. Similarly, forest soils exhibited increased moisture retention at field capacity (FC) and available water content (AWC) compared to other land use systems. The highest moisture content in clay loam soils at FC and AWC was observed to be 32.63% and 23.8%, respectively. Overall, water stable aggregates (WSA) (>0.25 mm) in forest soils were higher (43.19%) compared to agricultural soils (40.83%), with the highest mean weight diameter (MWD) of 0.96 mm in forest soils, which increased with finer texture.

Keywords: Aggregate stability, available water content, bulk density, Land use system

Soil is a vital component of any ecosystem, playing a pivotal role in determining the agricultural productivity of a particular land use system. It serves not only as a medium for crop growth but also sustains crop productivity while simultaneously maintaining or enhancing environmental and soil quality (Lal, 2008). The decline in soil quality, driven by anthropogenic activities, emerged as a significant challenge for the global scientific community in the 20th century and has continued to remain a pressing issue on the international agenda into the 21st century.

Both land use and soil management practices significantly influence soil properties and processes, including soil organic carbon dynamics, aggregation, bulk density, erosion, oxidation, mineralization, and leaching (Celik, 2005; Liu *et al.*, 2010). Faulty agricultural practices have resulted in substantial reductions in soil organic matter and the deterioration of soil fertility, leading to lower crop yields and soil quality (Korschens, 2002). Assessing land-use-induced changes in soil properties is crucial for addressing the issue of agro-ecosystem transformation and promoting sustainable land productivity (Yao *et al.*, 2010). Therefore, sustainable land use systems are essential to mitigate the risk of soil degradation while preserving soil fertility.

The adoption of different land use systems alters soil characteristics, which consequently affects soil fertility in terms of available macro- and micronutrients (Onwudike *et al.*, 2015), alteration of soil reaction, soil organic matter, soil physical condition, and microbial activity in the rhizosphere (Sarawathy *et al.*, 2007). Land use changes can also impact various natural resources and ecological processes, such as surface runoff and erosion, and changes soil resilience to environmental impacts (Hacisalihoglu, 2007). The increasing intensity of land use may lead to erosion and soil compaction by altering soil physical and chemical properties. Several studies have focused on establishing relationships between organic carbon, soil erosion, and the role of soil aggregation in organic carbon protection under different land use systems (Berhe *et al.*, 2007). In recent times, there has been growing concern among the scientific community about this alarming situation. Therefore, the objective of this study was to assess the effect of different land use systems (agriculture, horticulture, agro-forestry, and forestry) on the physical properties of soil in the eastern districts of Haryana, namely Ambala, Panchkula, and Yamunanagar.

MATERIALS AND METHODS

Soil samples were collected from four types of land use systems—agriculture, horticulture, agro-forestry, and forestry—at various locations in the districts of Ambala, Panchkula, and Yamunanagar in Eastern Haryana, and their soil properties were analyzed. The sampling sites' locations, along with their textural class and coordinates, are provided in Table 1 and Figure 1. A total of 180 surface soil samples (0-15 cm) in triplicates (12 from each location) were collected from the four types of land use systems and analyzed for various physical properties, including soil texture, bulk density, aggregate size distribution, and moisture retention characteristics. Particle size analysis (mechanical

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Table 1. Locations and coordinates of sampling sites in selected districts of Eastern Haryana, India

Sr. No.	Location	Village	Block	District	Latitude	Longitude	Soil Texture
1	L_1	Adhoi	Barara	Ambala	30.1909°N	77.0176°E	Clay loam
2	L_2	Taprian	Barara	Ambala	30.3274°N	77.1073°E	Clay loam
3	L_3	BurjSahid	Naraingarh	Ambala	30.4179°N	77.0754°E	Clay loam
4	L_4	Bari Bassi	Naraingarh	Ambala	30.4629°N	77.0733°E	Clay loam
5	L_5	Rataur	Naraingarh	Ambala	30.5054°N	77.0607°E	Clay loam
6	L_6	Garian	Pinjore	Panchkula	30.8271°N	76.8804°E	Loamy sand
7	L_7	ChandiMandir	Pinjore	Panchkula	30.7352°N	76.8949°E	Loamy sand
8	L_8	Mauli	Raipur Rani	Panchkula	30.5321°N	76.9813°E	Sandy loam
9	L_9	Golpura	Raipur Rani	Panchkula	30.5127°N	76.9876°E	Sandy loam
10	L_{10}	KakarMajra	Raipur Rani	Panchkula	30.4921°N	77.0090°E	Sandy loam
11	L_{11}	Rattangarh	Jagadhari	Yamunanagar	30.0725°N	77.1972°E	Loam
12	L_{12}	Aurangabad	Jagadhari	Yamunanagar	30.1022°N	77.2327°E	Loam
13	L_{13}	Udhamgarh	Jagadhari	Yamunanagar	30.1760°N	77.3215°E	Sandy loam
14	L_{14}	Sherpur	Chhachhrauli	Yamunanagar	30.2465°N	77.3819°E	Sandy loam
15	L_{15}	Bhilpura	Chhachhrauli	Yamunanagar	30.2508°N	77.4249°E	Loam

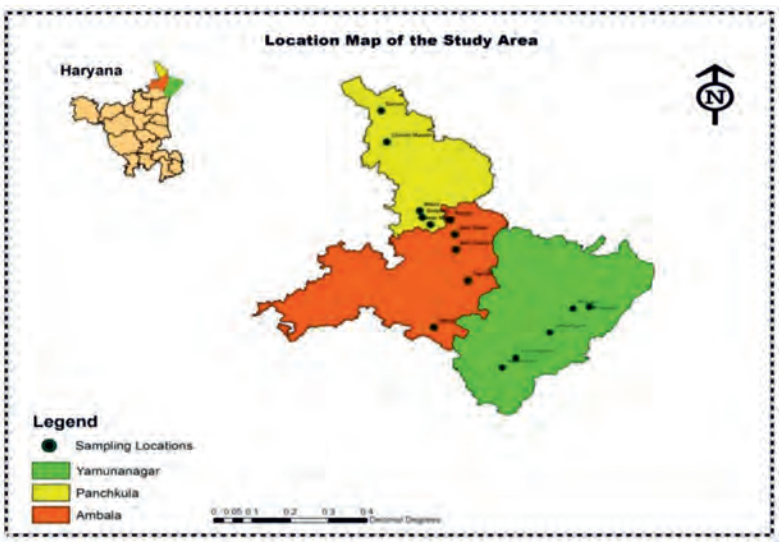

Fig. 1. Sampling sites in selected districts of Eastern Haryana

analysis) was conducted using the International Pipette Method of Robinson, as outlined by Piper (1966). The textural class of each sample was determined based on the relative proportions of sand, silt, and clay in the sample, utilizing the textural triangle provided by the International Society of Soil Sciences (ISSS). The Core method was employed to evaluate the bulk density of undisturbed soil samples using the volume-mass relationship. Soil moisture retention characteristics were determined by measuring the moisture retained on a mass basis by the soil at 0.1, 0.3, 0.5, 1, 3, 5, and 15 bar suctions using a pressure plate apparatus (Richards, 1947). Plant-available moisture content was calculated from the difference in moisture retention values at 33 and 1500 kPa suctions. The aggregate size distribution of soil samples was determined using Yoder's standard wet sieving method (Yoder, 1936). The equation given by Yonker and McGuiness (1957) was used to calculate the mean weight diameter (mm) as given below:

$$MWD = \sum_{i=1}^{n} d_i w_i$$

Table 2. Bulk density (Mg m^{-3}) of soils under different land use systems at different locations

District	Location (L)	Bulk density (Mg m^{-3})				
		Agriculture	Horticulture	Agro-forestry	Forestry	Mean
Ambala	L_1	1.24	1.30	1.28	1.21	1.26
	L_2	1.28	1.32	1.25	1.23	1.27
	L_3	1.36	1.39	1.28	1.30	1.33
	L_4	1.34	1.35	1.30	1.18	1.29
	L_5	1.30	1.32	1.29	1.28	1.30
Panchkula	L_6	1.55	1.56	1.59	1.48	1.55
	L_7	1.58	1.53	1.49	1.50	1.53
	L_8	1.51	1.49	1.48	1.43	1.48
	L_9	1.48	1.43	1.45	1.40	1.44
	L_{10}	1.49	1.45	1.49	1.41	1.46
Yamunanagar	L_{11}	1.33	1.38	1.34	1.31	1.34
	L_{12}	1.37	1.31	1.36	1.31	1.34
	L_{13}	1.53	1.45	1.32	1.41	1.43
	L_{14}	1.41	1.42	1.37	1.39	1.40
	L_{15}	1.39	1.32	1.35	1.32	1.35
Mean		1.41	1.40	1.38	1.34	
CD ($p \leq 0.05$)		Location (L) = 0.02; Land use System (LUS) = 0.01; L×LUS = 0.04				

where, n = number of size fraction, d_i = mean diameter of each size range, w_i = fraction weight of aggregate in that size range of total dry weight of the sample analyzed. The statistical analysis was carried out using a two-factor randomized block design (RBD) analysis with OPSTAT software (Sheoran *et al*., 1998).

RESULTS AND DISCUSSION

Bulk density

An examination of bulk density (BD) data at various locations (Table 2) revealed significant variations among different land use systems. The mean BD value across all locations was the highest (1.41 Mg m^{-3}) under agriculture, while the lowest value of BD (1.34 Mg m^{-3}) was found under forest land use systems. Among the different locations, the lowest average BD value was observed at L_1 (1.26 Mg m^{-3}), while the highest was recorded at L_6 (1.55 Mg m^{-3}). Overall, the BD values followed the order: agriculture > horticulture > agro-forestry > forestry. The interactive effect of location and land use systems was found to be non-significant. At the majority of locations, the forest land use system resulted in significant reductions in soil bulk density, followed by agro-forestry and horticulture. This decrease in bulk density under forest land use systems may be attributed to the accumulation of organic materials, such as leaf litter and plant biomass (Sepehya *et al.*,

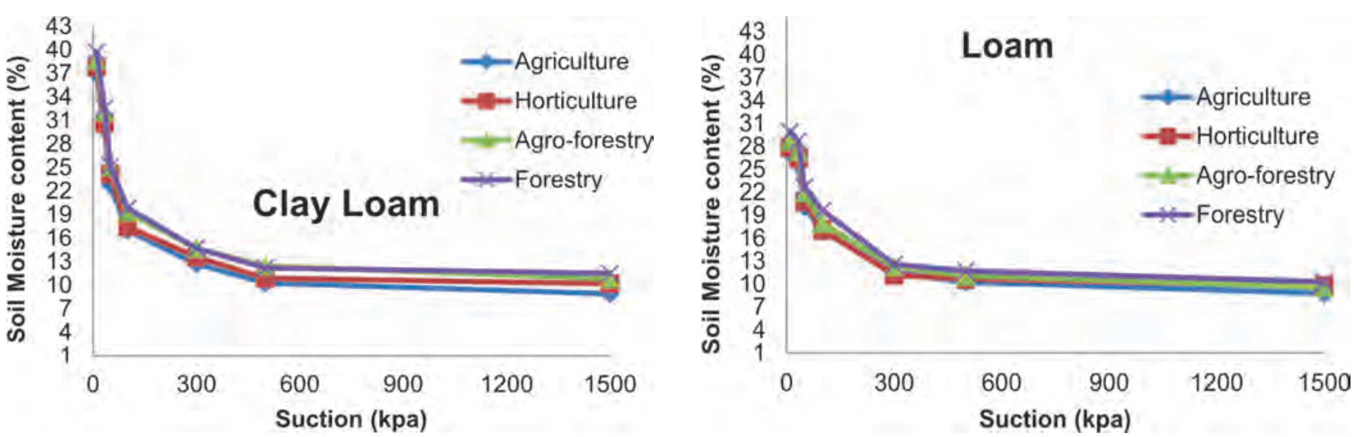

Fig. 2. Soil moisture retention curves of clay loam and loam soils under different land use systems

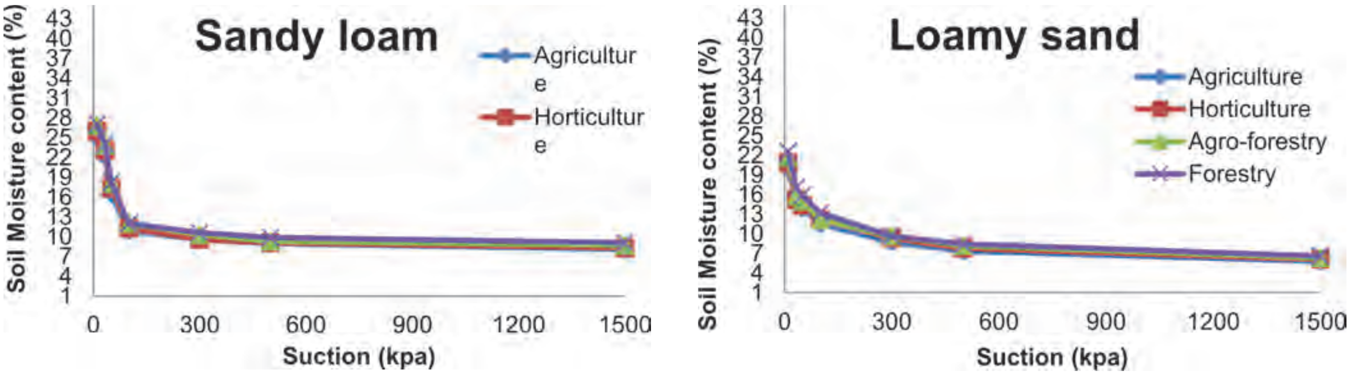

Fig. 3. Soil moisture retention curves of sandy loam and loamy sand soils under different land use systems

2012; Abbasi and Tahir, 2012). Similar findings were reported by Tripathi *et al.* (2007), who concluded that forest and mixed forest systems had higher organic matter content, possibly associated with greater soil biological activity, including earthworms (Kahlon *et al.*, 2012), which further reduces bulk density compared to agricultural land. Consistent results were also reported by Tesfahunegn and Gebru (2020). Furthermore, soils under agricultural land use systems exhibited the highest values of BD compared to other land use systems. This may be due to greater soil compaction caused by the use of heavy machinery for tillage operations, contributing to the reduction of soil organic carbon by disrupting soil aggregates and structure, thereby exposing organic matter for decomposition (Marcela, 2009; Negasa *et al.*, 2017).

Soil moisture retention characteristics

Water retention, storage, and transport within the soil are directly influenced by the pore size distribution of the soil and indirectly by the soil texture (Arnhold *et al.*, 2015). Additionally, the water holding characteristics of soils, expressed as plant available moisture content and field capacity (FC), are directly related to the textural class as well as the soil organic carbon (SOC) content (Dlapa *et al.*, 2020), with the most significant effects observed in finer textured soils. For ease of interpretation of the moisture retention characteristics of soils, the moisture retained by soils at various locations among different types of land use systems were averaged and plotted for soils with loamy sand, sandy loam, loam, and clay loam textures, as shown in Figures 2 and 3. The moisture retained by soils at field capacity (33 kPa suction) and available water content for different textured soils under different types of land use systems are presented in Figure 4.

Data revealed that among all textural classes (loamy sand, sandy loam, loam, and clay loam) of soil, forest land use systems exhibited higher amounts of moisture content at field capacity (FC) and available water content (AWC) compared to other land use systems. However, a significant increase in moisture content

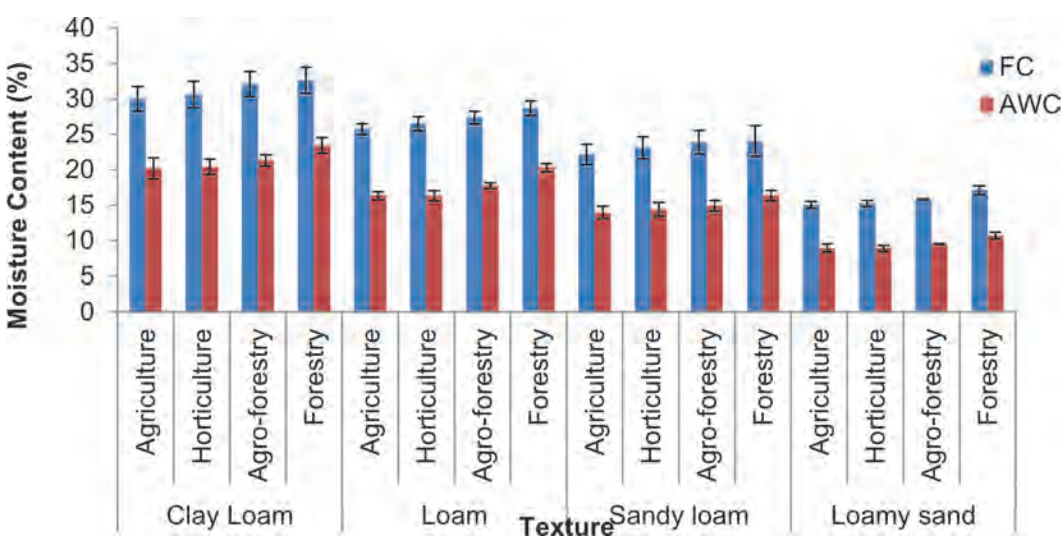

Fig. 4. Field capacity and available water content in soils under different land use systems in different textured soils

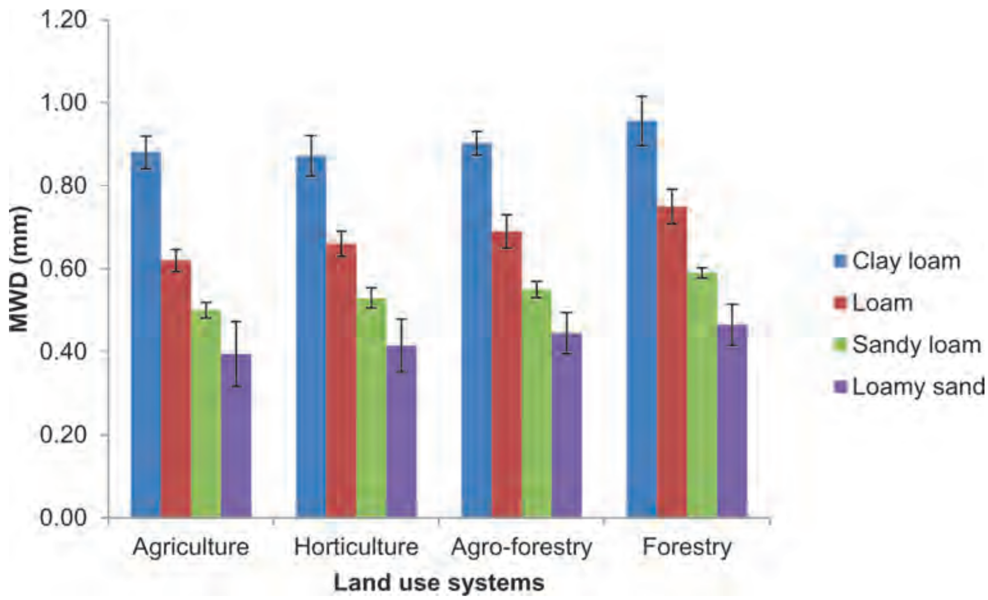

Fig. 5. Average mean weight diameter (MWD) in mm of different textured soils under different land use systems

was observed only in clay loam soils due to the higher proportion of macro and micro-pores leading to higher porosity in these soils (Brady and Weil, 2002). The moisture content in clay loam soils at FC and AWC was 32.63% and 23.8%, respectively, under forest land use systems, while it was 30.0% and 21.6%, respectively, under agriculture land use systems.

Overall, the moisture content in different textured soils at all levels of suctions was observed to be superior in forest soils compared to other types of land use systems, following the trend: forest > agro-forestry > horticulture > agriculture. Forest soils retain more available water compared to cultivated lands due to a higher content of clay, better root distribution throughout the soil profile (Owuor *et al.*, 2018; Gabriela de Queiroza *et al.*, 2020), and higher organic carbon contents, providing a larger surface area for absorption and retention of water molecules (Materechera and Mkhabela, 2001). Similar findings were reported by Hadda *et al.* (2020), indicating that cultivated land had lower moisture retention capacity due to soil cultivation degrading soil structure and aggregation (Wakene, 2001).

Aggregate size distribution

The water stable aggregates (WSA) with diameters >0.25 mm in forest soils were higher (43.19%) compared to agro-forestry soils (42.48%), horticultural soils (41.5%), and agricultural soils (40.83%). The amount of WSA (>0.25 mm) increased with the fineness of soil texture at various locations among different land use systems (Table 3). The mean value for water stable aggregates varied from 24.97% at L_7 (loamy sand) to 61.62% at L_1 (clay loam) under different land use systems. Among different textured soils, the highest aggregate stability was observed with clay loam soil (0.96 mm) under the forest system, followed by loam, sandy loam, and loamy sand soil. This could be attributed to forest soils with permanent vegetation and plant cover receiving more yearly input of organic matter, acting as binding material in soil, leading to an increase in soil flora and fauna and consequently increasing the amount of water stable aggregates (Chen *et al.*, 2017). In contrast, agricultural land exhibited lower aggregate stability (Liu *et al.*, 2019), which may be due to lower organic matter content attributed to continuous cultivation and rapid decomposition of soil organic matter (Bot and Benites, 2005). Soil texture also plays a crucial role in soil aggregate formation, with soils high in clay content exhibiting higher stability of soil aggregates (Zeng *et al.*, 2018).

Significant differences in mean weight diameter (MWD) were observed under different land use systems, with forestry systems having the highest value, following the order: forestry > agro-forestry > horticultural > agricultural land use system (Fig. 5). MWD in forest soils was significantly higher compared to other land use systems due to higher aggregate stability associated with improved organic carbon content (Guo *et al.*, 2020; Gonzalez-Rosado *et al.*, 2020), regular addition of leaf litter to soils (Somasundaram *et al.*, 2012), and better rooting structure (Ronaldo *et al.*, 2017; Yang *et al.*, 2020). Additionally, soils under agriculture are disturbed due to tillage operations, which in turn reduces the amount and stability of aggregates in the soil (Shukla *et al.*, 2004). Moreover, the use of agrochemicals may

Table 3. Water stable aggregates (>0.25 mm) of soils under different land use systems

District	Location (L)	Water stable aggregates (%) (> 0.25 mm)				
		Agriculture	Horticulture	Agro-forestry	Forestry	Mean
Ambala	L_1	60.49	61.51	62.11	62.37	61.62
	L_2	57.83	58.31	58.89	60.28	58.83
	L_3	57.94	56.62	57.80	58.71	57.77
	L_4	60.00	61.42	62.05	62.08	61.39
	L_5	59.00	58.31	60.14	60.73	59.55
Panchkula	L_6	26.35	27.28	28.44	28.82	27.72
	L_7	23.55	24.30	25.42	26.60	24.97
	L_8	30.41	31.11	32.10	33.11	31.68
	L_9	31.12	32.59	33.84	34.23	32.95
	L_{10}	32.84	33.79	33.92	34.04	33.65
Yamunanagar	L_{11}	36.37	37.70	38.24	39.05	37.84
	L_{12}	35.18	36.10	37.55	38.00	36.71
	L_{13}	31.43	31.96	32.58	33.90	32.47
	L_{14}	30.71	31.37	32.60	33.15	31.96
	L_{15}	39.25	40.08	41.51	42.70	40.89
Mean		40.83	41.50	42.48	43.19	
CD ($p \leq 0.05$)	Location (L) = 0.22; Land use System (LUS) = 0.11; L×LUS = 0.43					

inhibit the growth of soil fauna, causing negative effects on soil aggregation (Kansakar *et al.*, 2002).

CONCLUSION

The various land use systems across different locations and soil types in Eastern Haryana exhibited significant effects on soil physical properties. Bulk density (BD) varied significantly among soils with different textures at different locations under different land use systems. The highest BD was observed in soils under agriculture (1.41 Mg m^{-3}), while the lowest BD (1.34 Mg m^{-3}) was found in soils under the forest land use system. Among the different land use systems, the values of BD followed the order: agriculture > horticulture > agro-forestry > forestry. Forest land use systems showed increased moisture retention at field capacity (FC) and plant available water content (AWC) compared to other land use systems across all soil textures. For instance, the moisture content in clay loam soils at FC and AWC was 32.63% and 23.8%, respectively, under forest land use systems. Overall, the trend of moisture retention followed: forest > agro-forestry > horticulture > agriculture. The water stable aggregates (WSA) of forestry soils were higher (43.19%) compared to agro-forestry soils (42.48%), horticultural soils (41.5%), and agricultural soils (40.83%). Similarly, the highest mean weight diameter (MWD) under different land use systems was observed in forest soils, following the order: forestry > agro-forestry > horticultural > agricultural land. The amount of WSA and MWD increased with the heaviness in texture from loamy sand to clay loam soils.

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