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Physical and Chemical Properties of Soil of Different Villages of District Solan, Himachal Pradesh, 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 research was conducted to assess the physical and chemical properties of soils from twenty-one villages of Solan district, Himachal Pradesh within its geographical coordinates ranging from the latitude 30°44'53" to 31°22'01" N and longitude 76°36'10" to 77°15'14" E, during 2023-2024, India. The villages represent diverse landforms, including contour farming, plains, and slopes. Soil samples were collected from two depths, 0-15 and 15-30 cm, and analysed them using standard laboratory protocols. The predominant soil texture was sandy loam, bulk density ranges from 1.22 to 1.39 Mg m^{-3}, particle density from 2.42 to 2.67 Mg m^{-3}, and percent pore space varied between 40.50% and 46.68%, while the percent water holding capacity ranges from 37.65% to 45.53%. Soil pH ranged from 6.61 to 7.47. Electrical conductivity was measured between 0.18 and 0.34 dS m^{-1},

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indicating non-saline conditions. Organic carbon content was medium 0.30% to high 0.61%. The available nitrogen content ranged from 232.68 to 279.64 Kg ha^{-1}, available phosphorus from 37.23 to 64.54 Kg ha^{-1}, and available potassium from 262.14 to 365.34 Kg ha^{-1}. These findings provide valuable insights into the soil health of the region, with implications for agricultural practices and land management.

Keywords: Solan district; soil physical-chemical parameters; landform types.

1. INTRODUCTION

Soil is an essential natural resource that plays a vital role in sustaining life and impacting national economies. It undergoes weathering processes on Earth's surface, encompassing physical, chemical, and biological elements [1]. The significance of soil lies in its ability to support terrestrial food production by providing crucial elements for plant growth, including water, nutrients, oxygen, anchorage, and temperature regulation. This ensures the sustainability and productivity of ecosystems and agriculture [2]. As a living system, soil performs a multitude of ecological functions. It serves as a medium for plant growth, acts as a habitat for organisms, conserves biodiversity, maintains water and air quality, provides raw materials, and serves as a platform for various structures [3]. The characteristics of soil and its management practices have a direct impact on ecosystem health and productivity. Soil plays a vital role in the production of food, fodder, fiber, fuel, and forest products, as well as in maintaining biodiversity and environmental quality [4]. Soil supports vegetation by supplying moisture and nutrients, while vegetation, in turn, protects soil from erosion and enhances fertility through the decomposition of litter [2]. This mutual interaction helps to preserve biodiversity and global environmental quality [1]. Soil properties, which are influenced by both natural and human factors, such as texture, mineralogy, carbon and nutrient storage, pH, and water holding capacity, are crucial for making informed decisions regarding crop production and land use [5]. Environmental factors, such as climate, landscape features, and topography, also have a significant impact on the spatial variation of soil [6]. Understanding these properties is essential for optimal land utilization and assessing the resilience of crops.

1.1 Objective

In the Solan district of Himachal Pradesh, where different landforms bring about unique management difficulties, soil health plays a critical role in ensuring agricultural productivity and environmental sustainability. The lack of soil data presents difficulties in implementing effective agricultural practices and land management. This study assesses the soil properties in twenty-one villages at two depths (0-15 and 15-30 cm) to improve fertility, water retention, and nutrient availability. The results will offer valuable information about soil health, informing improved farming practices and sustainable agriculture strategies across Solan’s varied landscapes.

2. MATERIALS AND METHODS

The 42 representative soil samples were collected from 21 different villages in Solan district, Himachal Pradesh. These samples were taken from 0-15 and 15-30 cm depth. The latitude range of the district is 30°44’53” to 31°22’01” N, while the longitude ranges from 76°36’10” to 77°15’14” E. The sampling process utilized a khurpi implement to excavate V-shaped soil samples in randomly selected farmers' fields, ensuring a random distribution of the samples. The collected soil samples were then analysed for various parameters including soil texture, bulk density (Mg m^{-3}), particle density (Mg m^{-3}), pore space (%), water holding capacity (%), pH, electrical conductivity (dS m^{-1}), organic carbon (%), available nitrogen (Kg ha^{-1}), phosphorus (Kg ha^{-1}), and potassium (Kg ha^{-1}). The analysis was performed following standard procedures as outlined by Bouyoucos [7] Muthuvel et al., [8] Jackson [9] Wilcox [10], Walkley and Black [11] Subbiah and Asija [3] Olsen et al., [12] and Toth and Prince [13]. The data collected during the investigation was analysed using the completely randomized design, following the "Analysis of Variance technique" introduced by Fisher [14].

3. RESULTS AND DISCUSSION

Statistical analysis (confidence level) reveals significant differences in bulk density, particle density, electrical conductivity, organic carbon, and nutrient contents among landforms. However, percent pore space, water holding capacity, and soil pH show non-significant differences.

The Table 2 indicates that soil texture varies across different terrains, in the contour farming area, the soil predominantly consists of sandy loam, with sand content ranging from 68.59 to 74.21%, silt from 19.36 to 25.32%, and clay from 5.14 to 11.32%. The sloppy area also exhibits sandy loam texture, with slightly lower sand content (63.65 to 69.56%) and higher silt (21.79 to 28.79%) and clay (6.82 to 11.23%). Meanwhile, the plain area shows a different sandy clay loam texture, with sand content between 53.39 to 57.07%, silt from 13.17 to 22.41%, and a significantly higher clay content ranging from 21.05 to 32.18%.

The data from Table 3 illustrates significant variations in soil physical properties such as bulk density, particle density, percent pore space and percent water holding capacity across different terrains: contour farming, sloppy areas, and plain areas, at a 0-15 and 15-30 cm depth.

The maximum bulk density, measured at 1.37 Mg m^{-3} for the 0-15 cm depth and 1.40 Mg m^{-3} for the 15-30 cm depth, was observed in the plain area (PS2) while the minimum bulk density, recorded at 1.22 Mg m^{-3} for the 0-15 cm depth and 1.25 Mg m^{-3} for the 15-30 cm depth, was found in the contour farming area (CS1). This indicates that bulk density increases with depth, which is consistent with the decrease in organic carbon levels [15].

The maximum particle density, recorded at 2.56 Mg m^{-3} for the 0-15 cm depth and 2.60 Mg m^{-3} for the 15-30 cm depth, was found in the sloppy area (SS2) while the minimum particle density, measured at 2.42 Mg m^{-3} for the 0-15 cm depth and 2.46 Mg m^{-3} for the 15-30 cm depth, was observed in the contour farming area (CS1). The higher particle density values suggesting a denser soil composition may vary within these regions, possibly due to differences in erosion patterns or organic matter content [15].

The maximum pore space, measured at 46.68% for the 0-15 cm depth and 45.38% for the 15-30 cm depth, was found in the contour farming area (CS2) while the minimum pore space, recorded at 41.75% for the 0-15 cm depth and 40.84% for the 15-30 cm depth, was observed in the plain area (PS6) and the sloppy area (SS2), respectively. Pore space decreases with increasing depth due to greater compaction in the subsurface. Surface soils have significantly more macro and micro pores compared to subsurface soils, primarily due to the higher organic matter content at the surface [16].

Table 1. The study area using GIS map

Area	Sample Id	Latitude (ºN)	Longitude (ºE)
Contour farming	CS_1	30°55'39.0"	77°04'43.2"
	CS_2	30°55'31.6"	77°07'01.7"
	CS_3	30°57'51.0"	76°58'40.7"
	CS_4	30°53'51.8"	77°10'06.6"
	CS_5	30°58'16.4"	76°58'03.4"
	CS_6	31°00'21.9"	76°55'42.6"
	CS_7	30°59'07.5"	76°58'50.8"
Sloppy area	SS_1	31°01'38.7"	76°55'42.5"
	SS_2	31°04'50.2"	76°56'37.6"
	SS_3	31°04'39.0"	76°58'03.0"
	SS_4	30°59'33.2"	76°57'32.4"
	SS_5	31°00'21.1"	76°58'15.5"
	SS_6	31°04'02.8"	76°55'53.8"
	SS_7	30°58'14.6"	77°06'20.3"
Plain area	PS_1	30°57'11.1"	76°47'58.7"
	PS_2	30°58'22.2"	76°44'39.8"
	PS_3	30°58'30.9"	76°46'35.9"
	PS_4	30°57'28.9"	76°45'30.4"
	PS_5	30°53'41.9"	76°51'23.4"
	PS_6	30°53'26.4"	76°52'52.9"
	PS_7	30°53'03.3"	30°53'03.3"

Table 2. Percent sand, silt and clay and their texture of soil of different villages of Solan District Himachal Pradesh

Area	Selected villages	Sand %	Silt %	Clay %	Texture
Contour farming	CS_1	74.21	20.21	5.58	Sandy Loam
	CS_2	73.68	21.18	5.14	Sandy Loam
	CS_3	70.12	24.32	5.56	Sandy Loam
	CS_4	70.59	24.23	5.18	Sandy Loam
	CS_5	68.59	25.32	6.09	Sandy Loam
	CS_6	71.12	22.14	6.74	Sandy Loam
	CS_7	69.32	19.36	11.32	Sandy Loam
Sloppy area	SS_1	65.52	27.37	7.11	Sandy Loam
	SS_2	63.65	27.20	9.15	Sandy Loam
	SS_3	64.39	28.79	6.82	Sandy Loam
	SS_4	67.26	24.28	8.46	Sandy Loam
	SS_5	65.16	23.61	11.23	Sandy Loam
	SS_6	67.48	24.10	8.42	Sandy Loam
	SS_7	69.56	21.79	8.65	Sandy Loam
Plain area	PS_1	56.54	22.41	21.05	Sandy Clay Loam
	PS_2	53.39	20.60	26.01	Sandy Clay Loam
	PS_3	55.58	20.79	23.63	Sandy Clay Loam
	PS_4	54.65	13.17	32.18	Sandy Clay Loam
	PS_5	55.05	21.48	23.47	Sandy Clay Loam
	PS_6	56.59	21.09	22.32	Sandy Clay Loam
	PS_7	57.07	20.29	22.64	Sandy Clay Loam

The maximum water holding capacity, measured at 45.53% for the 0-15 cm depth and 44.27% for the 15-30 cm depth, was found in the contour farming area (CS5) while the minimum water holding capacity, recorded at 39.42% for the 0-15 cm depth and 37.53% for the 15-30 cm depth, was observed in the sloppy area (SS1). Water holding capacity decreases with depth due to soil compaction and reduced pore space, impacting moisture retention [16].

The maximum soil pH, measured at 7.45 for the 0-15 cm depth and 7.48 for the 15-30 cm depth, was found in the plain areas (PS3, PS5 and PS1, PS3) while the minimum soil pH, recorded at 6.61 for the 0-15 cm depth and 6.64 for the 15-30 cm depth, was observed in the contour farming areas (CS3, CS5 and CS1, CS3). The increase in soil pH with depth is primarily attributed to the accumulation and decomposition of organic matter, which releases alkaline compounds such as carbonates and bicarbonates. This phenomenon is further influenced by microbial activity, which converts organic materials into humic substances that can raise soil pH over time [2].

The maximum electrical conductivity of soil, measured at 0.34 dS m^{-1} for the 0-15 cm depth and 0.32 dS m^{-1} for the 15-30 cm depth, was found in the contour farming area (CS7) while the minimum electrical conductivity, recorded at 0.21 dS m^{-1} for the 0-15 cm depth and 0.18 dS m^{-1} for the 15-30 cm depth, was observed in the plain area (PS1). Plain regions generally support most crops, but vegetable-based systems in contour farming areas exhibit higher salt accumulation compared to cereal-based systems in the plain [17,15].

The maximum organic carbon in soil, measured at 0.54% for the 0-15 cm depth and 0.52% for the 15-30 cm depth, was found in the contour farming area (CS3) while the minimum organic carbon, recorded at 0.32% for the 0-15 cm depth and 0.29% for the 15-30 cm depth, was observed in the plain area (PS2). Vegetable-based cropping systems in contour farming areas typically have higher organic carbon due to practices like incorporating farmyard manure and organic residues, enhancing decomposition and enriching soil organic carbon levels in surface layers [18].

Table 3. Bulk density (Mg m^{-3}), particle density (Mg m^{-3}), pore space (%) and water holding capacity (%) of soil at 0-15 and 15-30 cm depths of different villages of Solan district, Himachal Pradesh

Area	Selected villages	Bulk density (Mg m^{-3})		Particle density (Mg m^{-3})		Pore space (%)		Water holding capacity (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Contour farming	CS_1	1.22	1.25	2.42	2.46	45.31	43.52	44.32	42.87
	CS_2	1.23	1.26	2.43	2.47	46.68	45.38	45.44	43.98
	CS_3	1.25	1.28	2.45	2.49	45.82	44.36	43.26	41.66
	CS_4	1.24	1.27	2.44	2.47	44.85	43.36	43.75	42.15
	CS_5	1.27	1.30	2.47	2.50	46.58	45.06	45.53	44.27
	CS_6	1.24	1.28	2.45	2.49	46.24	44.75	45.28	43.98
	CS_7	1.26	1.29	2.46	2.49	45.61	42.94	43.58	41.98
Sloppy area	SS_1	1.28	1.31	2.53	2.57	44.28	42.93	39.61	37.69
	SS_2	1.31	1.34	2.56	2.60	42.32	40.84	40.45	38.45
	SS_3	1.30	1.33	2.55	2.59	44.06	42.84	41.95	39.65
	SS_4	1.28	1.31	2.52	2.56	42.91	41.06	39.96	37.53
	SS_5	1.29	1.33	2.53	2.57	43.65	41.72	40.65	37.95
	SS_6	1.27	1.31	2.51	2.56	42.94	41.18	39.42	37.65
	SS_7	1.26	1.29	2.46	2.50	44.57	42.73	42.48	39.93
Plain area	PS_1	1.35	1.38	2.60	2.64	42.54	40.87	40.39	38.41
	PS_2	1.37	1.40	2.62	2.66	44.16	42.86	42.25	39.96
	PS_3	1.36	1.39	2.61	2.65	43.67	41.86	41.44	39.74
	PS_4	1.36	1.38	2.61	2.64	42.56	40.85	40.86	38.52
	PS_5	1.37	1.39	2.63	2.67	42.58	40.75	40.76	38.47
	PS_6	1.34	1.36	2.58	2.62	41.75	40.50	39.23	37.65
	PS_7	1.35	1.37	2.59	2.63	44.54	42.76	42.49	40.18
F test		S	S	S	S	NS	NS	NS	NS
S. EM (±)		0.008	0.008	0.008	0.009	0.804	0.703	0.709	0.739
C.D. @ 5%		0.023	0.022	0.023	0.025	NS	NS	NS	NS

Table. 4. Soil pH, electrical conductivity (dS m $^{-1}$), organic carbon (%) at 0-15 and 15-30 cm depths of different villages of Solan district, Himachal Pradesh

Area	Selected villages	pH		Electrical conductivity (dS m $^{-1}$)		Organic carbon (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Contour farming	CS_1	6.63	6.65	0.33	0.31	0.50	0.48
	CS_2	6.62	6.67	0.30	0.28	0.52	0.50
	CS_3	6.61	6.64	0.31	0.29	0.54	0.52
	CS_4	6.63	6.66	0.33	0.31	0.48	0.46
	CS_5	6.61	6.64	0.31	0.29	0.47	0.45
	CS_6	6.64	6.68	0.32	0.30	0.49	0.47
	CS_7	6.63	6.67	0.34	0.32	0.41	0.39
Sloppy area	SS_1	7.08	7.12	0.29	0.26	0.43	0.41
	SS_2	6.96	6.99	0.24	0.21	0.42	0.40
	SS_3	6.85	6.89	0.25	0.22	0.36	0.34
	SS_4	6.73	6.77	0.26	0.23	0.37	0.35
	SS_5	6.75	6.78	0.25	0.22	0.38	0.36
	SS_6	6.82	6.86	0.28	0.25	0.40	0.38
	SS_7	6.62	6.65	0.24	0.21	0.46	0.44
Plain area	PS_1	7.43	7.48	0.21	0.18	0.35	0.32
	PS_2	7.42	7.46	0.22	0.19	0.32	0.29
	PS_3	7.45	7.48	0.23	0.20	0.33	0.31
	PS_4	7.42	7.46	0.24	0.21	0.36	0.33
	PS_5	7.45	7.47	0.26	0.23	0.33	0.30
	PS_6	7.42	7.45	0.25	0.22	0.30	0.27
	PS_7	7.43	7.47	0.28	0.25	0.34	0.31
F test		NS	S	S	S	S	S
S. EM (±)		0.216	0.014	0.009	0.007	0.020	0.006
C.D. @ 5%		NS	0.041	0.027	0.021	0.058	0.018

Table 5. Available nitrogen, phosphorus and potassium in soil (Kg ha^{-1}) at 0-15 and 15-30 cm depths of different villages of Solan district, Himachal Pradesh

Area	Selected villages	Available nitrogen (Kg ha^{-1})		Available phosphorus (Kg ha^{-1})		Available potassium (Kg ha^{-1})	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Contour farming	CS_1	279.27	268.18	64.54	60.35	365.34	353.56
	CS_2	278.86	268.94	60.19	56.12	364.45	350.36
	CS_3	270.04	261.63	61.83	56.91	356.45	342.05
	CS_4	277.32	268.04	63.23	59.01	362.76	349.12
	CS_5	265.38	255.37	62.32	58.23	358.64	345.68
	CS_6	276.32	264.87	64.38	59.49	363.44	352.36
	CS_7	275.13	266.95	59.97	55.82	360.25	344.52
Sloppy area	SS_1	262.59	249.61	50.17	45.25	325.96	314.36
	SS_2	253.96	241.28	46.83	42.65	311.88	304.04
	SS_3	256.62	249.06	48.25	43.33	334.25	325.52
	SS_4	262.24	250.23	52.81	48.36	326.16	312.64
	SS_5	258.09	247.14	51.36	47.22	314.08	303.58
	SS_6	264.96	255.87	56.55	52.47	327.79	314.61
	SS_7	279.64	269.68	58.26	53.89	349.14	335.23
Plain area	PS_1	247.36	238.82	45.37	42.16	289.12	281.08
	PS_2	242.59	232.68	40.26	36.64	276.04	265.62
	PS_3	250.40	239.76	42.84	39.31	282.92	263.61
	PS_4	246.94	236.17	41.56	37.65	283.52	275.44
	PS_5	248.27	235.54	40.25	37.23	271.36	262.14
	PS_6	252.35	244.12	47.65	44.08	309.18	298.63
	PS_7	249.80	237.30	46.65	43.39	297.52	286.72
F test		S	S	S	S	S	S
S. EM (±)		0.817	1.009	0.800	0.888	0.925	1.294
C.D. @ 5%		2.332	2.880	2.284	2.536	2.639	3.692

The maximum available nitrogen in soil, measured at 279.64 Kg ha^{-1} for the 0-15 cm depth and 269.68 Kg ha^{-1} for the 15-30 cm depth, was found in the sloppy area (SS7) while the minimum available nitrogen, recorded at 242.59 Kg ha^{-1} for the 0-15 cm depth and 232.68 Kg ha^{-1} for the 15-30 cm depth, was observed in the plain area (PS2). Available nitrogen levels decrease with increasing profile depth, likely due to the reduction in organic matter content [19].

The maximum available phosphorus in soil, measured at 64.54 Kg ha^{-1} for the 0-15 cm depth and 60.35 Kg ha^{-1} for the 15-30 cm depth, was found in the contour farming area (CS1), while the minimum, recorded at 40.25 Kg ha^{-1} for the 0-15 cm depth and 37.23 Kg ha^{-1} for the 15-30 cm depth, was observed in the plain area (PS5). Higher available phosphorus levels in surface soil are often due to favourable soil pH and high organic matter content, particularly in higher topographic positions [20].

The maximum available potassium in soil, measured at 365.34 Kg ha^{-1} for the 0-15 cm depth and 353.56 Kg ha^{-1} for the 15-30 cm depth, was also found in the contour farming area (CS1) while the minimum available potassium, recorded at 271.36 Kg ha^{-1} for the 0-15 cm depth and 262.14 Kg ha^{-1} for the 15-30 cm depth, was observed in the plain area (PS5). Surface soil shows high available potassium levels due to organic residue breakdown and potassium fertilizer application, while subsurface soil has decreased availability [20-22].

4. CONCLUSION

The study highlights significant soil property variations across contour farming, sloppy areas, and plains in Solan district, Himachal Pradesh. Contour and sloppy areas feature sandy loam textures with high sand content, while plains exhibit sandy clay loam textures with more clay. Bulk and particle densities increase with depth, indicating soil compaction. Contour farming areas excel in pore space and water holding capacity, while plains show higher pH and lower electrical conductivity. Organic carbon is most abundant in contour farming areas, and nutrient levels-nitrogen, phosphorus, and potassium are generally higher there. These findings emphasize the need for tailored soil management strategies across diverse terrains.

STUDY JUSTIFICATION

Assessing soil properties in areas like contour farming, plains, and slopes evaluates fertility, productivity, and health, enabling accurate nutrient estimation and application for increased yield and sustainable farming. Soil health cards ensure proper fertilizer or manure use, preventing land degradation. This research provides crucial information for effective soil management, enhancing productivity, and promoting sustainable farming in the Solan district. Understanding unique soil qualities across terrains supports customized approaches benefiting the environment and agriculture.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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