E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(5): 257-262
Received: 09-03-2024
Accepted: 13-04-2024

Samom Bidyalakshmi Devi
Senior Scientist, Soil Laboratory, The Green Foundation (An Non - Profit Organization), Imphal, Manipur, India

Thokchom Biren Singh
Cluster Coordinator & Jr. Scientist, Integrated Organic Farming Demonstration Project, The Green Foundation (An Non-Profit Organization), Imphal, Manipur, India

Corresponding Author:
Samom Bidyalakshmi Devi
Senior Scientist, Soil Laboratory, The Green Foundation (An Non - Profit Organization), Imphal, Manipur, India

Assessment of physical properties of soil under various agricultural land in Imphal valley of Manipur, India

Samom Bidyalakshmi Devi and Thokchom Biren Singh

DOI: https://doi.org/10.33545/2618060X.2024.v7.i5Sd.773

Abstract
This study investigates the spatial variation in soil physical properties across five agricultural land-use sites (Heingang, Khonghampat, Uchiwa, Langol, and New Keithelmanbi) within Imphal Valley. The analysis aims to elucidate the significance of these properties for maintaining ecosystem health and promoting sustainable land management practices. Soil physical properties were evaluated through analysis of mechanical composition (sand, silt, and clay content), bulk density, particle density, porosity, water-stable aggregate stability, gravimetric moisture content, and water holding capacity. Soil texture analysis revealed a predominantly clayey composition with variations across locations. Heingang possessed the highest clay content (51.5%) followed by Langol (66.9%) and New Keithelmanbi (52.4%). Conversely, Uchiwa exhibited the highest sand content (40.7%). Bulk density (1.28-1.39 Mg/m³) and particle density (2.33-2.56 Mg/m³) influenced soil compaction and water retention capacity. Porosity ranged from 43.3% to 47.8%, impacting water infiltration and nutrient availability for plants. Remarkably, high water-stable macroaggregate percentages (83.9%-94.4%) indicated good soil stability. However, variations in moisture content and water holding capacity were observed. Heingang displayed the highest available water capacity (0.37 m³/m³), while Khonghampat exhibited the lowest readily available water content (0.27 m³/m³). Correlation analyses revealed significant relationships between soil properties, informing management strategies. Particularly, strong correlations between bulk density, particle density, and water-stable aggregates were observed in these clayey soils. These findings emphasize the necessity of understanding soil physical properties to enhance soil health, optimize land management practices, and ensure sustainable agricultural productivity in the region.

Keywords: Soil physical properties, soil health, texture, bulk density, porosity land management, Imphal valley, sustainable agriculture

Introduction

Soil, a complex mixture of minerals, organic matter, air, water, and living organisms, serves as the important life-support system of terrestrial ecosystems (Brady and Weil, 2008) [3]. In agricultural land, soil fertility is important, as it determines the soil's capacity to supply essential nutrients for plant growth (Tisdale *et al*., 1993) [16]. However, soil physical properties exhibit significant spatial variation due to the interaction of biological, physical, and chemical processes over time (Hillel, 1998) [6]. Furthermore, the practices related to land use exert substantial impacts on physical properties, thereby influencing the health and productivity of plants (Lal and Stewart, 1990) [11]. These factors are fundamental in assessing the physical properties of soil under various agricultural lands in the Imphal valley.

A recent study by Singh and Singh (2002) [14] reported a concerning decline in biodiversity within Manipur's agricultural lands. This research investigates a potential contributing factor: the hypothesis that variations in soil physical properties across these lands may significantly impact biodiversity (Hillel, 1998) [6]. Specifically, we aim to elucidate how soil physical properties differ within various agricultural land-use sites situated in Imphal Valley, Manipur, India

Understanding the variations in soil physical properties is essential for several important factors. By identifying potential links between soil physical properties, we can guide soil management practices to enhance soil health (Lal, 2004) [9]. Furthermore, a comprehensive understanding of soil physical properties is vital for developing effective strategies to optimize agricultural productivity while ensuring the long-term sustainability of soil health (Brady and Weil, 2008) [3].

This research also sheds light on soil quality as a potential contributing factor to biodiversity decline, which has implications for conservation efforts.

Building on the established knowledge of complex interactions between soil properties, land use, and plant health, this study focus on assessing the physical properties of soils under various agricultural land uses within Manipur's Imphal Valley. By elucidating the relationships between these properties and soil health, the findings aim to contribute to a deeper understanding of agricultural land ecosystems in the region. Ultimately, this knowledge will serve as a cornerstone for the development of improved management and conservation strategies, fostering sustainable agricultural productivity.

Site Description

Study Area

This investigation was carried out in Imphal Valley, Manipur situated in the North eastern region of India (23°50' N - 25°42' N latitude; 92°59' E - 94°46' E longitude). The valley experiences a tropical climate with moderate temperatures ranging from 14.5 °C to 38 °C. Average annual rainfall varies between 1200 mm and 2700 mm.

Sampling Sites

Five agricultural land-use sites were chosen for soil sample collection within Imphal Valley. These sites are Heingang, Khonghampat, Uchiwa, Langol, and New Keithelmanbi. The map and GPS co-ordinates, elevation of the study Site given in Fig. 1 and table 1. Twelve samples were collected from each site at a depth of 0-30 cm in October 2023. A total of 60 samples were collected and stored in well-labeled zip-lock polyethylene bags for further analysis of their physical properties.

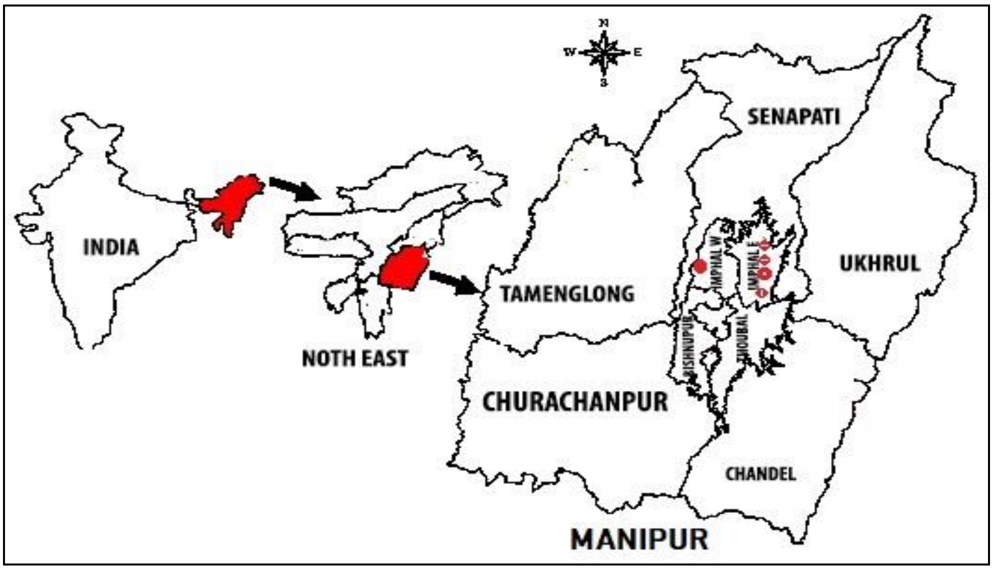

Fig 1: Map showing the study site

Table 1: Location GPS co-ordinates, elevation of the study Site

Study Site	Co-ordinate	Elevation (m amsl)
Heingang	24.8426°N, 93.9487° E	790
Khonghampat	24.8932° N, 93.9043° E	776
Uchiwa	24.5672° N, 93.8963° E	764
Langol	24.4978° N, 93.0789° E	838
New Keithelmanbi	24.9787° N, 93.9055° E	835

Various soil properties were analysed using standard methodologies: texture analysis followed Bouyoucos (1962) [2], bulk density was determined per Blake and Hartge (1986) [1], particle density was measured as described by Blake and Hartge (1986) [1], porosity was calculated based on their method, water-stable macro and microaggregate percentages were determined according to Kemper and Rosenau (1986) [8], Mean Weight Diameter (MWD) was calculated following Kemper and Chepil (1965) [7], moisture content was determined gravimetrically, Available Water Capacity (AWC) was calculated using Richards' method (1941) [13], and readily available water was determined following Cassel and Nielsen (1986) [4].

Statistical analysis

Pearson coefficient (r) correlation was performed to assess significant differences among various soil physical properties. All analyses were conducted using SPSS statistics version 18.0 software.

Results and Discussion

Mechanical composition and texture

The soils of Heingang, Khonghampat, Uchiwa, Langol, and New Keithelmanbi exhibit varying textural compositions, predominantly clayey in nature. Heingang soil consists of 20.5% sand, 28% silt, and 51.5% clay, making it dense with good water retention but challenging for root penetration. Khonghampat has a similar clayey texture with 21.4% sand, 28.4% silt, and 49.9% clay, retaining water well but being slightly less dense. Uchiwa presents a balanced composition with 40.7% sand, 18.6% silt, and 40.6% clay, classified as silty clay, offering better porosity. Langol, with 12.1% sand, 20.7% silt, and 66.9% clay, has a high clay content, excellent for water retention but posing root penetration challenges. New Keithelmanbi like similar Heingang with 24.6% sand, 23% silt, and 52.4% clay, ensuring good water retention due to its clay content (Fig. 2).

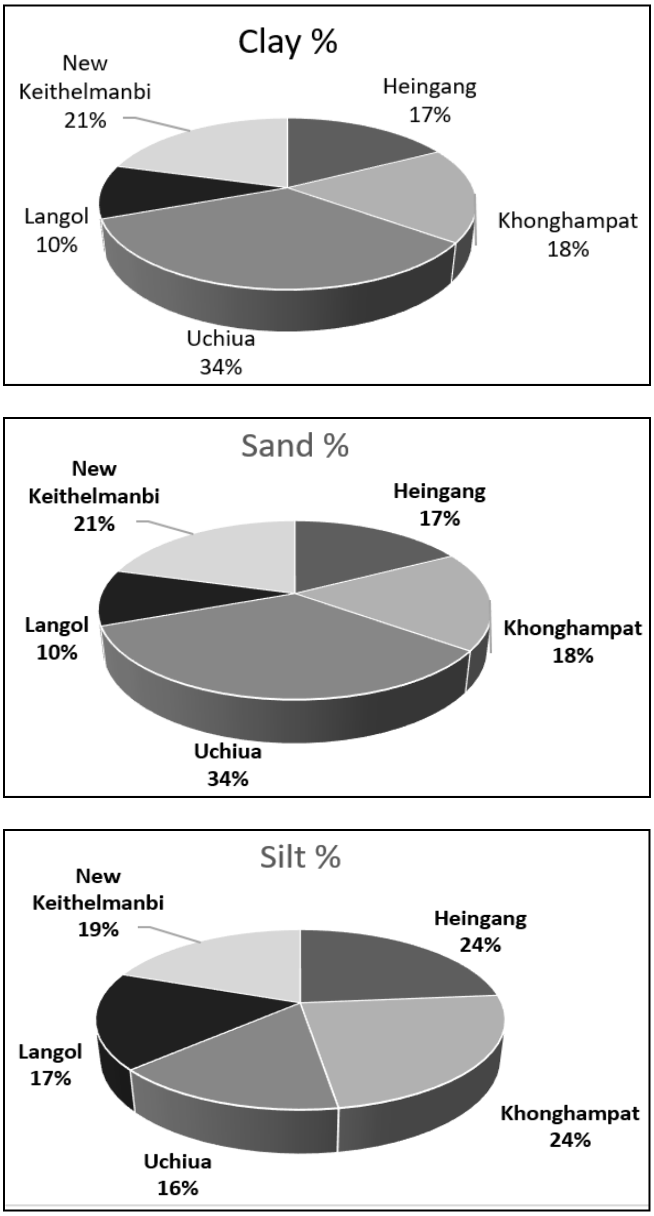

Fig 2: Showing the texture of soil of the various study site

Bulk Density

Bulk density represents the mass of soil per unit volume and is a crucial indicator of soil compaction. The table 2 shows the findings for bulk density in the studied regions are as follows: Langol has the lowest bulk density (1.28±0.05 Mg/m³), suggesting better soil porosity and potentially higher root penetration and water infiltration. Heingang and Khonghampat have similar moderate bulk densities (1.31±0.05 Mg/m³ and 1.32±0.04 Mg/m³, respectively), indicating relatively good soil structure. Uchiwa has the highest bulk density (1.39±0.06 Mg/m³), which may imply more compacted soil with lower porosity. New Keithelmanbi falls in between with a bulk density of 1.35±0.04 Mg/m³, indicating moderately compacted soil. These differences are essential for understanding soil compaction and its impact on plant growth and water movement. Optimal soil management practices are essential to maintain a balance in bulk density, ensuring adequate soil structure for root development and aeration.

Particle Density

Particle density is the mass of soil particles per unit volume, excluding pore space. The particle density data shows variations among the sites shown in table 2. Uchiwa has the highest particle density (2.56±0.15 Mg/m³), indicating a higher proportion of solid soil particles, which may affect soil porosity and compaction. Heingang (2.51±0.12 Mg/m³) and New Keithelmanbi (2.47±0.11 Mg/m³) also have relatively high particle densities, suggesting dense soil structure. Khonghampat has the lowest particle density (2.33±0.11 Mg/m³), indicating a potentially less dense soil with better porosity. Langol has a moderate particle density (2.40±0.13 Mg/m³). These differences are crucial for understanding soil texture, porosity, and potential root growth and water movement in the Imphal Valley's agricultural lands. Understanding these variations is essential for implementing effective soil management practices tailored to the specific needs of each site.

Porosity %

Porosity, the percentage of pore space in the soil, is a critical factor affecting soil health and plant growth. The table 2 shows the findings for porosity % of the different study sites i.e., The porosity data indicates that Heingang has the highest porosity (47.8±3.5%), suggesting well-aerated soil with good water retention capabilities. Langol (46.7±3.6%) and Uchiwa (45.7±3.5%) also have high porosity, indicating favorable conditions for root growth and water infiltration. New Keithelmanbi (45.3±4.5%) shows moderate porosity, while Khonghampat has the lowest porosity (43.3±4.2%), potentially indicating denser soil with lower water and air movement. These variations in porosity are important for assessing soil health and its suitability for different agricultural practices. This can lead to poorer water infiltration, increased runoff, and reduced nutrient availability, potentially stunting plant growth. Such soils may also have issues with root aeration, leading to root stress and decreased plant vigor.

Water-Stable Macroaggregate %

Water-stable macroaggregates are larger soil particles that resist breakdown when wet, playing a crucial role in soil stability and erosion prevention. The table 2 shows the findings for Water-Stable Macroaggregate % of the different study sites i.e., Khonghampat (94.40±7%) and Langol (93.80±6%) exhibit the highest percentages, suggesting very stable soil structure and high resistance to erosion. Heingang (89.30±5%) and New Keithelmanbi (83.90±4%) also show high stability, though slightly lower than Khonghampat and Langol. In contrast, Uchiwa has a significantly lower percentage (6.20±0.5%), indicating poor soil structure and higher susceptibility to erosion. These differences are critical for understanding soil health and planning appropriate soil conservation measures. This can lead to increased surface runoff, soil loss, and nutrient depletion, negatively impacting plant growth and soil health.

Water-Stable Microaggregate %

Water-stable microaggregates, smaller soil particles that contribute to soil structure, play a crucial role alongside macroaggregates in determining soil health and functionality. The table 2 shows the findings for Water-Stable Microaggregate % of the different study sites i.e., New Keithelmanbi exhibits the highest percentage of water-stable microaggregates (16.10±1.3%), indicating better soil structure stability and resistance to erosion. Conversely, Khonghampat has the lowest percentage (5.62±1.1%), suggesting comparatively weaker soil structure and greater susceptibility to erosion. Heingang, Uchiwa, and Langol fall in between, with moderate percentages of water-stable microaggregates. These variations highlight differences in soil stability and erosion resistance, which are crucial factors for soil health and agricultural sustainability.

Mean Weight Diameter (MWD)

The mean weight diameter (MWD) data reveals differences in soil aggregation among the sites The table 2 shows the findings for mean weight diameter of the different study sites i.e.,Khonghampat exhibits the highest MWD (5.69±0.21 mm), indicating larger and more stable soil aggregates, likely facilitating better soil structure and water infiltration. Langol follows closely with an MWD of 5.54±0.22 mm, suggesting similar soil aggregation characteristics. Uchiwa and New Keithelmanbi have intermediate MWD values (3.64±0.19 mm and 5.02±0.20 mm, respectively), indicating moderate soil aggregation. Heingang has the lowest MWD (3.28±0.24 mm), suggesting smaller and less stable aggregates, potentially impacting soil structure and water retention. These variations are significant for understanding soil quality and its implications for agricultural productivity.

Table 2: Soil physical properties (Bulk density, Particle density, Porosity (%), Water stable macro aggregate %, Water stable micro aggregate%, Mean Weight Diameter) of different study site

Site	Bulk density Mg.m-3 (Mean ± SD)	Particle density Mg.m-3 (Mean ± SD)	Porosity (%) (Mean ± SD)	Water stable Macro aggregate % (Mean ± SD)	Water stable micro aggregate % (Mean ± SD)	Mean Weight Diameter (Mean ± SD)
Heingang	1.31±0.05	2.51±0.12	47.8±3.5	89.30±5	10.70±1.2	3.28±0.24
Khonghampat	1.32±0.04	2.33±0.11	43.3±4.2	94.40±7	5.62±1.1	5.69±0.21
Uchiwa	1.39±0.06	2.56±0.15	45.7±3.5	6.20±0.5	13.20±1	3.64±0.19
Langol	1.28±0.05	2.40±0.13	46.7±3.6	93.80±6	6.20±0.8	5.54±0.22
New Keithelmanbi	1.35±0.04	2.47±0.11	45.3±4.5	83.90±4	16.10±1.3	5.02±0.20

Moisture Content: The table 3 shows moisture content of the various agricultural field, i.e., Langol and Heingang have the highest soil moisture retention at low tensions (10kPa and 30kPa), indicating excellent water availability for crops. Khonghampat and New Keithelmanbi exhibit moderate moisture retention, suggesting balanced water availability but with some variability. Uchiwa has the lowest moisture retention across all tension levels, indicating less water availability, which may necessitate more frequent irrigation. These variations are crucial for tailoring irrigation and soil management practices to optimize agricultural productivity in the Imphal Valley.

Available Water Capacity (AWC)

The table 3 shows the variation of Available Water Capacity f different sites. it indicates Khonghampat has the highest available water capacity (0.24±0.02 m³/m³), suggesting superior water retention, while New Keithelmanbi has the lowest (0.19±0.02 m³/m³), indicating poorer retention. Heingang, Uchiwa, and Langol have moderate water retention capacities. These variations are essential for optimizing soil management and irrigation practices to enhance agricultural productivity in the Imphal Valley.

Table 3: Soil Moisture content, Available water capacity and Readily available water of different study site

Site	Moisture content ($m^3.m^{-3}$)					Available water capacity (m^3m^{-3})	Readily available water (m^3m^{-3})
	10 kPa	30 kPa	100 kPa	1000 kPa	1500 kpa		
Heingang	0.63±0.02	0.48±0.04	0.45±0.05	0.29±0.01	0.26±0.03	0.22±0.04	0.18±0.04
Khonghampat	0.55±0.04	0.49±0.03	0.41±0.02	0.28±0.02	0.25±0.02	0.24±0.02	0.16±0.06
Uchiwa	0.53±0.03	0.42±0.05	0.38±0.01	0.26±0.03	0.23±0.04	0.20±0.03	0.15±0.04
Langol	0.64±0.05	0.50±0.02	0.45±0.02	0.29±0.02	0.27±0.05	0.23±0.04	0.19±0.03
New Keithelmanbi	0.55±0.02	0.43±0.03	0.40±0.03	0.27±0.04	0.24±0.02	0.19±0.02	0.15±0.02

Readily Available Water

Langol has the highest readily available water content (0.19±0.03 m³/m³), beneficial for crop growth, while Uchiwa and New Keithelmanbi have the lowest (0.15±0.04 m³/m³ and 0.15±0.02 m³/m³, respectively) table 3. This finding give the important for tailoring irrigation and soil management practices to maintain optimal soil moisture levels across different sites in the Imphal Valley.

Table 4: Soil Correlation coefficient analysis physical properties of different study site

	Sand %	Silt %	Clay %	BD	PD	Porosity %	WS Macro %	WS Micro %	AWC
Sand %	1								
Silt %	-0.422	1							
Clay %	-.909*	0.007	1						
BD	.972**	-0.415	-.880*	1					
PD	0.67	-0.462	-0.518	0.626	1				
Porosity %	-0.187	-0.17	0.294	-0.27	0.581	1			
WS Macro %	-.925*	0.668	0.715	-0.847	-0.711	-0.003	1		
WS Micro %	0.591	-0.342	-0.485	0.709	0.75	0.186	-0.454	1	
AWC	-0.605	0.519	0.419	-0.72	-0.747	-0.178	0.527	-.979**	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The strong negative correlation between sand and clay content (r = -0.909, $p<0.05$) and the moderate negative correlation between sand and silt content (r = -0.422, $p<0.05$) indicate that the soils in Imphal Valley are dominated by one particle size fraction with little variation. These findings suggest that as the proportion of sand increases, the proportions of clay and silt decrease significantly, which aligns with the basic principles of soil texture classification. Soils dominated by one particle size fraction typically exhibit uniform physical properties, affecting their water retention and permeability characteristics. This is consistent with known soil behaviour where texture impacts various soil functions (Brady and Weil, 2008) [3].

Clay content shows a strong positive correlation with water-stable macroaggregation (r = 0.715, $p<0.05$) and a strong negative correlation with available water capacity (r = -0.419, $p<0.05$). The positive correlation with macroaggregation suggests that higher clay content contributes to better soil structural stability, which is essential for reducing erosion and enhancing root growth (Six *et al*., 2004) [15]. However, the negative correlation with available water capacity indicates that although clay-rich soils are structurally stable, they may not be as effective in retaining water available to plants, possibly due to reduced pore space and slower infiltration rates (Hillel, 1998) [6].

Bulk density is highly correlated with sand content (r = 0.972, $p<0.01$) and negatively correlated with porosity (r = -0.847, $p<0.05$). The high correlation between bulk density and sand content suggests that sandy soils are denser due to lower organic matter content and larger particle sizes, which compact more tightly (Danielson and Sutherland, 1986) [5]. The negative correlation with porosity further supports this, as higher bulk density typically implies reduced pore space, affecting aeration and root penetration (Lal and Shukla, 2004).

Particle density shows a moderate positive correlation with sand content (r = 0.670, $p<0.05$) and a moderate negative correlation with silt content (r = -0.462, not significant). The moderate positive correlation between particle density and sand content suggests that sandier soils have higher particle densities, possibly due to the mineral composition of sand particles, which are often composed of heavier minerals like quartz (Brady and Weil, 2008) [3]. The non-significant negative correlation with silt content indicates a trend but not a definitive relationship, implying that further research could be beneficial to fully understand these dynamics.

Water-stable macroaggregation and microaggregation are moderately positively correlated (r = 0.454, $p>0.05$), and available water capacity is negatively correlated with both sand content (r = -0.605) and clay content (r = -0.419), though these correlations are not significant. The positive correlation between macroaggregation and microaggregation suggests that factors promoting one type of aggregation might also enhance the other, reflecting overall soil health and structure (Tisdall and Oades, 1982) [17]. The trends towards negative correlations between available water capacity with both sand and clay content, although not significant, suggest that the optimal soil for water retention might be one with balanced texture, supporting the concept of loam soils being ideal for agricultural productivity (Rawls *et al*., 1998) [12].

Conclusion

This study revealed significant spatial variations in soil physical properties across agricultural lands within Imphal Valley. Clayey textures dominated the investigated sites. Notably, strong positive correlations were observed between bulk density and particle density, and between water-stable macroaggregates and silt content. Conversely, microaggregation percentages exhibited negative correlations with clay content. These findings emphasize the importance of adopting site-specific soil management strategies for optimal soil health. Effective strategies in Imphal Valley likely involve strategic additions of organic matter and tailored water management practices that consider the specific soil texture at each location. To achieve this, a comprehensive soil management framework is recommended. This framework would encompass detailed soil mapping, regular soil health monitoring, and integration with land-use planning. By implementing such a comprehensive approach, we can support the long-term sustainability of agricultural practices in Imphal Valley.

Reference

1. Blake GR, Hartge KH. Bulk density. In: Klute, A. (Ed.), Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods, 2nd ed., Agronomy Monograph 9, American Society of Agronomy—Soil Science Society of America, Madison; c1986, p. 363-382.
2. Bouyoucos GJ. Hydrometer method improved for making particle size analysis of soils. Agron J. 1962;54:464-465.
3. Brady NC, Weil RR. The Nature and Properties of Soils. Pearson Education, Inc; c2008.
4. Cassel DK, Nielsen DR. Field capacity and available water capacity. In: Klute, A. (Ed.), Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods, Agronomy Monograph 5, American Society of Agronomy—Soil Science Society of America, Madison; c1986. p. 901-926.
5. Danielson RE, Sutherland PL. Porosity. In: Klute, A. (Ed.), Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods. Soil Science Society of America, American Society of Agronomy, Madison, WI; c1986. p. 443-461.
6. Hillel D. Environmental Soil Physics: Fundamentals, Applications, and Environmental Considerations. Academic Press; c1998.
7. Kemper WD, Chepil WS. Size distribution of aggregates. Methods of Soil Analysis: Part 1 Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling. 1965;9:499-510.
8. Kemper WD, Rosenau RC. Aggregate stability and size distribution. In: Klute, A. (Ed.), Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods, 2nd ed., Agronomy Monograph 9, American Society of Agronomy—Soil Science Society of America, Madison; c1986, p. 425-442.
9. Lal R. Soil carbon sequestration impacts on global climate change and food security. Science. 2004;304:1623-1627.
10. Lal R, Shukla MK. Principles of Soil Physics. CRC Press; c2004.
11. Lal R, Stewart BA. Soil Degradation: A Global Threat. Advances in Soil Science, Springer; c1990.
12. Rawls WJ, Gimenez D, Grossman R, Pachepsky YA, Ritchie JC. Use of soil texture, bulk density and slope of the water retention curve to predict saturated hydraulic conductivity. Transactions of the ASAE. 1998;41:983-988.
13. Richards LA. Moisture retention by some irrigated soils as related to soil-moisture tension. J Agric Res. 1944;69:215.
14. Singh JS, Singh SP. Forests of Himalaya: Structure, Functioning, and Impact of Man. Gyan Publishing House; c2002.
15. Six J, Elliott ET, Paustian K. Soil macroaggregate turnover and microaggregate formation: a mechanism for C

sequestration under no-tillage agriculture. Soil Biol Biochem. 2004;32:2099-2103.
16. Tisdale SL, Nelson WL, Beaton JD, Havlin JL. Soil Fertility and Fertilizers. Macmillan Publishing Company; c1993.
17. Tisdall JM, Oades JM. Organic matter and water-stable aggregates in soils. J Soil Sci. 1982;33:141-163.