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Assessment of Physico-Chemical Properties of Soil from Different Blocks of Namchi District of Sikkim, 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 present study was carried out at Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj. Department of Soil Science and Agricultural Chemistry (U.P.), during the year 2023-2024. The soil samples were collected at three depths: 0-15 cm, 15-30 cm, and 30-45 cm, from nine different villages of three different blocks under Namchi district A total of 27 soil samples were collected and analyzed for their physical and chemical parameters by using the standard Laboratory Technique. The result showed that the soil color varied from light brown to dark brown in dry condition and red to reddish brown/dark red in wet condition. The soil texture of Namchi, Temi and Sikkip blocks were mainly sandy clay loam. The Bulk Density reported 1.1 -1.29 Mg m^{-3}, particle density reported 2.1- 2.6 Mg m^{-3}, percent of pore Space varied 45-47.6%, water holding capacity ranged from 45-49.3 %. The composition of

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available nitrogen ranged from 312kgha^{-1}-200khha^{-1}, available phosphorus ranged from15kgha^{-1}-26kgha^{-1} and available potassium ranged from 243kgha^{-1}-309kgha^{-1}. Results suggest that farmers should adopt appropriate soil management techniques, such as crop rotation and conservation tillage, which will contribute to maintain the soil's physical characteristics to ensure the sustainability of agricultural practices and the long-term health of the soil.

Keywords: Physico-chemical parameters; Namchi; Sikkim.

1. INTRODUCTION

"The soil is the most important constituent to fulfilment of all the basic needs of human beings. Soil is an important component of our farming. An eminent position in global cultivation of wheat, rice, jawar, pulses, sugarcane, vegetables and fruits etc. is occupied by Indian agriculture and reason of physical, chemical condition of whatever land is indispensable for proper implementation of the other management practices. Thus the physico-chemical study of territory is very significant because both physical and chemical properties which bear upon the soil productivity. This, physico-chemical study of soil is based on various parameters like pH, electrical conductivity, texture, moisture, temperature, soil organic matter, available nitrogen, phosphorus and potassium. This knowledge will help to the people who are interested to work in agricultural field" [1] "An understanding of physical and chemical condition of any soil is essential for proper implementation of the other management practices [2-5]. The physical properties of a soil play an important role in determining its suitability for crop production. The characteristics like for supporting power and bearing capacity, tillage practices, moisture storage capacity and its availability to plants, drainage, ease of penetration by roots, aeration, retention of plant nutrients and availability to plants are all intimately connected with the physical properties of the soils" [6,7]. "Therefore the physico-chemical study of soil is very important because both physical and chemical properties which affect the soil productivity [8-10]. This physico-chemical study of soil is based on various parameters like pH, electrical conductivity, texture, moisture, temperature, soil organic matter, available nitrogen, phosphorus and potassium. This knowledge will create awareness among the farmers about economic productivity" [11]. "Physical properties play an important role in determining soil's suitability for agricultural, environmental and engineering uses. The supporting capability; movement, retention and availability of water and nutrients to plants; ease in penetration of roots, and flow of heat and air are directly associated with physical properties of the soil. Physical properties also influence the chemical and biological properties. The most pertinent physical properties of soil relevant to its use as a medium for plant growth are discussed in the following sections" (Phogat *et al.,* 2015).

2. MATERIALS AND METHODS

2.1 Description of the Study Area

Namchi district of Sikkim is located on the map with the GPS coordinates of 27°09'20.5"N 88°22'07.0"E. It lies at an altitude of 400 m to 2000 m with unique and countryside escape of endless waves of agricultural field and the terraced slopes intercepted by spring patched forest and encompasses a total area of around 75000 hectares. 9 villages from 3 blocks under Namchi district were selected for the study of Physico-chemical properties of the soil. The distance between villages under one block varied from 2km-5km and the distance between the blocks ranged from 10km-30km.

2.2 Soil Sampling

A total of 27 soil samples were collected at different depths of 0-15cm, 15-30cm and 30-45 cm, from three different blocks and three villages per each block of Namchi district of Sikkim with the help of a soil auger. These samples were air dried in shade for one week to obtain constant weight then crushed with wooden hammer, after that it was sieved with 0.2mm sieve to obtain composite samples of each site and each depth. The physical properties of soils, soil color, texture, bulk density (Mg m^{-3}), particle density (Mg m^{-3}), percent pore space and percent water holding capacity were analyzed with the following standard procedures: Munsell, [12] Bouyoucos [13] Muthuvel *et al.,* [14] and chemical properties pH, EC (dSm^{-1}) at 25°C, percent organic carbon, available nitrogen, phosphorus and potassium (kg ha^{-1}), Ca^{+3} C mol(p^{+}) kg^{-1} and Mg^{+3} C mol(p^{+})

kg^{-1} were analyzed by following Jackson [15] Wilcox [16] Walkley and Black [17] Subbiah and Asija [18] Olsen *et al.,* [19] Toth and Prince [20] and Jackson (1973) at 0-15, 15-30 and 30-45 cm depths.

2.3 Statistical Analysis

The data recorded during the investigation were subjected to statistical analysis by CRD (Completely Randomized Design), as per the method "Analysis of Variance (ANOVA) technique" given by Fisher,1960. The data derived from various determinations were subjected to statistical analysis including mean, Pearson's Correlation, t-test and ANOVA. The means for the levels of soil in the three divisions was determined using ANOVA and t-test and the means were compared to determine whether they were significantly different or not [21-23].

3. RESULTS AND DISCUSSIONS

3.1 Physical Properties of Soil

The data of all the physicochemical properties of the soil of some selected areas under Namchi District of Sikkim, along with its line graphs and correlation concerning depths 0-15cm, 15-30cm and 30-45cm are presented in Tables 1-5. The data show that soil texture varied from sandy clay loam to loam at different depths of soil which was found to be similar to the study of Deb *et al.* [24]. The colors of dry condition were light brown, brown, dark brown and pale brown and those of wet condition were light gray, dark gray, red, reddish brown and dark brown. The dominant color was found to be red and dark brown due to the presence of sesquioxide and high organic matter content. These results were similar to [25].

The bulk density varied from 1.1-1.29 Mgm^{-3} and the particle density varied from 1.15-2.6 Mgm^{-3}. The porosity of the soil decreased with depth in loamy soils but increased with depth in sandy loam soil. The bulk density, particle density and porosity were widely considered essential factors contributing to the water holding capacities of the soil. It was observed that the mean percent of water holding capacity decreases with increase in bulk density and particle density and increases with an increase in porosity, which had similar results to that of Guo *et al.,* [26] and Bisth *et al.* [27].

3.2 Chemical Properties of Soil

The value of pH ranges from 5-6.3 with a mean of 5.3, 5.5 and 5.6 for depth. The results were similar to Pradhan *et al.* [28]. The organic carbon status of soil sample ranged from 0.38-0.74% with a mean value of 0.57, 0.53 and 0.54 for depth. The organic carbon content decreased with range because the top 0-15cm is associated with intensive cropping associated with farmers' application of organic manures during the cultivation of different crops. Debnath *et al.* [29] also reported the higher organic carbon content in rice growing soils of Terai Zone of west bengal where the farmers usually apply organic manure.

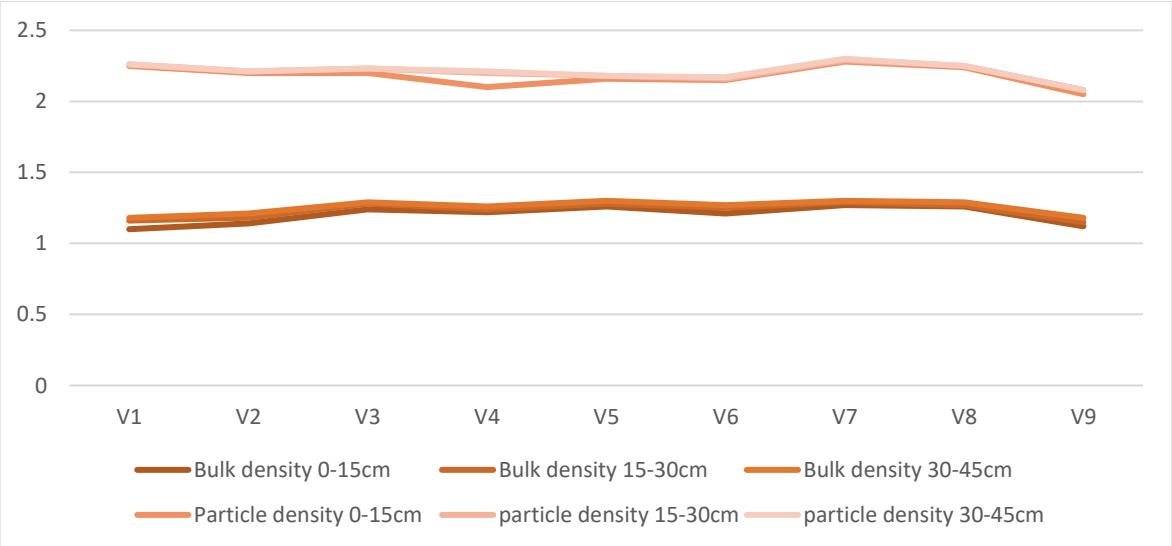

Fig. 1. Bulk density and particle density at depths 0-15cm,15-30cm and 30-45cm respectively

Table 1. Bulk density and particle density (Mgm^{-3})

	Villages	Bulk density			Particle density		
		0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
Namchi	V1	1.1	1.16	1.18	2.25	2.26	2.26
	V2	1.14	1.18	1.21	2.2	2.21	2.21
	V3	1.24	1.28	1.29	2.2	2.23	2.23
Temi	V4	1.22	1.24	1.26	2.1	2.2	2.21
	V5	1.26	1.28	1.3	2.16	2.18	2.18
	V6	1.21	1.25	1.27	2.15	2.16	2.17
Sikkip	V7	1.27	1.29	1.3	2.28	2.29	2.3
	V8	1.26	1.27	1.29	2.24	2.25	2.25
	V9	1.12	1.15	1.18	2.05	2.08	2.08
		F-test	S.Em. (±)	C.D @5%	F-test	S.Em.(±)	C.D @5%
Due to depth		S	0.1158	0.00016	S	0.0158	0.005775
Due to village		S	0.1174	0.00202	S	0.0652	3.1309

Table 2. Pore space and water holding capacity (%)

	Villages	Pore Space			Water holding Capacity		
		0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
Namchi	V1	47	46	45.5	45	43	42
	V2	46	45	45.6	45	44	43
	V3	46	45	45	44	43	42.5
Temi	V4	48	46	45.7	45.61	45	44.8
	V5	48	47	46	47	46.5	46
	V6	47	46.8	46	46	45	45
Sikkip	V7	49	48	46	47	46	45
	V8	47	46	45.5	46	45.8	45
	V9	48	47.6	46	47	48	47.8
		F-test	S. Em. (±)	C.D @5%	F-test	S. Em. (±)	C.D @5%
Due to depth		NS	0.82059	1.3905	S	0.640435	0.00077
Due to village		NS	0.760381	0.000519	S	1.47176	5.1807

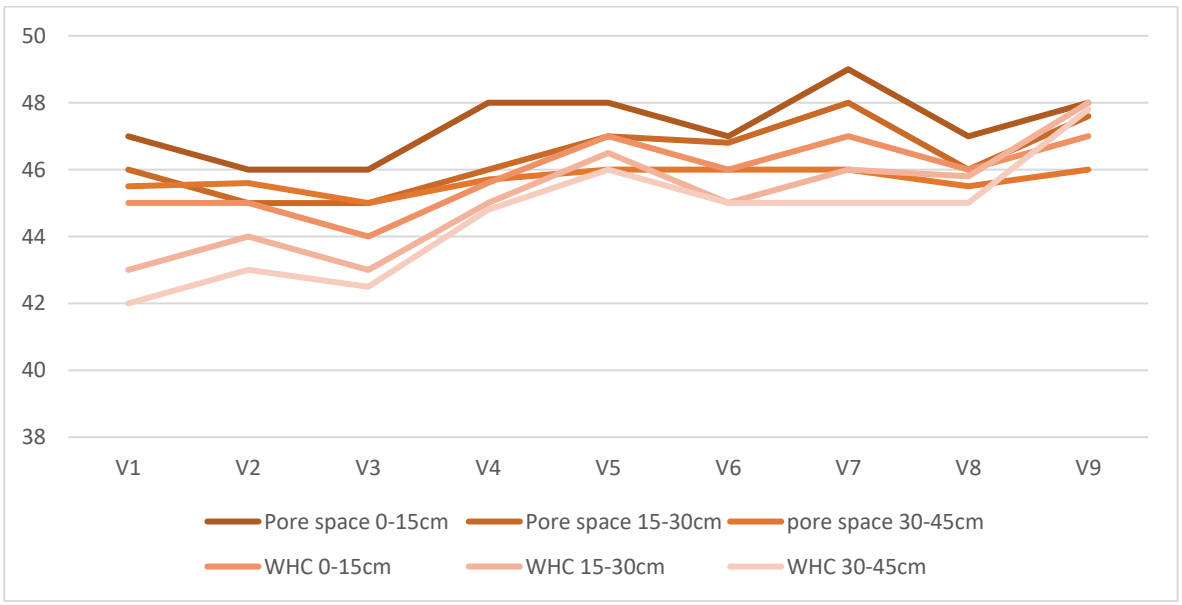

Fig. 2. Pore space and WHC at depths 0-15cm, 15-30cm and 30-45cm respectively

Table 3. pH, EC (dSm^{-1}) and Organic carbon (%)

	Village	pH			EC			OC		
		0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
	V1	5.5	5.6	5.8	0.06	0.07	0.08	0.5	0.49	0.45
Namchi	V2	5.3	5.4	5.5	0.04	0.05	0.07	0.6	0.56	0.55
	V3	5.8	5.9	6	0.04	0.05	0.06	0.8	0.74	0.72
	V4	5	5.3	5.4	0.08	0.09	1.02	0.5	0.5	0.48
Temi	V5	5	5.2	5.4	0.07	0.09	1	0.4	0.38	0.38
	V6	5.2	5.3	5.4	0.06	0.07	0.08	0.6	0.6	0.59
	V7	6	6.2	6.3	0.13	0.14	0.15	0.5	0.49	0.46
Sikkip	V8	5.3	5.4	5.6	0.11	0.12	0.13	0.6	0.5	0.6
	V9	5.4	5.6	5.8	0.13	0.14	0.15	0.7	0.6	0.59
		F-test	S. Em. (±)	C.D @5%	F-test	S. Em. (±)	C.D @5%	F-test	S. Em. (±)	C.D @5%
Due to depth		NS	0.15003	5.5309	NS	0.12649	0.099391	NS	0.02320	0.0090
Due to village		NS	0.32265	7.9913	NS	0.13667	0.446734	NS	0.10596	1.72

Table 4. Available Nitrogen, Available Phosphorus and Available potassium (Kg/ha)

Blocks	Villages	Available Nitrogen			Available phosphorus			Available potassium		
		0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
	V1	272	268	266	17.5	18	15	287.4	283	280
Namchi	V2	200	189	186	15	16.5	26	312	298.5	292
	V3	312	310	308	21	25	19.5	358	321	296
	V4	240	237	255	16	18	23	287	280.8	234
Temi	V5	245	240	232	25	27	21	243	233	220.5
	V6	311	300	326	18	26	23	287	279	256
	V7	243	231	229	20.5	21	24	289	285	283
Sikkip	V8	289	285	279	22	26	23	316	309.4	301.5
	V9	254	248	245	21	25	19	321	305	285
		F-test	S. Em. ±	C.D @5%	F-test	S. Em. ±	C.D@5%	F-test	S. Em. ±	C.D @5%
		S	4.703	0.10568	S	1.4972	0.172046	S	14.083	0.0001
		NS	37.35	3.67	NS	2.4043	0.176288	NS	27.328	7.13

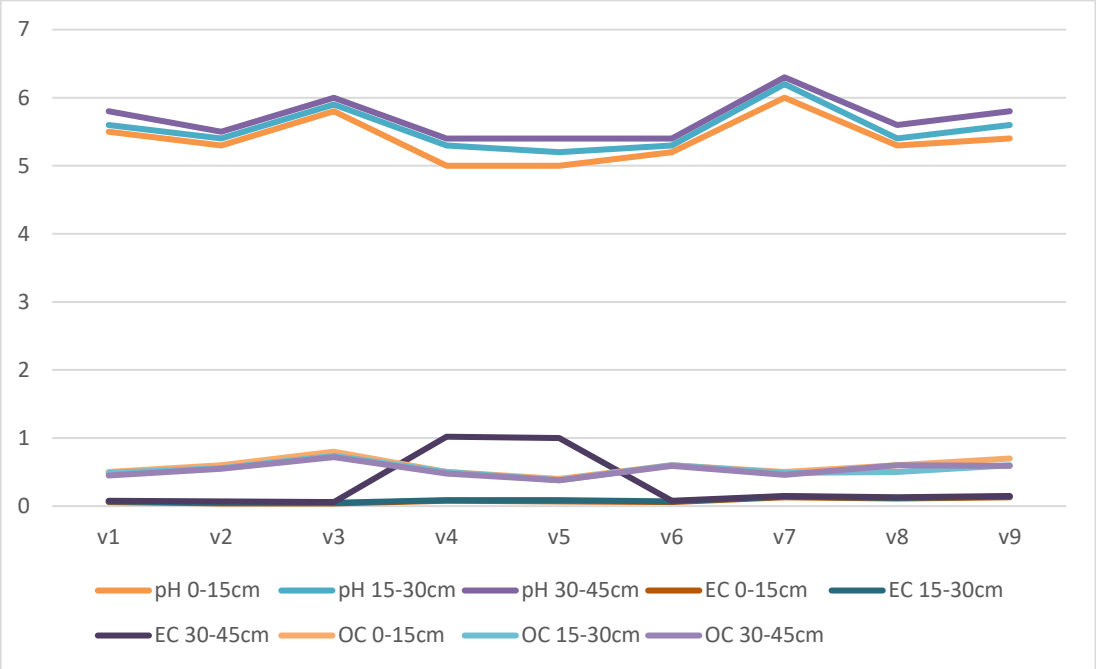

Fig. 3. pH, EC and OC at depths 0-15cm, 15-30cm and 30-45cm respectively

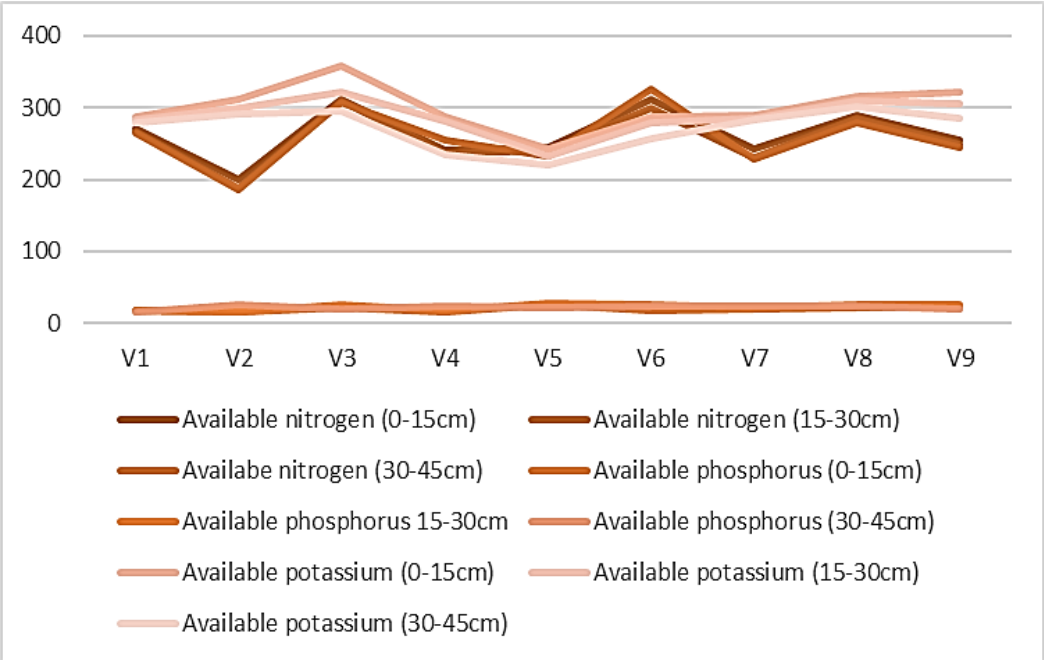

Fig. 4. NPK range at depths 0-15cm, 15-30cm and 30-45cm respectively

The available nitrogen content of soil ranged from 200-326kgha $^{-1}$. This is believed to be due to the addition of organic amendments to soil. The study of Mishra *et al.* [30] showed similar results. The available phosphorus content ranged from15-26 kgha^{-1} which is similar to the findings of Ram *et al.* [31]. Available Potassium content of soil ranged from 238-348 kgha $^{-1}$ which is considered medium to high and this could be because of the presence of feldspar and muscovite mica found in the soils of this region. This finding is similar to that of Ram *et al.* [32].

Table 5. Exchangeable calcium(meq/100g), Exchangeable magnesium(meq/100g)

Blocks	Villages	Exchangeable calcium			Exchangeable magnesium		
		0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
	V1	0.33	0.30	0.27	0.28	0.25	0.21
Namchi	V2	0.39	0.35	0.29	0.21	0.19	0.11
	V3	0.28	0.25	0.3	0.29	0.15	0.15
	V4	0.12	0.9	0.06	0.31	0.27	0.24
	V5	0.06	0.05	0.03	0.56	0.43	0.28
	V6	0.10	0.9	0.4	0.29	0.24	0.21
Temi	V7	0.15	0.12	0.10	0.04	0.04	0.06
	V8	0.18	0.10	0.08	0.07	0.06	0.05
	V9	0.32	0.21	0.21	0.56	0.03	0.09
Sikkip							
		F-test	S. Em. ±	C.D @5%	F-test	S. Em. ±	C.D @5%
Due to depth		S	0.0865	0.2232	S	0.0707	4.977
Due to village		NS	0.1342	0.3003	NS	0.113	4.283

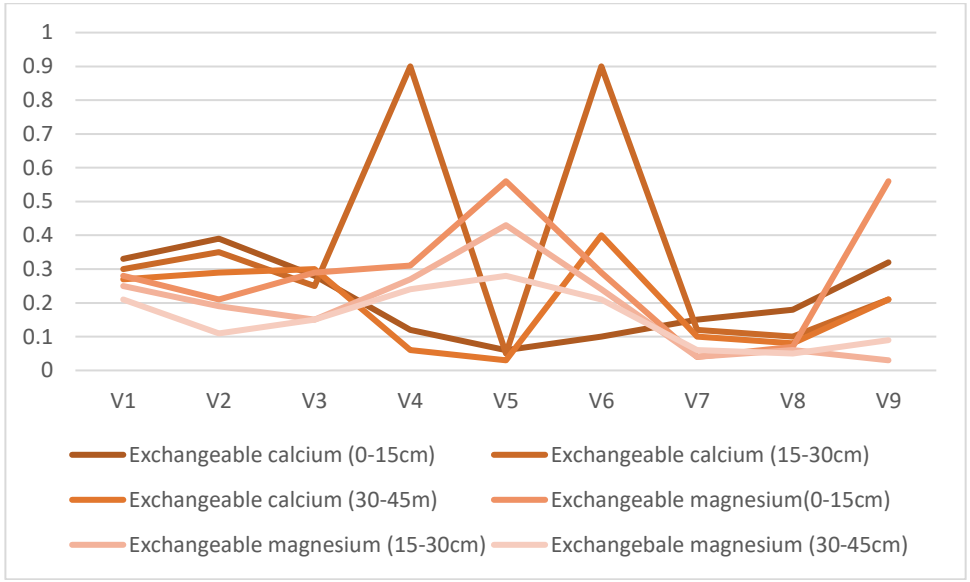

Fig. 5. Ca, mg and S range at depths 0-15cm, 15-30cm and 30-45cm respectively

Table 6. Correlation of different physical and chemical parameters of soil from different villages under Namchi, Temi and Sikkip blocks at depths 0-15cm, 15-30cm and 30-45cm

Table 6(a). At depth 0-15cm

	bd	pd	porespace	WHC	pH	EC	OC	N	P	K	Ca	Mg
bd	1											
pd	0.500135	1										
porespace	0.091614	0.084462	1									
WHC	-0.09161	-0.08446	-1	1								
pH	0.08072	0.330142	0.113089	-0.11309	1							
EC	0.17856	-0.37849	-0.27894	0.278944	0.220274	1						
OC	-0.16802	-0.16408	0.133768	-0.13377	0.39428	-0.11767	1					
N	0.243141	0.366331	0.304553	-0.30455	0.191973	-0.10313	0.450183	1				
P	0.526295	0.356968	-0.44343	0.44343	0.082372	0.372862	-0.06185	0.30043	1			
K	-0.14701	-0.15113	0.351391	-0.35139	0.503716	-0.08214	0.941985	0.334777	- 0.16083	1		
Ca	-0.7605	-0.27406	0.076942	-0.07694	0.338544	-0.21328	0.520385	-0.22888	- 0.42201	0.613408	1	
Mg	-0.31511	-0.34764	-0.57606	0.576059	-0.48419	-0.09544	-0.01719	-0.06608	0.3035	-0.25113	- 0.03862	1

Table 6(b). At depth 15-30cm

	Bd	Pd	pore space	WHC	pH	EC	OC	N	P	K	Ca	Mg
Bd	1											
Pd	0.296016	1										
pore space	0.100055	-0.65954	1									
WHC	-0.44591	-0.07294	0.312696	1								
pH	0.179045	-0.21915	0.236801	-0.32979	1							
EC	0.075107	-0.70611	0.809031	0.030852	0.290983	1						
OC	-0.092	0.015247	-0.39441	-0.10027	0.351368	-0.34189	1					
N	0.319765	-0.30056	-0.09972	-0.26173	0.080046	-0.12909	0.468986	1				
P	0.461121	-0.23313	0.338874	0.291167	-0.10745	0.271624	0.108198	0.61185	1			
K	-0.19829	-0.16377	-0.3996	-0.33662	0.436775	-0.01698	0.778611	0.284321	- 0.09894	1		
Ca	-0.08858	0.001668	-0.16615	-0.20436	-0.38743	-0.35097	0.208507	0.122818	- 0.26206	- 0.03814	1	
Mg	0.110351	0.511518	-0.19686	0.187457	-0.63068	-0.54301	-0.44126	-0.08329	- 0.02438	- 0.78883	0.265682	1

Table 6(c). At depth 30-45cm

	Bd	Pd	pore space	WHC	pH	EC	OC	N	P	K	Ca	Mg
Bd	1											
Pd	0.343273	1										
pore space	-0.02188	-0.38325	1									
WHC	-0.46758	-0.04557	0.571334	1								
pH	0.066343	-0.40659	-0.1858	-0.30499	1							
EC	0.304299	0.322417	0.293387	-0.02594	-0.49135	1						
OC	0.012964	0.052528	-0.57794	-0.26312	0.172445	-0.59766	1					
N	0.272216	-0.23467	-0.28774	-0.38141	-0.02108	-0.21795	0.520824	1				
P	0.438433	0.45594	0.250247	-0.05477	-0.21853	0.096862	0.037069	-0.33485	1			
K	-0.39749	-0.01083	-0.24368	0.256089	0.013249	-0.6929	0.552961	0.401265	-0.1552	1		
Ca	-0.39749	-0.01083	-0.24368	0.256089	0.013249	-0.6929	0.552961	0.401265	-0.1552	1	1	
Mg	0.046139	0.323104	0.105339	0.176722	-0.57227	0.666603	-0.44731	0.1787	- 0.29139	- 0.01579	- 0.01579	1

The exchangeable calcium content of soil ranged from 0.06-0.39meq/100g and the exchangeable magnesium content of soil ranged from 0.04-0.56meq due to the amount of rainfall prevailing in the study area that causes surface leaching of basic cations; these findings were similar to the study of Ray *et al.* [33].

4. CONCLUSION

The study of the physical and chemical properties of soils of the Namchi district of Sikkim concluded that the soils have good physical properties for the cultivation of most crops. The color of the soil is dominantly red and brown. The bulk density and particle density values were considerably low and increased with increase in depth. The water holding capacity decreases with an increase in depth and increases with an increase in pore space. The high clay component of the soil was discovered to contribute to its good pore space and water-holding capacity. Low pH and EC values have been recorded. Mostly all the villages showed high organic carbon content as well as high available nitrogen concentration which may be due to the adoption of organic farming. The available nitrogen, phosphorus and potassium content is high due to the application of organic soil amendments and good management practices. The soils had a medium to high range of phosphate and potassium, with values decreasing as depth increased. Very low values of exchangeable calcium and magnesium was found in all the regions which may be due to heavy rainfall prevailing in the area and surface leaching of basic cations (Ca^{+2} and Mg^{+2}) by the excessive rainfall. The main aim of the study was to determine the physical and chemical properties of the soils in the selected villages of different blocks under Namchi district of Sikkim, India. Not only would this be beneficial to make practical decisions in adopting farming techniques and incorporate fertilizers but also add to the database on soils in these areas for reference for further scientific research. All these soil properties indicates good crop cultivation like ginger, cardamom, paddy, buckwheat, oranges and guava and vegetables like cabbage, squash and spinach.

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 writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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