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Influence of Agricultural Practices on Soil pH, EC, and Organic matter in various Agricultural Land in Imphal Valley, Manipur, India

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Abstract

This study investigates the impact of agricultural practices on soil properties essential for plant growth and ecosystem health in Imphal Valley. Soil samples were collected from five distinct agricultural sites (Heingang, Khonghampat, Uchiwa, Langol, and New Keithelmanbi) and analyzed for pH, cation exchange capacity (CEC), organic matter, exchangeable Ca, exchangeable Mg, free Fe_2O_3 and Al_2O_3. Soil pH ranged from 4.7 (acidic) to 6.4 (slightly acidic) across locations, indicating the need for potential amendments in some areas. Moderate variation in organic carbon matter (32.4-39.3 g/kg) was observed, highlighting the importance of organic matter management for soil health. Cation Exchange Capacity (CEC): CEC values varied notably (5.9-9.6 Cmol(P^+)kg^{-1}), suggesting the influence of factors beyond organic matter on nutrient retention capacity. Significant variations in exchangeable calcium and magnesium levels were observed, potentially impacting nutrient availability for plants. Higher organic matter content correlated with higher CEC, while lower pH corresponded with lower exchangeable magnesium. Heingang exhibited high organic matter and CEC despite low pH, highlighting the need for pH adjustments. Uchiwa showed soil properties with near-neutral pH and high nutrient levels. Langol exhibited low CEC despite high organic matter, suggesting the influence of other soil characteristics. The study revealed significant variations in soil pH, organic carbon, and CEC, highlighting the importance of site-specific management practices. Strategic amendments like liming for acidic soils and organic matter enhancement can optimize nutrient availability and promote sustainable agricultural productivity in Imphal Valley.

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Keywords

Soil pH, Organic matter, Cation Exchange Capacity, Exchangeable Cations, Imphal Valley, Liming.

Introduction

Soil forms the foundation of terrestrial ecosystems, essential for agricultural productivity, environmental health, and sustaining life on land. Several key parameters, including pH, electrical conductivity (EC), and organic matter content, play important roles in determining soil health and nutrient availability, directly influencing plant growth and ecosystem stability (Brady & Weil, 2008).

Soil pH dictates the solubility and availability of key plant nutrients which are important for plant uptake and growth (Amacher *et al.,* 2007). Deviations from optimal pH levels can severely limit nutrient availability, impacting crop yields and soil fertility (Wang *et al.,* 2006). ECE measures the concentration of salts and dissolved minerals in soil, affecting a plant's water uptake and growth (Ayers & Westcot, 1985). High salinity levels can impede plant growth and reduce agricultural productivity. Organic matter, derived from the decomposition of plant and animal matter, is vital for maintaining good soil structure, promoting moisture retention, and facilitating nutrient cycling (Lal, 2006). Adequate levels of organic matter content are important for long-term soil fertility and ecosystem health. Exchangeable calcium (Ca) and magnesium (Mg), along with free ferric oxide (Fe_2O_3) and aluminium oxide (Al_2O_3), also exert significant control over soil fertility and plant health by impacting nutrient availability, soil structure, and ultimately, crop productivity.

The Imphal Valley in Manipur, India, presents a unique confluence of geography and agriculture. However, significant variations in soil physical properties across agricultural lands impact crop productivity, biodiversity, and overall environmental sustainability. This lack of comprehensive data on the spatial variability of soil pH, EC, and organic matter content within the Imphal Valley hinders the development of optimal management practices for sustainable agriculture Previous research highlights the complex relationships between soil properties, agricultural practices, and ecosystem health (Devi *et al.,* 2024). Despite this understanding, gaps remain in our knowledge of how these properties vary across the diverse agricultural landscapes of Imphal Valley. This study aims to fill this gap by systematically investigating the distribution of soil pH, EC, and OC content across different agricultural land uses.

This study will employ advanced soil sampling and analysis techniques to generate extensive datasets encompassing variations in pH, CEC, organic matter, exchangeable Ca, exchangeable Mg, free Fe_2O_3 and Al_2O_3levels within Imphal Valley. The findings are expected to provide valuable insights for optimizing soil management practices specific to specific agricultural land uses.

Enhanced understanding of soil variability will aid in developing strategies to sustain soil health and fertility (Lal, 2015), improve crop productivity (Yang *et al.,* 2010), mitigate environmental impacts associated with agriculture (Petersen *et al.,* 2005), and promote biodiversity within the region (Benton *et al.,* 2003). This research investigates the impact of soil properties on ecosystem health within Imphal Valley, Manipur, India. The goal is to contribute to broader conservation efforts by elucidating these important relationships. Understanding the influence of soil properties on ecosystems is essential for maintaining healthy environments that support diverse plant and animal communities (Brussaard *et al.,* 2017).

This research endeavours to advance the field of soil science by offering a detailed analysis of soil chemical properties in this agricultural region. The findings hold the potential to inform best practices and policy decisions, ultimately contributing to a more sustainable future for agriculture and the environment in Imphal Valley.

Materials and Methods

Study Area

This research investigates the impact of soil properties on ecosystem health within Imphal Valley, Manipur, India, a region within the northeastern Indian state bounded by Nagaland to the north, Mizoram to the south, Assam to the west, and Myanmar to the east and south. The valley experiences a tropical climate with moderate temperatures ranging from 14.5 °C to 38 °C and an average annual rainfall ranging from 1200 mm to 2700 mm. This research area is situated at (23°50' N - 25°42' N latitude; 92°59' E - 94°46' E longitude), where the tropical climate influences the soil's chemical composition and physical properties.

Sampling Sites and sampling design

To study the influence of spatial variability in soil properties on ecosystem health across Imphal Valley's diverse agricultural landscapes, five representative sites were chosen for intensive soil sampling (Figure 1): Heingang (24.8426°N, 93.9487°E, 790 m amsl), Khonghampat (24.8932°N, 93.9043°E, 776 m amsl), Uchiwa (24.5672°N, 93.8963°E, 764 m amsl), Langol (24.4978°N, 93.0789°E, 838 m amsl), and New Keithelmanbi (24.9787°N, 93.9055°E, 835 m asl).

This selection encompasses a range of elevations and climatic gradients, reflecting the valley's heterogeneity and ensuring the capture of potential variations in topsoil (0-30 cm) properties that might influence plant growth and ecosystem health. A total of 60 soil samples were collected in October 2023, with 12 samples obtained from each site using a stratified random sampling technique to account for microenvironmental variations within each location.

Sample Preparation and analysis

To minimize disturbance to soil structure and potential contamination, samples were collected using a soil auger and stored in pre-labeled zip-lock polyethylene bags. Upon arrival at the laboratory, samples were air-dried in a shaded environment to preserve their natural state. Subsequently, the samples were gently crushed and sieved through a 2-mm mesh to obtain a homogenous fraction suitable for further analysis (methods detailed in Table 1).

Statistical analysis

Pearson coefficient (r) correlation was performed to assess significant differences among various soil physical properties. All analyses were conducted using SPSS statistics version18.0 software.

Results and Discussion

pH

Soil pH measurements across the different study sites in Imphal Valley revealed a range of acidic conditions, with values varying from 4.7 to 6.4 (Table 2 and Figure2). Specifically, Heingang exhibited the lowest pH (4.7 ± 0.61), indicating the most acidic soil conditions. Khonghampat (4.9 ± 0.54) and Langol (4.9 ± 0.39) show similar levels of acidity. Uchiwa, on the other hand, possessed the least acidic soil (6.4 ± 0.44). The observed variability in pH suggests potential differences in soil properties across the valley, with Uchiwa potentially having undergone processes that mitigated soil acidity. Conversely, the higher variability observed in Heingang pH (4.7±0.61) might indicate ongoing processes influencing soil acidity. Consistent pH values, as observed in New Keithelmanbi (5.0 ± 0.36), suggest a more stable soil environment, which is often desirable for optimal agricultural productivity.

Organic Matter Content

Organic matter content showed significant variation across the study sites, ranging from 32.4 to 39.3 g/kg (Table 2). Heingang and Langol observed the highest levels of organic matter (39.0 ± 2.38 g/kg and 39.3 ± 3.86 g/kg, respectively), suggesting higher soil fertility in these locations. In contrast, Uchiwa and New Keithelmanbi possessed lower organic matter content (32.4 ± 4.11 g/kg and 33.0 ± 4.65 g/kg, respectively) and observed higher variability. These disparities likely reflect variations in agricultural practices and overall soil health across Imphal Valley. Generally, higher organic matter content is associated with improved soil fertility and potentially translates to better crop yields.

Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC), a measure of the soil's ability to retain and exchange plant-essential nutrients, exhibited variations across the study sites, ranging from 5.9 to 9.6 Cmol(P+)/kg (Table 2). Heingang observed the highest CEC (9.6 ± 0.4 Cmol(P^+)/kg), suggesting a superior capacity to retain and provide these essential nutrients for plant growth, indicative of potentially higher soil fertility. Conversely, Langol exhibited the lowest CEC (5.9 ± 0.5 Cmol(P^+)/kg), implying a lower capacity to retain nutrients, which could limit plant growth. Notably, New Keithelmanbi showed consistent CEC values (6.3 ± 0.2 CmolCmol(P^+)/kg), suggesting a more stable soil environment in terms of nutrient availability, potentially beneficial for sustained agricultural productivity.

Exchangeable Calcium (Ca)

Exchangeable calcium (Ca) content, an essential element for plant growth and soil health, varied significantly across the study sites, ranging from 1.25 to 3.25 Cmol(P^+)/kg (Table 2). Uchiwa exhibited the highest level of exchangeable Ca (3.25 ± 0.1 Cmol(P+)/kg), suggesting strong soil structure and potentially superior fertility compared to other locations. Conversely, Heingang and New Keithelmanbi observed the lowest levels of exchangeable Ca (1.25 cmol(P^+)/kg) with Heingang showing greater variability (±0.5 Cmol(P^+)/kg). This variability in Heingang's Ca content might indicate ongoing processes affecting soil health. Adequate levels of exchangeable calcium are essential for optimal plant growth and development, and the observed variations across the valley highlight the importance of considering this factor for sustainable agricultural practices.

Exchangeable Magnesium (Mg)

Exchangeable magnesium (Mg) content, another vital nutrient for plant growth, exhibited significant variation across the study sites (Table 2). Values ranged from 0.50 to 2.10 Cmol(P^+)/kg, with Uchiwa observed the highest level (2.10 ± 0.15 Cmol(P^+)/kg). This suggests potentially higher soil quality for agriculture in Uchiwa compared to other locations due to sufficient Mg availability. Heingang, on the other hand, exhibited the lowest exchangeable Mg content (0.50 ± 0.25 Cmol(P^+)/kg), highlighting a potential limitation for plant growth in this area. The observed variability in exchangeable Mg content across the valley underscores the importance of considering this nutrient in site-specific agricultural practices.

Free Iron Oxide (Fe2O3)

Free iron oxide content varies from 0.19% to 0.36%. Uchiwa has the highest Fe2O3 content at 0.36% (±0.006), which can influence soil properties and colour. New Keithelmanbi has the lowest at 0.19% (±0.007), indicating the least presence of iron. Variability in Fe2O3 content impacts soil management practices and fertility assessments.

Free iron oxide (Fe_2O_3) content, which can influence soil properties like colour and nutrient availability, exhibited variations across the study sites, ranging from 0.19% to 0.36% (Table 2). Uchiwa showed the highest Fe_2O_3 content (0.36% ± 0.006), potentially affecting these soil properties to a greater extent compared to other locations. Conversely, New Keithelmanbi exhibited the lowest Fe_2O_3 content (0.19% ± 0.007), indicating a potentially lower influence of iron oxides on its soil characteristics. The observed variability in Fe_2O_3 content highlights the importance of considering this factor during soil management practices and fertility assessments for optimal agricultural productivity across Imphal Valley.

Free Aluminium Oxide (Al_2O_3)

Free aluminium oxide (Al_2O_3) content, another factor influencing soil properties, exhibited variations across the study sites, ranging from 0.03% to 0.14% (Table 2). Khonghampat displayed the highest Al_2O_3 content (0.14% ± 0.002), potentially impacting soil properties and potentially leading to aluminium toxicity in plants. Conversely, Heingang exhibited the lowest Al_2O_3 content (0.03% ± 0.001), suggesting a lower risk of aluminium toxicity in this location. Notably, consistent Al_2O_3 measurements were observed in Uchiwa, Langol, and New Keithelmanbi (±0.001), indicating relatively stable aluminium levels across these sites, which might be favourable for plant growth.

The analysis of soil properties in Imphal Valley revealed significant relationships shown in (Table 3) that can guide agricultural practices. A strong negative correlation between soil pH and organic matter (r = -0.702) indicates that more acidic soils tend to accumulate organic matter due to slower decomposition rates. This organic matter is crucial for maintaining good soil health by improving structure, water retention, and nutrient supply. Cation exchange capacity (CEC), a measure of the soil's ability to retain nutrients, showed a moderate positive correlation with iron oxides (Fe_2O_3, r = 0.410) but a negative correlation with aluminium oxides (Al_2O_3, r = -0.466). This suggests that iron oxides might enhance nutrient retention, while high aluminium oxide content could have negative effects, potentially due to aluminium toxicity in acidic soils. Exchangeable calcium and magnesium, essential plant nutrients, displayed strong positive correlations with soil pH (r = 0.921* for calcium and r = 0.849 for magnesium). This implies that managing soil acidity through practices like liming could significantly improve the availability of these nutrients in the soil. Finally, free iron oxide (Fe_2O_3) content showed a moderate positive correlation with both pH (r = 0.624) and exchangeable calcium (r = 0.855), suggesting that soils with higher pH and calcium also tend to have higher iron oxide levels, which might contribute positively to soil fertility. Understanding these interrelationships between soil properties is crucial for developing targeted strategies to improve soil health and promote sustainable agricultural practices in Imphal Valley.

Soil properties such as pH, electrical conductivity (EC), organic matter, cation exchange capacity (CEC), and exchangeable cations vary significantly across agricultural lands in Imphal Valley, highlighting regional soil health and fertility differences (Liu *et al.,* 2018). The study revealed notable differences among the five sites: Heingang, Khonghampat, Uchiwa, Langol, and New Keithelmanbi. Uchiwa showed higher values in critical soil parameters, indicating more favourable conditions for agriculture.

Elevated levels of organic matter, CEC, and exchangeable cations suggest fertile soil supporting robust plant growth, reducing the need for soil amendments (Lal, 2015; Mueller *et al.,* 2017). Heingang, despite high CEC, exhibited variable pH and lower exchangeable calcium and magnesium levels, challenging consistent productivity. Addressing these issues may require applying lime and magnesium fertilizers to stabilize soil pH (Yang *et al.,* 2010; Petersen *et al.,* 2005). New Keithelmanbi had lower organic matter and nutrient content, necessitating targeted interventions.

Figure.1 Map showing the study site

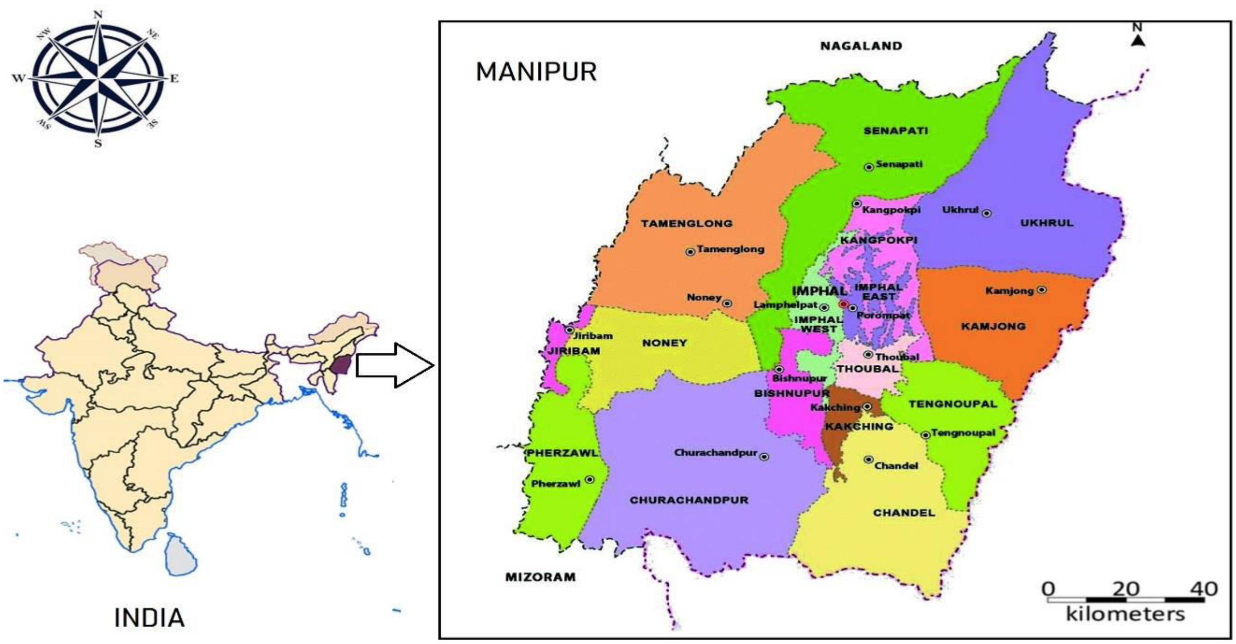


Table.1 Show the Soil chemical analysis method

Parameter	Method
pH	Digital pH meter
Organic Matter (g/kg)	Walkley-Black method (1934).
CEC (Cmol(P+)kg^{-1})	Ammonium acetate method Chapman (1965).
Exchangeable Ca (Cmol(P+)kg^{-1})	AAS Thomas (1982).
Exchangeable Mg (Cmol(P+)kg^{-1})	AAS Thomas (1982).
Free Fe_2O_3 (%)	DCB extraction Mehra & Jackson (1960).
Free Al_2O_3 (%)	Ammonium oxalate extraction Schwertmann (1964).

Table.2 Showing the chemical properties of soil in various agricultural filed

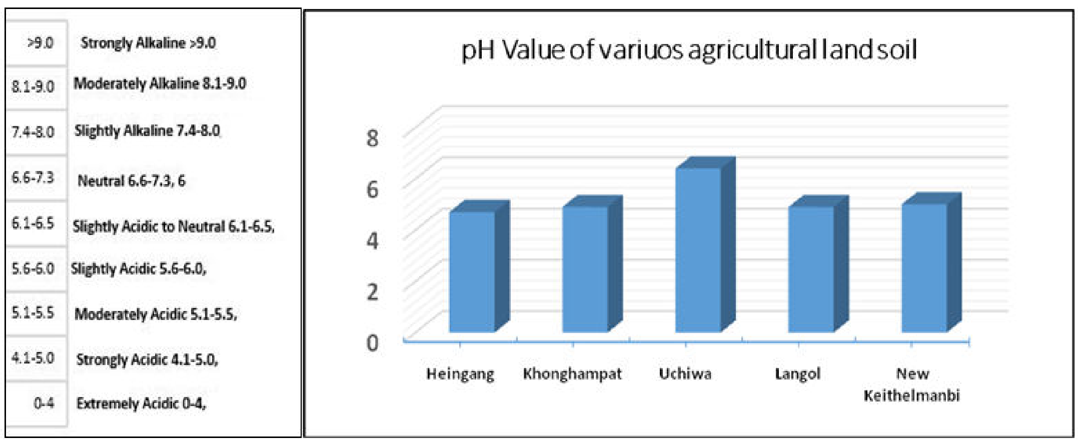
Site	pH	Organic Matter (g/kg)	CEC (Cmol (P$^+$)kg^{-1})	Exchangeable Ca (Cmol (P$^+$)kg^{-1})	Exchangeable Mg (Cmol (P+)kg^{-1})	Free Fe_2O_3 (%)	Free Al_2O_3 (%)
Heingang	4.7±0.61	39±2.38	9.6±0.4	1.25±0.5	0.50±0.01	0.26±0.005	0.03±0.001
Khonghampat	4.9±0.54	36.2±3.52	8±0.3	2.00±0.4	1.50±0.01	0.33±0.003	0.14±0.002
Uchiwa	6.4±0.44	32.4±4.11	8±0.6	3.25±0.1	3.75±0.01	0.36±0.006	0.06±0.001
Langol	4.9±0.39	39.3±3.86	5.9±0.5	1.75±0.3	2.50±0.01	0.26±0.009	0.09±0.001
New Keithelmanbi	5.0±0.36	33±4.65	6.3±0.2	1.25±0.4	1.00±0.01	0.19±0.007	0.09±0.001

Table.3 The table shows the correlation-coefficient of the various soil chemical properties

	pH	Organic matter	CEC	EC_Ca	EC_Mg	Free_Fe2O3	Free_Al2O3
pH	1						
Organic_matter	-.702	1					
CEC	.031	.152	1				
EC_Ca	.921*	-.502	.078	1			
EC_Mg	.849	-.374	-.269	.908*	1		
Free_Fe2O3	.624	-.155	.410	.855	.652	1	.
Free_Al2O3	-.193	-.119	-.466	.026	.031	.119	1

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

Figure.2 Figure shows the pH of the various agricultural land soil



Applying organic fertilizers can enhance soil health by improving structure, water retention, and nutrient availability, promoting better crop growth (Benton *et al.*, 2003). The variability in soil properties across Imphal Valley underscores the need for location-specific soil management practices. Tailored interventions, such as organic fertilizers and lime, are essential to address specific challenges at each site. Regular soil monitoring is crucial for identifying nutrient deficiencies and pH imbalances, enabling timely management practices (Mueller *et al.*, 2017; Lal, 2015). This study provides a baseline for future soil fertility assessments, supporting informed agricultural policies tailored to each location within Imphal Valley. By addressing site-specific needs, farmers can optimize crop yields and contribute to sustainable agricultural growth in Manipur, India. Tailored soil management practices are vital for enhancing soil fertility and productivity, ensuring sustainable practices, and supporting regional agricultural development (Lal, 2015).

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