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Comparative Analysis of Soil Fertility in Indonesia and Burkina Faso

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Abstract

Soil fertility reduction is a significant constraint on agricultural output in both wet tropical and semi-arid environments. The purpose of this study was to assess and compare the soil fertility status in Wonosalam District (Indonesia) and Toudweogo (Burkina Faso) by analysing specific physical and chemical parameters. Soil samples were obtained from these areas and tested for texture, pH, organic matter, total nitrogen, accessible phosphorus, exchangeable potassium, cation exchange capacity (CEC), and base saturation (BS). The results revealed considerable disparities between the two contexts. Wonosalam soils had a clayey texture (58.67% clay), but Toudweogo soils were mostly sandy (69.28% sand). The soil pH was acidic in both places. Organic matter content was moderate in Indonesia (3.13%), but low in Burkina Faso (1.23%). Total nitrogen

levels were low in both regions (0.11% and 0.06%, respectively). Indonesia had much higher available phosphorus and exchangeable potassium levels (14.33 mg/100 g and 53 mg/100 g) than Burkina Faso (1.67 mg/100 g and 4.17 mg/100 g). CEC levels were medium in Wonosalam (21.72 cmol kg⁻¹) and low in Toudweogo (6.10 cmol kg⁻¹), but both soils maintained substantial base saturation. Sustainable management solutions should be site-specific: liming and balanced fertilization are recommended for Indonesian soils, whereas organic matter restoration, integrated soil fertility management, and water conservation practices are required for Burkina Faso soils. These findings emphasize the significance of tailoring soil management to local pedoclimatic conditions in order to boost agricultural output and long-term soil sustainability.

Keywords: Soil Fertility, Soil Texture, Integrated Soil Fertility Management, Indonesia, Burkina Faso

1. Introduction

Soil serves as the medium for root development, the primary source of soil nutrients, and the source of water for growing plants, and its health is vital for food production (Ali *et al.*, 2021) [2]. It is a complex mixture of organic materials, minerals, gasses, liquids, and organisms that cohabit to support life on our planet (Mohanty *et al.*, 2021) [25]. Enhancing and sustaining soil health structural and chemical qualities, as well as monitoring and controlling soil conditions from seedbed preparation to harvest, has long been a key focus for increasing production. Soil with adequate physical conditions allows better and timely seed germination, root system establishment, plant growth and this is called soil fertility. Soil fertility refers to the ability of soil to sustain agricultural plant growth (Tang, L. 2025) [40]. Fertile soil provides a habitat with required nutrients and appropriate chemical, physical, and biological properties to sustain plant growth (Tudi, M. *et al.*, 2022) [34] without toxic substances that inhibit plant development (Ebanyat, P. *et al.*, 2021) [10]. Soil fertility levels are highly dynamic and can fluctuate (Ariadi *et al.*, 2021) [3] and plant diversity has a substantial impact on soil fertility, both physically and chemically. Soil fertility varies by region and is influenced by both human and natural factors such as climate, topography, organic matter content, cation exchange capacity, and pH changes (Munawar, 2018) [26].

Over the last few decades, agricultural land in many tropical regions has expanded and intensified as demand for crop commodities and human population has increased. This is especially evident in Indonesia, the world's fifth most populous country, where there is a growing demand for locally agricultural products (Tahirah, S. M., 2023) [41]. Conventional farming techniques, such as overfertilization and heavy pesticide usage in many parts of Indonesia, have prompted environmental and public health concerns (Abe, S. *et al.*, 2020) [1]. These concerns include biodiversity loss, pollution, unsustainable development, and soil erosion. These factors impacted the soil fertility in Indonesia (Chavez, J. *et al.*, 2024) [8].

Furthermore, Soils in Sub-Saharan Africa (SSA) are unhealthy, owing primarily to years of crop nutrient mining and a lack of organic or inorganic resupply (John, 2013). According to The Food and Agriculture Organization (FAO) of the United Nations in 2017, these soils, in their current form, are not able to offer enough nutrition for the region's population, with 236.5 million people undernourished in SSA, an increase of 60 million in 10 years and a prevalence rate of more than 23%. In Burkina Faso, a landlocked country in West Africa, cultivated soils are generally acidic, with negative soil nutrient balance (Bassolé, Z. *et al*, 2023) [4]. Many soils in Burkina Faso have depleted organic matter and low nutrient reserves, primarily due to overcultivation, minimal fertilizer inputs, and poor soil conservation practices (FAO, 2017) [13]. Low soil fertility reduces crop nutrient availability, which in turn lowers yield potential, food production levels and lack of income for agricultural households (Westerberg, 2017) [43].

Indonesia and Burkina Faso represent two contrasting tropical agricultural systems that illustrate the diversity of soil fertility challenges across the tropics. Indonesia is predominantly characterized by a humid tropical climate with high annual rainfall and temperatures (Hildegardis, C. *et al*, 2019) [19]. Burkina Faso lies mainly within the Sahelian and Sudanian agro-ecological zones and experiences a semi-arid to sub-humid climate with pronounced rainfall variability (Newborne, P., 2016) [28]. Although both Indonesia and Burkina Faso face significant soil fertility constraints, the nature and drivers of these constraints differ substantially due to climatic conditions, soil formation processes, land use intensity, and socio-economic factors.

Therefore, the objective of this study is to conduct a comparative analysis of soil fertility in Indonesia and Burkina Faso by examining key soil physicochemical properties, dominant soil constraints, and their implications for agricultural productivity and sustainability. By highlighting similarities and differences between humid and semi-arid tropical soil systems, this study aims to contribute to the development of context-specific yet transferable strategies for sustainable soil fertility management, climate-resilient agriculture, and long-term food security in tropical regions.

2. Materials and Methods

2.1 Study Area

This research was conducted from December 2025 to January 2026. The study area in Indonesia is located in Wonosalam district, Jombang Regency East Java and geographically at 112° 21' 05" to 112° 23' 22" East Longitude and 07° 44' 59" to 07° 40' 01" South Latitude. The research site is known to have been several sub-districts that have been cultivate a porang plant with a total area of 466.7 ha. Wonosalam is the sub-district where the existence of the most extensive porang plant (351.2 ha). Burkina Faso is a landlocked country in West Africa, located in the heart of the Sahel between 8° and 16° north latitude. Surrounded by Mali, Niger, Benin, Togo, Ghana, and Ivory Coast, its capital is Ouagadougou. The study area in Burkina Faso is located at Toudweogo in the northern part of Ouagadougou, province of Kadiogo (12° 26' N 001° 30' W) with an area of 10 Ha.

2.2 Tools and Material

The research equipment is divided into two categories: field sampling tools and laboratory analysis tools. For sampling, we used a hoe, crowbar, hammer, GPS, clinometer, plotter, cutter, trowel, camera, bucket, and writing instruments. Laboratory analysis equipment includes digital scales, spectrophotometers, burettes, shakers, film bottles, pipettes, volumetric flasks, measuring pipettes, centrifuges, digestion tubes, fume hoods, Erlenmeyer flasks, beakers, test tubes, reaction flasks, ovens, cups, and test tubes. Materials used for field sampling include rubber, gauze, and plastic.

2.3 Soil Sampling

Stratified random sampling was used for soil sampling based on different slope classes (0-8%, 8-15%, and 15-25%). The method used is to take soil sample points randomly on each land map unit. Soil samples were taken from the soil depth of 0-25 cm at different locations of the site. These samples are samples of undisturbed soil used for the analysis of all parameters.

2.4 Data Analysis

Soil test analysis was conducted at the Land Resources Laboratory, Faculty of Agriculture, UPN "Veteran" Jawa Timur, East Java in Indonesia and at the Soil Analysis Laboratory from The Institute for Agricultural and Environmental Research in Burkina Faso. Soil chemical analysis included exchange capacity (CEC) (NH₄OAc Extract Method); Organic Carbon analysis (Walkley and Black Method); Total Phosphorus (P) and Potassium (K) analysis (25% HCl Extract Method) according to the reference from Eviati & Sulaeman (2012) [11]; pH (H₂O), Nitrogen (N), organic matter (OM) and Base saturation (BS). We also analysed the texture of each sample as a physical parameter. Eviati & Sulaeman's (2012) [11] technical soil analysis data were used to establish criteria for each metric. Soil fertility status is determined using technical guidelines from Soil Research Center Bogor (Pusat Penelitian Tanah, 1995) [32].

2.4.1 Assessment of Soil Chemical Properties

Each soil chemical properties parameter was then categorized based on the criteria of Eviati & Sulaeman's (2012) [11] in Table 1, by assigning marks based on laboratory analysis and specific assessment standards for each parameter.

Table 1: Soil parameters criteria according to Eviati & Sulaeman's (2012) [11]

Parameters	Very Low (VL)	Low (L)	Medium (M)	High (H)	Very High (VH)
Organic Carbon (%)	<1.0	1.0-2.0	2.0-3.0	3.0-5.0	>5.0
Total P (mg/100g)	<15	15-20	21-40	41-60	>60
Total K (mg/100g)	<10	10-20	21-40	41-60	>60
Nitrogen (N)	<0.10	0.10-0.20	0.21-0.50	0.51-0.75	> 0.75
CEC (cmol(+)/kg)	<5	5-16	17-24	25-40	>60
Base Saturation (%)	<20	20-40	41-60	61-80	81-100

2.4.2 Soil Fertility Evaluation

After the criteria for each soil chemical parameters (CEC, Base Saturation, P₂O₅, K₂O, and Organic C) were determined, the soil fertility status was assessed based on the technical guidelines for soil fertility evaluation from Soil Research Center Bogor (Pusat Penelitian Tanah, 1995) [32] presented in Table 2.

Table 2: Soil Fertility Combination according to Pusat Penelitian Tanah (1995) [32]

No	CEC	BS	Total P, Total K, Organic Carbon	Fertility Status
1	H	H	H ≥ 2 without L	High
2	H	H	H ≥ 2 with L	Medium
3	H	H	M ≥ 2 without L	High
4	H	H	M ≥ 2 with L	Medium
5	H	H	H > M > L	Medium
6	H	H	L ≥ 2 with H	Medium
7	H	H	L ≥ 2 with M	Low
8	H	M	H ≥ 2 without L	High
9	H	M	H ≥ 2 with L	Medium
10	H	M	M ≥ 2	Medium
11	H	M	Another Combination	Low
12	H	L	H ≥ 2 without L	Medium
13	H	L	H ≥ 2 with L	Low
14	H	L	Another Combination	Low
15	M	H	H ≥ 2 without L	Medium
16	M	H	M ≥ 2 without L	Medium
17	M	H	Another Combination	Low
18	M	M	H ≥ 2 without L	Medium
19	M	M	M ≥ 2 without L	Medium
20	M	M	Another Combination	Low
21	M	L	3 H	Medium
22	M	L	Another Combination	Low
23	L	H	H ≥ 2 without L	Medium
24	L	H	H ≥ 2 with L	Low
25	L	H	M ≥ 2 without L	Medium
26	L	H	Another Combination	Low
27	L	M	H ≥ 2 without L	Medium
28	L	M	Another Combination	Low
29	L	L	All Combination	Low
30	VL	H, M, L	All Combination	Very Low

3. Results and Discussion

3.1 Analysis of soil texture

The results of the soil texture analysis in Indonesia and Burkina Faso are shown in Table 3.

Table 3: Results of the soil texture analysis in Indonesia and Burkina Faso

Wonosalam district				
Sample N°	Sand %	Silt %	Clay%	Texture
1	8	44	47	Silty Clay
2	4	18	78	Clay
3	10	38	51	Clay
Mean	7.33	33.33	58.67	Clay

Toudweogo, Burkina Faso				
Sample N°	Sand %	Silt %	Clay%	Texture
1	76.47	15.69	7.84	Sandy
2	62.75	13.72	23.53	Sandy

3	68.63	13.72	17.65	Sandy
Mean	69.28	14.37	16.34	Sandy

The physical analysis revealed a clear contrast between the soils of Wonosalam District (Indonesia) and Toudweogo (Burkina Faso). The Indonesian soil presented a clayey texture (mean: 58.67% clay, 33.33% silt, 7.33% sand), whereas the Burkinabe soil showed a sandy texture (mean: 69.28% sand, 14.37% silt, 16.34% clay).

In Wonosalam (Indonesia), the soil texture is dominated by Clay due to the claystone origin of the soil, which has a clay content ranging from 48% to 84% in this region. Indonesia's high clay content is indicative of volcanic soils produced under humid tropical conditions, which encourage intense chemical weathering (Pratamaningsih, M. M. *et al*, 2023) [31]. Clay soils are normally distinguished by their high water-holding capacity, increased nutrient retention, and stronger aggregation due to the large specific surface area and electrochemical activity of clay minerals (Yu, M. *et al*, 2022) [45]. These soils may hold cations like Ca²⁺, Mg²⁺, and K⁺, while also protecting organic matter from fast mineralization. These soils developed in tropical region with volcanic parent materials have many unique properties, and high potential for agricultural use (Hikmatullah & Nugroho, 2010) [18]. In contrast, Toudweogo (Burkina Faso) soils are sandy, with low clay content and they are frequent in West African Sahelian zones, where physical weathering of granitic foundations produces coarse-textured soils prone to leaching and erosion (Mwangi, J. *et al*, 2025) [27]. They derived from ferruginous tropical soils and aeolian deposits (Pal, D. K. *et al*, 2014) [30]. Sandy soils are characterized by large pores, high permeability and very low capacity to retain nutrients and organic matter (Bhatt, R. *et al*, 2025) [7]. According to a number of studies, sandy Sahelian soils are among the most deteriorated agricultural soils due to their inability to effectively store organic matter or fertilizers (Kihara, J. *et al*, 2012; Vågen *et al.*, 2021) [24, 42]. The following graph in figure 1, compares the mean soil texture from Wonosalam (Indonesia) and Toudweogo (Burkina Faso).

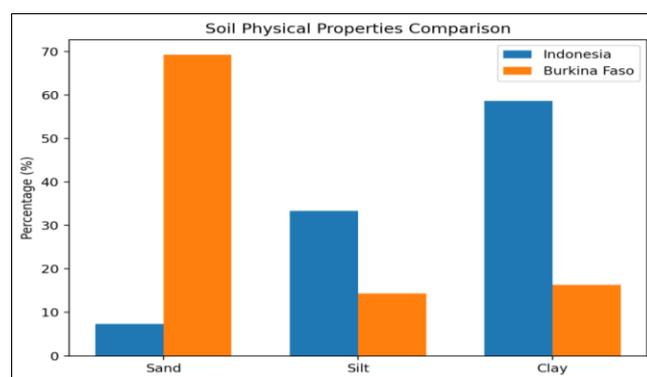


Fig 1: Graphic representing soil texture analysis in Indonesia and Burkina Faso

3.2 Analysis of some soil chemical properties

The results of the soil chemical parameters analysis in Indonesia and Burkina Faso are shown in Table 4.

Table 4: Results of the soil chemical parameters analysis in Indonesia and Burkina Faso

Wonosalam district, Indonesia								
Sample N°	PH (H ₂ O)	Organic matter (MO)%	Organic Carbon (C) %	Nitrogen (N) %	Phosphorus (P) mg/100g	Potassium (K) mg/100g	Cation exchange capacity (CEC) Cmol / Kg	Base saturation (BS) %
1	5.48	3.48	2.02	0.09	11.49	41.32	20.81	74.49
2	4.78	2.60	1.51	0.09	15.34	20.07	24.53	60.64
3	5.42	3.30	1.90	0.15	16.15	97.61	19.83	59.58
Mean	5.22	3.13	1.81	0.11	14.33	53	21.72	64.90
Interpretation	Acidic	Medium	Low	Low	Very low	High	Medium	High

Toudweogo, Burkina Faso								
Sample N°	PH (H ₂ O)	Organic matter (OM)%	Organic Carbon (C) %	Nitrogen (N) %	Phosphorus (P) mg/100g	Potassium (K) mg/100g	Cation exchange capacity (CEC) Cmol / Kg	Base Saturation (BS) %
1	5,76	1,89	1,04	0,09	2,00	5,55	6,05	64,40
2	6,01	1,10	0,64	0,06	0,61	2,77	5,47	66,70
3	5,66	0,70	0,41	0,04	2,39	4,20	6,78	70,80
Mean	5,81	1,23	0,69	0,06	1,67	4,17	6,10	67,30
Interpretation	Slightly acidic	Low	Very low	Very low	Very low	Very low	Low	High

The following graph in figure 2, compares the mean chemical properties of soils from Wonosalam (Indonesia) and Toudweogo (Burkina Faso).

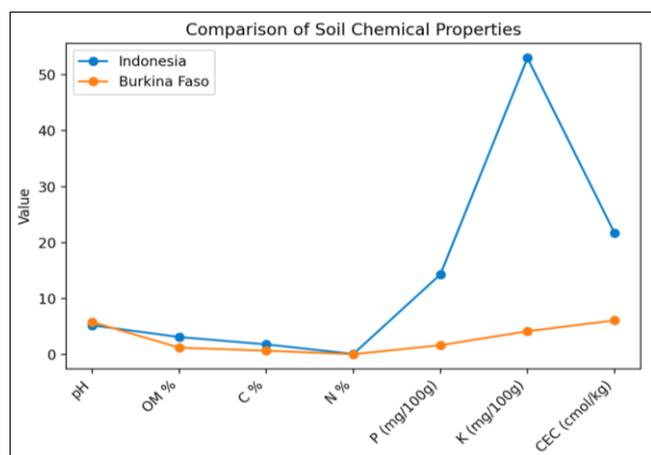


Fig 2: Graphic representing soil chemical properties analysis in Indonesia and Burkina Faso

3.2.1 Soil pH

From the results, we noticed that the mean pH was 5.22 in Wonosalam (Indonesia) and 5.81 in Toudweogo (Burkina Faso). Both soils are acidic, although the Indonesian soil is more acidic. Soil pH is one of the most essential soil chemical factors since it governs nearly all chemical reactions in the soil, including nutrient solubility, microbial activity, and cation exchange activities. This pronounced acidity in Indonesia is typical of highly weathered soils (Ultisols, Oxisols) under high rainfall, which leaches basic cations (Ca^{2+} , Mg^{2+} , K^+) and increases the dominance of exchangeable Al^{3+} and H^+ ions. In humid tropical regions like Indonesia, excessive rainfall causes base cations (Ca^{2+} , Mg^{2+} , K^+ , and Na^+) to leach, leaving hydrogen (H^+) and aluminum (Al^{3+}) ions predominate in the exchange complex (Hue N., 2022) [17]. This process explains the stronger acidity observed. By contrast, semi-arid areas like Burkina Faso have stronger leaching due to less rainfall, which raises pH levels a little bit. The mild acidity of Sudano-Sahelian soils is usually caused by their low degree of weathering (Sidsi, B. *et al*, 2026) [36].

3.2.2 Organic matter and organic carbon

Organic matter content differed greatly between the two soils. Wonosalam soils contained 3.13% organic matter, whereas Toudweogo soils contained only 1.23%. Organic carbon followed the same trend (1.81% vs 0.69%). This is a major fertility difference. Higher soil organic matter (SOM) in Indonesia results from a combination of high-density tropical vegetation providing massive carbon input, consistent heavy rainfall, and waterlogged, anaerobic conditions that inhibit decomposition (Jamaluddin *et al*, 2024) [21]. By contrast, Organic matter is very low in Toudweogo and Sahelian soils are globally known as chronically organic-matter-deficient soils. Burkina Faso is in the Sudano-Sahelian climate zone, which is defined by: high temperatures (typically above 30-40 °C), a protracted dry season (7-9 months), little and sporadic rainfall. These stimulate microbial activity and speed the mineralization of organic wastes (Bationo, A. *et al*, 2006) [6]. Furthermore, there is inadequate rainfall to support dense vegetation. Due to low biomass output, very little plant residue returns to the soil. As a result, organic matter inputs are quite limited (Woomer, P. L. *et al*, 2022) [44].

3.2.3 Nitrogen

Total nitrogen content was 0.11% in Indonesia and 0.06% in Burkina Faso. Both values are low, especially in Toudweogo. This nitrogen comes from soil microbes decomposing organic matter into ammonium (NH_4^+), which is then quickly transformed into nitrate (NO_3^-) via nitrification (Grzyb, A. *et al*, 2021). Nitrogen availability is closely linked to organic matter and as a result, when soil organic matter is low, as it is in Burkina Faso, nitrogen levels fall as well. Even in Indonesia, where organic matter is moderate, it is still insufficient to provide considerable amounts of nitrogen for continuous cropping (Chiriach, O. P. *et al*, 2025) [9].

3.2.4 Available phosphorus

Available phosphorus showed a very strong difference: 14.33 mg/100 g in Indonesia and 1.67 mg/100 g in Burkina Faso. This indicates severe phosphorus deficiency in Burkina Faso soils. It is one among the least accessible nutrients in tropical soils due to its strong fixation by iron and aluminum oxides or precipitation with calcium, depending on pH. Low soil pH values in each country,

which fall between 5.5 and 6.0 (slightly acidic), are believed to be closely related to low total P soil values. According to the view of Eviati & Sulaeman (2012) [11], Susanto and Nursyamsi (2014) [39], the retention or lack of nutrient P content in the land is one of the limiting factors that generally grows on any soil with a pH value near acid. Since element P is strongly absorbed by acid oxides at near-acid pH, the low level of P content of nutrients on the ground, either completely or readily, is related to pH.

3.2.5 Potassium

Exchangeable potassium showed one of the strongest contrasts between the two study sites. The mean potassium content reached 53 mg/100 g in Wonosalam (Indonesia), classified as high, whereas it was only 4.17 mg/100 g in Toudweogo (Burkina Faso). The most important explanation for the higher potassium in Indonesia is the clayey texture of Wonosalam soils. Clay particles have negative electrical charges on their surfaces. These charges attract and hold positively charged ions, such K⁺ (Gurav, P. *et al*, 2019) [14]. Therefore, clay soils behave as nutrient reservoirs. Clay minerals absorb potassium ions and gradually release them to plants; therefore, soil fertility tests consistently indicate a high correlation between exchangeable potassium and clay content and cation exchange capacity (Havlin, J. *et al*, 2022) [16]. According to the Food and Agriculture Organization of the United Nations, the very low potassium content measured in Toudweogo is typical of Sudano-Sahelian soils and is mainly caused by the combined effects of sandy texture, low cation exchange capacity, weak organic matter status, climatic conditions and long-term nutrient mining.

3.2.6 Cation Exchange Capacity and Base Saturation

Cation exchange capacity (CEC) and base saturation (BS) are two closely related chemical markers that characterize the soil's ability to retain and provide nutritional cations to plants. CEC is the total number of negatively charged exchange sites in the soil, while base saturation reflects the proportion of those sites filled by basic nutritional cations (Ca²⁺, Mg²⁺, K⁺, and Na⁺). The results revealed a significant difference between the two research locations. Soils in Wonosalam, Indonesia had a medium CEC of 21.72 cmol kg⁻¹, while those in Toudweogo, Burkina Faso had a low CEC of 6.10 cmol kg⁻¹. In contrast, the base saturation percentages were quite similar: 64.9% in Indonesia and 67.3% in Burkina Faso. The higher CEC measured in Wonosalam soils is consistent with their clayey texture and higher organic matter content. Clay particles and organic colloids provide numerous exchange sites capable of storing plant nutrients. Toudweogo's sandy soils (about 69% sand) have limited organic matter and few colloidal particles. Sandy particles are chemically inert and have virtually no electrical charge, therefore they cannot hold cations. As a result, nutrients remain in the soil solution and can be easily lost by leaching or erosion. Soils with CEC below 10 cmol kg⁻¹ have limited nutrient-holding ability and poor buffering against fertility decrease (Brady & Weil, 2021).

Despite the strong difference in CEC, base saturation values were high in both soils. Wonosalam soils have a larger exchange complex, therefore the same percentage of base saturation reflects a substantially greater quantity of accessible nutrient cations. High base saturation in clay soils typically indicates good chemical fertility, however in sandy soils it may merely represent low soil acidity rather than nutrient richness (Havlin *et al.*, 2022) [16].

3.3 Evaluation of fertility status in Wonosalam and Toudweogo

To better understand the productive potential of the studied soils, their fertility status was assessed using key chemical indicators. The following table 5 summarizes the values of exchange capacity, base saturation from each sample and their fertility status according to Soil Fertility Combination from Pusat Penelitian Tanah (1995) [32].

Table 5: Result of Analysis of Soil Fertility Status

Wonosalam district, Indonesia			
Sample No	CEC	BS	Fertility status
1	20.81 (Medium)	74.49 (High)	Medium
2	24.53 (Medium)	60.64 (Medium)	Medium
3	19.83 (Medium)	59.58 (Medium)	Medium

CEC: Cation exchange capacity; BS: Base saturation

Toudweogo, Burkina Faso			
Sample No	CEC	BS	Fertility status
1	6,05 (Low)	64.40 (High)	Low
2	5,47 (Low)	66.70 (High)	Low
3	6,78 (Low)	70.80 (High)	Low

CEC: Cation exchange capacity; BS: Base saturation

The entire soil fertility status was assessed using two integrative indicators: cation exchange capacity (CEC). These characteristics combine the soil's ability to store nutrients and the proportion of nutrient cations occupying the exchange complex, and they are extensively employed as global soil fertility indexes in tropical agronomy. The results indicate clear differences between the two study areas. All samples from Wonosalam District (Indonesia) were classified as medium fertility, whereas all samples from Toudweogo (Burkina Faso) were classified as low fertility. In wonosalam, this fertility level can be attributed mostly to the clayey texture and greater organic matter content. Clay particles and humus colloids include multiple adsorption sites for calcium, magnesium, and potassium, reducing nutrient loss by leaching. As a result, nutrients remain available in the root zone for an extended period of time (Nithin, S. *et al*, 2025) [29]. As a result in Toudweogo, the fertility status was classed as low. The apparent paradox of high BS but poor fertility is explained by the soil's low nutrient-holding capacity. Soil fertility is low because of the sandy texture and low organic matter content. Sahelian soils are inherently low in fertility due to a sandy texture and low organic matter, resulting in poor nutrient retention and high rates of nutrient leaching. Because of low cation exchange capacity, applied fertilizers are rapidly lost from the root zone, leading to poor crop responses (Srivastava, R. *et al*, 2024) [38].

3.4 Strategies for sustainable soil fertility management in Indonesia and Burkina Faso

The comparative analysis highlighted significant differences in soil fertility constraints between Wonosalam (Indonesia) and Toudweogo (Burkina Faso). Indonesian soils exhibit moderate fertility and Burkinabe soils display very low cation exchange capacity (CEC), low organic matter, and severe nutrient depletion. Therefore, effective soil fertility management strategies must be tailored to address the specific limiting factors in each location.

For Indonesia, effective soil management involves: Acidity amelioration through targeted application of lime or dolomite to optimize pH and nutrient availability, avoiding over-liming; Phosphorus management using P-efficient crops and careful fertilizer application to enhance accessibility; Organic matter conservation via agroforestry, cover cropping with legumes, and biochar application to improve soil properties; and integrated Nutrient Management, which balances mineral fertilization with organic inputs for enhanced soil health.

For Burkina Faso, Organic resource management prioritizes increasing soil organic carbon through techniques like zai, stone lines, and the application of compost and manure to enhance water retention and nutrient supply. Targeted mineral phosphorus fertilizers and legume rotations are crucial for combating nutrient poverty. Soil and water conservation is essential as fertility management relies on water availability. Micro-dosing fertilizer at planting is an effective strategy for resource-poor farmers. Overall, promoting climate-smart agriculture and enhancing soil health monitoring while empowering local communities is vital for sustainable management. Improve the Organic matter conservation via agroforestry, cover cropping, and biochar application to improve soil properties.

Comparative studies highlight that tropical clay soils (Indonesia) are more resilient to nutrient depletion, while semi-arid sandy soils (Burkina Faso) are highly vulnerable to degradation. Souza *et al.* (2024) ^[37] demonstrated that high-activity clay soils in tropical regions maintain critical fertility levels longer due to their buffering capacity, even under intensive cultivation. Husein *et al.* (2021) ^[20] emphasized that semi-arid sandy soils are highly vulnerable to degradation, with fertility declining rapidly unless conservation agriculture and organic amendments are applied. According to Juo, A. S. R., & Franzluebbers, K. (2003) ^[23], moderately weathered tropical soils derived from basalt or volcanic parent material are invariably more fertile than sandy soils derived from quartzite or granite, confirming the resilience of Indonesia's soils compared to Burkina Faso's.

4. Conclusion

The comparison of soil fertility in Wonosalam (Indonesia) and Toudweogo (Burkina Faso) demonstrates the significant impact of agro-ecological circumstances on soil characteristics and agricultural sustainability. Despite acidity, poor nitrogen and phosphate availability, Indonesia's clay-rich soils benefit from increased organic matter, potassium stores, and moderate cation exchange capacity. These traits, when combined with lime application, coordinated nutrient management, and careful water regulation, lay the groundwork for long-term productivity. In contrast, Burkina Faso's sandy soils have very low organic matter, nitrogen, phosphorus, potassium, and cation exchange capacity. Despite high base saturation, nutrient stocks are limited, leaving these soils vulnerable and reliant on organic additions, agroforestry, and conservation agriculture for fertility restoration.

This comparison demonstrates that soil fertility challenges vary by context: tropical clay soils in Indonesia are more resilient but require interventions to address acidity and nutrient imbalances, whereas semi-arid sandy soils in Burkina Faso necessitate intensive organic input strategies to increase fertility and resilience to degradation.

Finally, sustained soil fertility management in both nations necessitates locally tailored solutions that integrate ecological restoration with socioeconomic support for farmers. To grow organic farming systems that improve productivity, resilience, and long-term sustainability, farmer training must be strengthened, organic inputs made more accessible, and supportive policies implemented.

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