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# SOIL FERTILITY STATUS OF VARIOUS ABACA- BASED AGROECOSYSTEMS IN ZAMBOANGA PENINSULA, PHILIPPINES

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## Abstract

The decline in soil fertility is considered the primary degradation process in major abaca-growing regions, as prolonged intensive cultivation has occurred without the application of fertilizers, leading to nutrient depletion in the soil. Abaca (Musa textiles, Nee) is cultivated alongside with anii, narra, coconut, fruit trees, and various forest trees. As a shade-loving plant, there is a wide area for possible abaca production expansion in the Zamboanga Peninsula. However, the soil fertility status of established abaca under different agroecosystems were not determined. Assessment of soil fertility status of the major abaca agroecosystems can help draw sound nutrient management strategy. The results indicate that the abaca agroecosystem possesses favorable soil texture, bulk density, and water-holding capacity. As far as the result of analyses after assessment, abaca agroecosystems demonstrate low levels of organic matter, soil organic carbon, nitrogen, phosphorus, exchangeable bases, and available manganese, zinc, and copper, while exhibiting high levels of available iron. An inverse relationship between soil pH and water holding capacity (WHC); soil pH and available zinc; and bulk density and soil organic carbon content were observed. The addition of organic matter or fertilizers is essential for sustaining soil fertility and ensuring long-term productivity.

**Keywords:** Coconut, Essential Elements, Falcata, Mixed Trees, Rubber.

## INTRODUCTION

Soil, a crucial natural resource, is currently grappling with numerous environmental challenges. Soil is responsible for critical functions within the ecosystem, such as supporting plant growth, largely regulating the flow of water through the hydrologic cycle, recycling waste products from society and nature, modifying the composition and properties of the atmosphere, providing habitat for a vast array of organisms, and serving as construction material and support for building foundations in built environments. (Brady, N. & Weil, R., 2008). Soils are indispensable for the existence of life on this planet. Although people may not realize it, their dependence on the ecological functions of soil is growing. The decline in soil fertility is a problem in many tropical countries. Therefore, protection from this important resource is necessary.

Intercropping is recognized as a sustainable technique that helps preserve and enhance the health, quality, and fertility of soil (Oelbermann et al., 2015; Chapagain and Riseman, 2014; and Dyer et al., 2012), and often boosts production and provides ecosystem benefits (Zhi et al., 2007). The implementation of intercropping in farming systems can yield substantial ecological and economic advantages, thereby augmenting the resilience and sustainability of the agricultural sector resulting in enhanced long-term profitability and yield stability (Glaze-Corcoran et al., 2020).

Abaca (*Musa textiles*, Nee) known worldwide as Manila hemp, is endemic to the Philippines and grown primarily for its fiber (Bande et al., 2013). About 97.0% of the total abaca production in the country is exported which generated an equivalent of more than Php8 billion revenue in 2019 (PhilFIDA, 2019). As a shade loving crop, it has good potential as intercropped into agroforestry systems. On Leyte Island, abaca-based agroecosystems are concentrated in mountainous areas where abaca is usually planted in the shade beneath tall trees or coconuts (Armecin and Gabon, 2008). The abaca farmers employed the multistorey cropping system, and commonly cultivated alongside abaca are anii, narra, coconut, fruit trees, and certain forest trees (Armecin, et al., 2011), and offers potential sources of income for small-scale tree farmers (Gonzal, 2005).

Abaca is one of the champion commodities in the Zamboanga Peninsula, alongside rubber, coconut, mango, seaweeds, and fish and fish products. Approximately 51% of the terrain is characterized by undulating topography, which includes sharp inclines and altitudes varying from 100 to 1,000 meters above sea level (Department of Trade and Industry, n.d.). A total of 400,000 hectares of land is potential for abaca plantation expansion (BSWM, 2019). Soil fertility decline is believed to be the predominant degradation process occurring in the most abaca growing areas. Intensive abaca cultivation in these areas has been done for years without applying any fertilizer as supplement to the crop (Lacuna-Richman, 2002).

This would lead to the depletion of the nutrient reserve in the soil that would cause significant reduction of the fiber yield. In this particular plant part (i.e., harvested fiber) some of the essential nutrients, such as potassium (k) and iron (Fe), predominate, which could be considered as potential risk of nutrient depletion due to crop removal (Armecin, 2008).

Nevertheless, combining abaca to other perennial crops like coconut, falcata, rubber, and fruit trees is believed to have an impact on soil fertility. Planting of native tree species to rainforestation rehabilitate degraded lands is an effective approach in restoring the functions of an abaca-based agroecosystem by improving soil quality suitable for the crop (Bande et al., 2016). However, there is limited information of soil fertility across different abaca agroecosystem. Assessment of soil fertility status of the major abaca agroecosystems in Zamboanga Peninsula can help draw sound nutrient management strategy. This will also serve as guide for government institutions in formulating programs for sustainable abaca production.

## MATERIALS AND METHODS

### Study Site

This study was conducted in Zamboanga Peninsula particularly in municipalities of Aurora and Molave in Zamboanga del Sur; Kalawit, Zamboanga del Norte; and Naga, Zamboanga Sibugay where major abaca plantations of different agroecosystem is located. The Zamboanga Peninsula region is located at the southernmost part of the Philippine archipelago, at the western tip of the island of Mindanao.

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Approximately 51% of the terrain is characterized by undulating topography, featuring sharp inclines and altitudes ranging from 100 to 1,000 meters above sea level. While about 310,000 hectares of coconut land offer potential for multi-cropping and grazing, about 60,000 hectares of agricultural land remain idle. The region experiences climates classified as Types 3 and 4. Year-round rainfall occurs, but dry weather dominates from December to May. The mean annual precipitation is 2,372 millimeters, making it advantageous for agricultural activities (Department of Trade and Industry, n.d.).

The abaca agroecosystems considered in the study were the following: abaca under coconut, abaca under falcata, abaca under rubber, and abaca under mixed trees (fruit trees and other trees). The study had an area of not less than 1.0 hectare each agroecosystem. Identification and validation of sites was coordinated with Philippine Fiber Industry Development Authority Regional Office IX. The study was conducted from May 2024 to September 2024.

## Soil Sampling Collection

We established three (3) 200-meter sampling plots in each agroecosystem. We collected composite samples from various points within each plot. Soil samples were collected to the same depth of 30 cm. Samples were air-dried, ground with a mortar and pestle, sieved to <2 mm mesh size, and submitted to Central Mindanao University- Soil and Plant Analysis Laboratory (CMU-SPAL) in Musuan, Maramag, Bukidnon, and in Regional Soils Laboratory in Butuan City, Caraga, for analysis. Table 1 provides brief descriptions of the sampling areas.

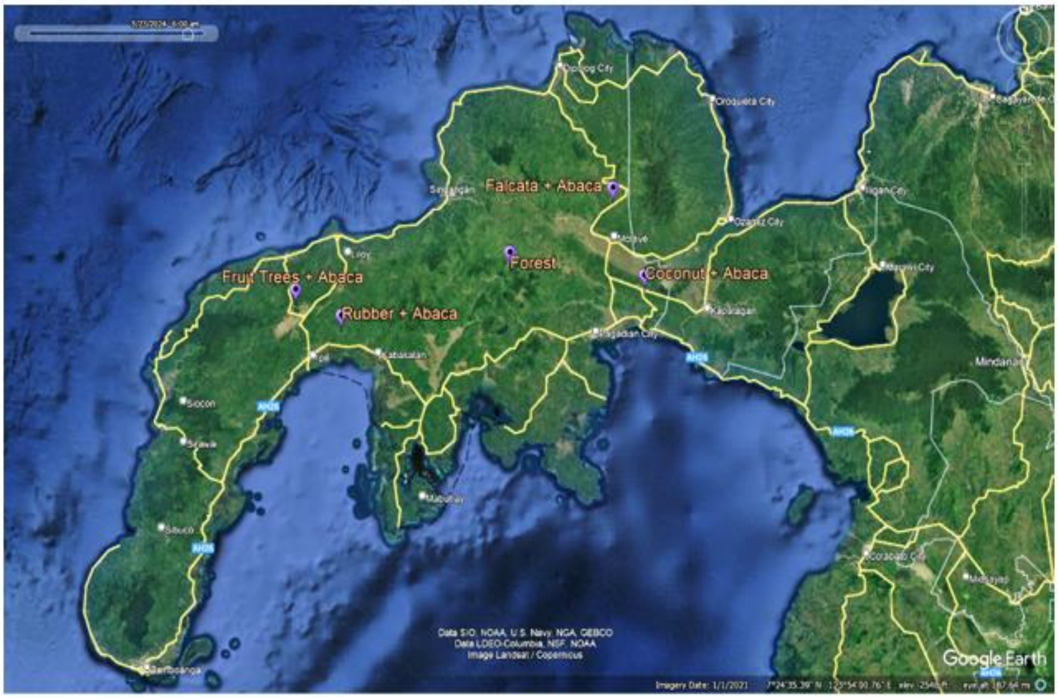

FIGURE 1. Map of sampling sites under different agroecosystem.

### Soil Laboratory Analyses

Bulk density was determined by driving an improvised metal canister (6 cm diameter and 10 cm height) into the 10-20 cm soil and was dried in drying oven at $105^{0}$ C for maximum of 48 hrs (DPRID, 2021). The hydrometer method was used in the soil texture determination.

The soil pH was determined using pH meter following 1:1 soil to water ratio. The organic matter (%) was determined following the Walkley-Black Method. The measure for available phosphorus was determined through Olsen Method.

The exchangeable basic cations ($K^+$, $Ca^{2+}$, $Mg^{2+}$, and $Na^+$) were extracted with 1M ammonium acetate at pH 7. The CEC of the soil was determined from ammonium acetate saturate sample. The available Mn, Fe, Zn, and Cu was determined using the DTPA (Diethylenetriamine Penta acetic acid) extraction- Microwave Plasma-Atomic Emission Spectrometry method.

Pearson correlation is used to determine the relationship between soil physical and chemical properties using the Statistical Tool for Agricultural Research (STAR).

**Table 1: Descriptions of the Sampling Areas of Different Abaca Agroecosystem in Zamboanga Peninsula**

| Type of Agroecosystem | Location | Altitude | Elevation (masl) | Land Use History |
|---|---|---|---|---|
| Abaca under coconut | Brgy. Romarate, Aurora, Zamboanga del Sur | 7°56'53.42"N<br>123°35'30.05"E | 315.2 | Abaca were planted 14 years ago under a 40 years old coconut trees. Some weeds such as kudzu, lantana, ferns, etc. |
| Abaca under falcata | Brgy. Bag-ong Argao, Molave, Zamboanga del Sur | 8°11'39.93"N<br>123°30'7.45"E | 416.3 | Falcata trees were planted 7 years ago while abaca was established 3 years ago. |
| Abaca under mixed trees | Brgy. Poblacion, Kalawit, Zamboang del Norte | 7°55'31.22"N<br>122°32'51.11"E | 197.2 | Abaca were planted more 15 years ago and has been grown under fruit trees and other trees. |
| Abaca under rubber | Brgy. Sulo, Naga, Zamboanga Sibugay | 7°51'1.65"N<br>122°41'0.95"E | 133.3 | Rubber plantation was established about 2 decades ago with planting distance of 3m x 2.5m x 23m. Abaca was established 6 years but did not harvest since 2020. |

## RESULTS and DISCUSSION

### *Soil Physical Properties of the Different Abaca Agroecosystem*

The soil's physical characteristics directly influence its supporting capacity, the flow, retention, and availability of water and nutrients to plants, the ease of root penetration, and the passage of air and heat. Physical characteristics also influence chemical and biological characteristics of the soil (Phogat et al., 2015). Previous studies have shown that agroforestry has good bulk density values (0.78–1.05 g $cm^{-3}$) that allow roots to penetrate (Dori et al., 2022). These values are much lower than those soil found in agriculture cropping fields (Rawat et al., 2018). According to Hailie et al. (2021), increased soil organic matter supported moisture conservation, resulting in a higher soil moisture content below the tree canopy compared to open areas. In line with the fact that agroforestry has a positive effect on soil properties, we focused on how the different abaca-based agroecosystems affect soil physical properties in this section (Table 2).

### *Soil texture*

Two soil textural classifications predominate in this study. The abaca cultivated in coconut, falcata, and rubber agroecosystems has a loamy soil texture, whereas the abaca in mixed agroecosystems has a sandy soil texture. Loam soil is better for farming because it holds more water and nutrients. Sandy soils, on the other hand, lose water and nutrients more easily, have less organic matter, don't swell or shrink as much, and let more nutrients and pollutants wash away (Phogat et al., 2015).

The abaca plants require fairly rich, well-drained, loamy soil for cultivation. Meanwhile, falcata can grow on a wide range of soils; it does not require fertile soil; it can grow well on dry soils and damp soils as long as the drainage is adequate (Lemmens and Soerianegara, 1995). On the other hand, according to Khan et al. (1979), as cited by Thomas et al. (2018), palm trees can thrive in a wide variety of soil types, including clayey soils and poorly drained low-lying areas.

Although the practices of agroforestry do not directly change the texture of the soil, they can affect the properties of the soil that interact with the texture. In agroforestry systems, for example, organic matter inputs can enhance nutrient retention and water holding capacity in sandy soils, while in clayey soils they can decrease density and improve aeration (Hombegowda et al., 2022).

### *Bulk density (BD)*

Bulk density is a measure of soil compaction. While low bulk density points to a well-structured soil with sufficient pore spaces, high bulk density can limit root development and water absorption. The bulk density of the various agroecosystems in this study varied from 0.99 to 1.24 g/$cm^3$. Values obtained in all agroecosystems are considered good since they do not exceed the critical limit for such soil parameters.

The amount of organic matter, its management, particle size, and soil texture determine the best and worst levels of BD in soil (Reichert et al., 2009). Agroforestry systems usually have less bulk density because of the activities of soil animals like earthworms that break up organic matter and the addition of organic matter through litter fall, fine root recycling, and twigs (Cardinael et al., 2019). For instance, Tshepiso et al. (2005) found that agroforestry systems result in lower bulk densities than non-agroforestry areas.

Bulk densities were lower in rubber tree plantations compared to annual cropping systems, as reported by Araujo et al. (2004). This may result from reduced soil disturbance caused by tillage and equipment usage, as well as the establishment of multi-crop systems with varying rooting depths to soften compacted soil layers.

### *Water Holding Capacity (WHC)*

The estimation of a soil's water holding capacity (WHC) is crucial in agriculture, providing a clear method for assessing the required moisture content for optimal plant growth and water infiltration (Viji and Rajesh, 2011). Management decisions regarding crop types, plant populations, irrigation scheduling, and nitrogen fertilizer application are influenced by the moisture availability for the crop during the growing season. Understanding the physical characteristics of soil allows for an improved understanding of the advantages and disadvantages associated with various soil types.

This study shows that abaca cultivated within a falcata agroecosystem exhibits the highest water holding capacity, followed by abaca in coconut, rubber, and mixed agroecosystems. This could potentially be attributed to a higher percentage of clay particles and organic matter in the soil of abaca within the falcata agroecosystem. Soil texture influences the water retention capabilities of soils of different locations, as soils with high clay percentage or both (high clay percentage and organic matter content) tend to have high WHC (Ogunkunle, 2010). Meanwhile, tree species add litter, which acts as a protective layer to maintain soil physical properties like soil moisture conservation, shield against soil compaction, and reduce soil losses from erosion or leaching (Xiong et al., 2008).

**Table 2: Soil physical analyses result of the different abaca agroecosystem**

| Type of Agroecosystem | Soil Texture | Bulk Density (g/cm$^3$) | WHC (%) |
|---|---|---|---|
| Abaca under Coconut | Sandy Loam | 1.19 | 74.44 |
| Abaca under Falcata | Sandy Clay Loam | 1.02 | 90.32 |
| Abaca under Mixed | Loamy Sand | 1.24 | 54.77 |
| Abaca under Rubber | Sandy Clay Loam | 0.99 | 64.96 |

### *Soil Chemical Properties of the Different Abaca Agroecosystem*

Understanding the interaction of chemical properties in soil is essential for assessing its capacity to store and release nutrients, ensuring sustainability, and maintaining nutrient cycling, plant biomass, and organic matter (Schoenholtz et al., 2000). Soil chemical indicators include soil pH, cation exchange capacity (CEC), organic matter, and nutrient levels (Kelly et al., 2009).

Cropping pattern is found to have influence on the chemical composition of the soil. In agroforestry system, previous studies have shown synergistic effects and changes in the soil chemical properties. These changes include increased agricultural productivity and improved soil fertility, nutrient loss reduction, soil organic matter increment, and make nutrient cycling easier. This can also lead to higher levels of nitrogen, phosphorus, and potassium in the soil (Dori et al., 2022; Hailie et al., 2021; Aschalew and Zebene, 2018; Zebene, 2016).

In the study of Niu et al. (2021) with the Quercus *leucotrichophora*-based agroforestry system, they observed that this system was superior in enhancing soil fertility compared to other agroforestry systems and open cropping systems. Considering the importance of agroforestry in the Philippine economy, this section examines the impact of various abaca-based agroecosystem on soil chemical properties. Results on soil chemical properties are shown in Table 3.

### *Soil pH*

The soil's pH affects nutrient availability, microorganism activity, and overall health. Decomposing tree litter and root exudates releases organic acids and other compounds into the soil, which can affect soil pH. Soil pH serves as a critical indicator, as it directly correlates with nutrient availability and solubility, while also influencing microbial activity. Consequently, pH assessment enables the prediction of nutrient availability potential within a specific production system (Sousa et al., 2007).

The result of this study indicates that soil pH in abaca under different agroecosystems varies from medium acidic (coconut), strongly acidic (mixed trees and rubber) and very strongly acidic (falcata). The chemical processes in legumes like falcata, which produce ammonium, could explain the strong acidity in abaca under the falcata agroecosystem. The conversion of ammonium to nitrate allows it to combine with basic cations, such as calcium, magnesium, and potassium, which then leach from the topsoil into the subsoil. Soils become more acidic as H ions replace these bases.

Rhoades and Binkley (1996) also observed a decline in soil pH from 5.9 to 4.6 in stands of *Albizia falcataria* (L.) Fosberg, which they attributed to increased acidification of the soil exchange complex. However, in the study of Sileshi et al. (2020), adding leguminous trees to agroforestry systems can help neutralize soil acidity and make more nutrients available, which makes the soil more fertile. Nevertheless, several studies show similar results indicating that an area in agroforestry system has significantly lower soil acidity (pH) than an area without one (Solanki, 2011; Kumar et al., 2008; Newaj et al., 2007).

### *Cation Exchange Capacity (CEC)*

Soil CEC quantifies the soil's capability to retain and exchange cations, including calcium, magnesium, sodium and potassium. A higher cation exchange capacity (CEC) signifies enhanced nutrient retention and accessibility for plants. The abaca under coconut recorded the highest cation exchange capacity (CEC) value at 20.21 me/100g. The abaca under falcata has a CEC of 14.51 me/100 g, while the abaca under rubber has a CEC of 10.67 me/100g. The abaca under mixed agroecosystem has the lowest CEC of 9.36 me/100g.

This may be associated with its soil texture, where coarse-textured, sandy soils have relatively low CEC because they have low clay content and typically low organic matter content. Agroforestry systems can improve cation exchange capacity (CEC) by incorporating organic matter, thereby augmenting the number of exchange sites in the soil. Trees in agroforestry systems provide a consistent supply of organic residues, thus preserving and improving soil cation exchange capacity over time (Fahad et al., 2022).

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### *Soil Organic Carbon*

Organic carbon (OC) improves soil physical properties and nutrients, making it one of the most important soil quality evaluation indices (Lal, 2004; Hammad et al., 2020). The SOC content of abaca under mixed agroecosystem (1.22%) has the lowest SOC content; followed by abaca under coconut (1.39%); and abaca under falcata (1.59%). The SOC content of abaca under rubber has the highest with 1.89%. It is the only agroecosystem in this study that has a little more than the critical concentration suggested for crop production in low-input tropical soils (Okalebo et al., 2002). Research has shown that agroecosystems possess comparatively low soil organic carbon (SOC) levels and exhibit sensitivity to environmental fluctuations (Minasny et al., 2017; Sanderman et al., 2017).

The high temperatures in the Philippines allow for rapid decomposition of organic matter aside from not applying any fertilizer to the crops, resulting in generally low levels of soil organic carbon in all abaca agroecosystem. In the study of Rawat et al. (2018), SOC content was significantly higher under the tree species (0.93 – 1.07%) as compared to agriculture field (0.75%). Effective management of crop residues can improve soil organic matter content (Singh et al., 2005). Some of the things that may help increase the SOC content of soil in tree-based systems are the addition of litter, the yearly recycling of fine root biomass and root exudates, and the slower oxidation of organic matter when trees are nearby (Gill and Burman, 2002).

Additionally, trees typically contain lignified cells in their litter, small branches, bark, roots, and other plant parts that may help biochemically in stabilizing the soil's organic carbon, thus raising the soil's SOC content (Six et al., 2002). In tropical regions, the incorporation of trees into agricultural systems has demonstrated an increase in soil organic carbon levels, thereby enhancing soil fertility and productivity (Lorenz & Lal, 2014).

### *Available Nitrogen*

Abaca under rubber agroecosystem has the most available N of 0.1633%; followed by abaca under falcata with 0.1367%; abaca under coconut with 0.1200%; and abaca under mixed agroecosystem with 0.1050%. The available nitrogen (%N) in all agroecosystem is considered low. Although there is an addition of organic residue in the form of tree litter and fine root biomass in the soil in all abaca agroecosystems, the deposition is merely not enough to increase the soil's available N to a sufficient level. This may also be caused by the extreme heat experienced in the past months in all areas, resulting in low organic matter levels and consequently affecting the soil’s available N.

In addition, farm owners do not apply any fertilizer or organic matter sources in their areas. Despite the low availability of N in all agroecosystems in this study, it still surpasses the amount found in agriculture alone by 0.0485% (Rawat et al., 2018). Moreover, Osman et al. (2001) found that the soil with an agroforestry system had a higher available N content than the soil without one. In the study of Chaudhry et al., (2007) in a polar-based agroforestry system, surface organic wastes decomposed more actively resulting in the highest concentration of available nitrogen in the surface layer.

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Similarly, studies have shown that integrating Faidherbia albida into cropping systems increases soil nitrogen levels and improves crop yields in African agroecosystems (Yengwe, J., 2017). Conversely, Dori et al. (2022) found no significant difference in available soil nitrogen when comparing parking land, home garden, and forest system soils. This result is also similar to the previous studies of soil available N of the different agroforestry (Karki et al., 2021; Thiago et al., 2016; Zebene and Goran, 2007).

### *Extractable Phosphorous*

Phosphorus is a critical macronutrient essential for plant growth and metabolic processes. Plant activities, including growth, respiration, and reproduction, are largely dependent on the phosphorus levels present in the soil (Wagh et al., 2013). Abaca under the falcata agroecosystem has the most exchangeable phosphorus with 4.33 ppm, followed by abaca under coconut with 4.00 ppm, abaca under mixed with 2.33 ppm, and abaca under rubber with 2.00 ppm. All abaca agroecosystems exhibit low exchangeable phosphorus in their soil. This result could potentially be caused by the low organic matter content of the soil in all abaca agroecosystems. The phosphorus content in the soil was greater in higher topographic positions compared to soils in lower topographic positions (Singh and Rathore, 2013). Adequate phosphorus availability enhances early plant growth and accelerates maturity (Solanki and Chavda, 2012). Soil exhibiting minimal leaching is recognized to have a higher concentration of phosphorus relative to soil with extensive leaching (Ashraf et al., 2012). The abaca plant's leaves exhibit significant phosphorous concentrations during the vegetative and flagleaf growth stages (Armecin, 2008). Miller and Donahue (2001) indicate that soils with high organic matter content provide greater supplies of organic phosphate for plant uptake compared to soils with low organic content. Researchers Dori et al. (2022) and Hailie et al. (2021) observed higher levels of available phosphorus in home gardens, while parkland and ficha systems recorded the lowest values. Amanuel (2022) demonstrates that the levels of available phosphorus were higher beneath the canopies of *Acacia abyssinica* and *Albizia gummifera* trees than in open areas. Hailie et al. (2021) demonstrated that fruit-based agroforestry practices in the Amhara region of Ethiopia showed increased levels of available phosphorus and exchangeable potassium. Fruit crops, characterized by their perennial nature and prolonged growth periods, act as important nutrient sinks that require replenishment to sustain production over time (Srivastava, 2017).

### *Exchangeable Bases*

Exchangeable base cations are crucial for sustaining soil nutrients (Collingnon et al., 2011), supplying vital nutrients for plant development (Luo et al., 2017), and mitigating soil acidification (Lucas et al., 2011). Abaca under coconut contained the greatest exchangeable $K^+$, exchangeable $Ca^{2+}$, exchangeable $Mg^{2+}$ and exchangeable $Na^+$ with 137.33ppm, 824.00ppm, 417.00ppm, and 36.17ppm, respectively. This may result from the incorporation of high organic matter during the frequent harvesting of both coconut and abaca. Armecin (2008) says that Mg was found in large amounts in the abaca plant's leaves during both the vegetative and flagleaf growth stages. He also says that calcium is the most common element in the pseudostem tissue during both the seedling and vegetative growth stages, and K is most common in the same tissue during all the growth stages that were studied, which means that there is a lot of this element in the fiber that was harvested.

In addition, Bajpai et al. (2006) reported increased potassium content in soil due to elevated organic matter levels. As reported by Hasan and Ashraful Alam (2006), agroforestry increases potassium availability when compared to treeless farming systems due to improved nutrient recycling through biochemical processes. Moreover, in the study of Miah et al. (2001), the available soil potassium was higher under alley cropping system as compared to the agriculture field as a result of release of organic acids due to organic matter accumulation under agroforestry and ultimately resulting in higher mineralization of potassium. Meanwhile, most fruit crops are nutritionally more efficient than annual crops due to their woody framework (nutrients locked therein), extended physiological stages of growth, differential root distribution pattern (root volume distribution), growth stages in terms of nutrient requirement, and preferential requirement of some nutrients by specific fruit crops (Scholberg and Morgan, 2012). In addition, higher K removal rate is recorded for fruit crops (Srivastava, 2017).

### *Micronutrient Analyses*

Micronutrient analyses results of all abaca agroecosystem are shown in Table 3. The abaca under coconut and falcata has medium available manganese content of 134.33 ppm and 66.20 ppm, respectively. Abaca under rubber has low available manganese (5.83 ppm) while abaca under mixed agroecosystem has the very low available manganese (2.57 ppm). Meanwhile, all agroecosystems have low availability of copper (Cu) ranging from 0.98 ppm to 4.94 ppm (abaca under mixed < abaca under rubber<abaca under falcata< abaca under coconut). In terms of available Zn, abaca under falcata has the most content (3.03 ppm), followed by abaca under coconut (1.16 ppm), which are both considered medium content. The available Zn in abaca under rubber (0.63 ppm), and abaca under mixed agroecosystem (0.18 ppm) are both considered low. On the other hand, an opposite observation has recorded where available Fe has high to very high content across all agroecosystem under study. The abaca under rubber has a very high content of available Fe (104.0 ppm) while abaca under coconut, mixed, and falcata has high amount (99.67 ppm, 65.47 ppm, and 37.17 ppm). Despite the low soil content of available Mn, Zn and Cu in all abaca agroecosystem under this study, the addition of tree litter may contribute to their availability. The quality of litterfall deposits differed among tree species, potentially resulting in changes in soil nutrient content across various agroforestry system soils (Yadav et al., 2008). A study by Armecin (2008) found a significant concentration of manganese in the leaves of the abaca plant during the vegetative and flagleaf growth stages. Regardless of the abaca plant's growth stage, the most abundant essential elements in its root are Fe and Zn, with Fe emerging as the most abundant micronutrient in the harvested fiber. Costa et al. (2018) discovered that agroforestry farms had elevated soil iron levels compared to non-agroforestry fields. This may be due to the substantial quantities of Mn, Fe, Zn, and Cu present in tree litter (Singh et al., 2013). Forest tree-based agroforestry systems recycle more plant nutrients than fruit tree-based agroforestry systems like lichi. With its deep rhizosphere and significant litter fall, agroforestry recycles plant micronutrients more effectively than conventional agriculture (Sarkar et al., 2020).

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**Table 3: Soil chemical analysis result of the different abaca agroecosystem**

| Type of Ecosystem | Soil pH | CEC (me/ 100g) | SOC (%) | OM (%) | Total N (%) | Ext. P (ppm) | Exch. K (ppm) | Exch. Ca (ppm) | Exch. Mg (ppm) | Exch. Na (ppm) | Av. Mn (ppm) | Av. Fe (ppm) | Av. Zn (ppm) | Av. Cu (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abaca under Coconut | 5.62 (MA) | 20.21 | 1.39 | 2.40 (ML) | 0.1200 | 4.00 (L) | 137.33 (MS) | 824.00 | 417.00 | 36.17 | 134.33 (M) | 99.67 (H) | 1.16 (M) | 4.94 (L) |
| Abaca under Falcata | 4.89 (VSA) | 14.57 | 1.59 | 2.73 (ML) | 0.1367 | 4.33 (L) | 61.00 (D) | 391.00 | 176.67 | 32.50 | 66.20 (M) | 37.17 (H) | 3.03 (M) | 2.76 (L) |
| Abaca under Mixed | 5.45 (SA) | 9.36 | 1.22 | 2.10 (ML) | 0.1050 | 2.33 (L) | 38.33 (D) | 351.33 | 101.97 | 24.73 | 2.57 (VL) | 65.47 (H) | 0.18 (VL) | 0.98 (L) |
| Abaca under Rubber | 5.18 (SA) | 10.67 | 1.89 | 3.27 (ML) | 0.1633 | 2.00 (L) | 26.67 (D) | 815.33 | 342.67 | 33.93 | 5.83 (L) | 104.03 (VH) | 0.63 (L) | 1.64 (L) |

Legend:

MA – Moderately acidic
SA – Strongly acidic
VSA – Very Strongly acidic
L – Low
ML – Moderately Low
MH – Moderately High
H – High
VH – Very High
D – Deficient
MD – Moderately Deficient
MS – Moderately Sufficient
S - Sufficient
M – Medium

### *Correlation between Soil Physical and Chemical Properties*

The results of Pearson's correlation (Table 4) indicated moderate, significant negative correlations between soil pH and water holding capacity (WHC), as well as between soil pH and available zinc (Zn). The findings suggest that an increase in soil pH correlates with a decrease in the availability of these parameters. A notable negative correlation was observed between bulk density and soil organic carbon (SOC), suggesting that an increase in bulk density results in a decrease in soil organic carbon content. This result is also reported in the studies of Rawat et al. (2018) and Gupta and Sharma (2008). An increase in the cation exchange capacity (CEC) of the soil corresponded with a significant rise in exchangeable potassium (K), as indicated by a high positive correlation coefficient.

**Table 4: Pearson correlation coefficients between physical and chemical properties of soil under different abaca agroecosystem**

| **Soil properties** | **Soil pH** | **BD** | **OC** | **CEC** |
|---|---|---|---|---|
| Soil pH | | 0.5841* | -0.1827$^{ns}$ | 0.2291$^{ns}$ |
| BD | 0.5841* | | -0.7632** | |
| WHC | -0.5854* | -0.4910$^{ns}$ | 0.2307$^{ns}$ | 0.4029$^{ns}$ |
| CEC | 0.2291$^{ns}$ | 0.1145$^{ns}$ | -0.2458$^{ns}$ | |
| OC | -0.1827$^{ns}$ | -0.7632** | | -0.2458$^{ns}$ |
| N | -0.1827$^{ns}$ | -0.7632** | 1.0000** | -0.2458$^{ns}$ |
| P | -0.1396$^{ns}$ | -0.2160$^{ns}$ | -0.2374$^{ns}$ | 0.5315$^{ns}$ |
| K | 0.4806$^{ns}$ | 0.0787$^{ns}$ | -0.0991$^{ns}$ | 0.7231** |
| Ca | 0.3743$^{ns}$ | -03180$^{ns}$ | 0.5673$^{ns}$ | 0.2528$^{ns}$ |
| Mg | 0.3751$^{ns}$ | -02533$^{ns}$ | 0.4523$^{ns}$ | 0.5206$^{ns}$ |
| Na | 0.1511$^{ns}$ | -0.4991$^{ns}$ | 0.5456$^{ns}$ | 0.4819$^{ns}$ |
| Mn | 0.2768$^{ns}$ | 0.1287$^{ns}$ | -0.1743$^{ns}$ | 0.8317** |
| Cu | 0.2919$^{ns}$ | 0.1187$^{ns}$ | 0.0386$^{ns}$ | 0.7479** |
| Zn | -0.6386* | -0.4643$^{ns}$ | 0.1771$^{ns}$ | 0.2908$^{ns}$ |
| Fe | 0.5723$^{ns}$ | -0.0665$^{ns}$ | 0.3011$^{ns}$ | 0.1378$^{ns}$ |

Arbitrary rating is modified from Rumsey (2011) as cited by Torred, 2017

Legend:

+/- 1 = perfect (positive+negative)
+/- 0.70 – 0.99 = Strong positive+negative
+/- 0.50 – 0.69 = Moderate positive+negative
+/- 0.30 – 0.49 = Weak positive+negative
+/- 0.10 – 0.29 = Very Weak positive+negative
+/- 0.10 – 0.09 = No linear Relationshipn
ns = non-significant
* = significant
** = Highly Significant

## CONCLUSION

Abaca cultivated in various agroecosystems demonstrates soil physical properties, including soil texture, bulk density, and water holding capacity, that are conducive to crop production. All abaca agroecosystems exhibit low content levels of organic matter, soil organic carbon, nitrogen, phosphorus, exchangeable bases, and available manganese, zinc, and copper, while maintaining a high concentration of available iron. An inverse relationship was observed between soil pH and water holding capacity (WHC) as well as available zinc and between bulk density and soil organic carbon content. The study indicates that this region is capable of cultivating abaca together with coconut, falcata, mixed tree species, and rubber. However, nutrient management practices must incorporate the addition of organic matter or fertilizers to maintain soil fertility and ensure long-term sustainability in production, as frequent harvesting has depleted soil nutrients without such applications from farmers.

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### Conflict of Interest

"The authors declare no conflict of interest."

### References

1) Amanuel, Tilahun Etafa, (2022). Effect of dominant shade tree species on selected soil physicochemical properties and coffee production in Sayyo district, western Ethiopia. https://doi.org/10.1016/j.tfp.2022.100245.

2) Araujo, Quintino & Comerford, Nicholas & Ogram, Andrew & al Agely, Abid & Filho, Lindolfo & Santos, Jorge. (2004). Soil carbon and physical property changes in Brazilian Coastal Tableland soils with land use following deforestation. Agroforestry Systems. 63. 193-198. 10.1007/s10457-004-3198-7.

3) Armecin, R. B. (2008). Nutrient Composition of Abaca (Musa textilisNee) at Seedling, Vegetative, and Flagleaf Stages of Growth. Journal of Natural Fibers, 5(4), 331–346. doi:10.1080/15440470802457136

4) Armecin, R. B., Cosico, W. C., & Badayos, R. B. (2011). Characterization of the Different Abaca-Based Agro-Ecosystems in Leyte, Philippines. Journal of Natural Fibers, 8(2), 111–125. doi:10.1080/15440478.2011.576114

5) Armecin, R.B., and F.M. Gabon. (2008). Biomass, organic carbon and mineral matter contents of abaca (Neè) at different stages of growth. Musa textilis Industrial Crops and Products 28, 340-345.

6) Aschalew, Emire, Zebene, Asfaw, (2018). Status of soil properties under canopy of farmers' preferred coffee shade tree species. In: Adola Rede District, Guji Zone, Southern Ethiopia.

7) Ashraf M, Bhat GA, Dar ID, Ali M. (2012). Physico-Chemical Characteristics of the Grassland Soils of Yusmarg Hill Resort (Kashmir, India),Eco.Balkanica, 4(1),31-38.

8) Bajpai RK, Chitale S, Upadhyay SK, Upkurar JS. (2006). Long term studies on soil physic-chemical properties and productivity of rice-wheat system as influenced by integrated nutrient management in inceptisols of Chattisgarh. Journal of Indian Society of Soil Science.54(1):24-29.

9) Bande, Marlito & Asio, Victor & Sauerborn, Joachim & Römheld, Volker. (2016). Growth Performance of Abaca (Née) Musa textilis Integrated in Multi-strata Agroecosystems. Annals of Tropical Research. 19-35. 10.32945/atr3813.2016.

10) Bande, Marlito & Grenz, Jan & Asio, Victor & Sauerborn, Joachim. (2013). Fiber yield and quality of abaca (Musa textilis var. Laylay) grown under different shade conditions, water and nutrient management. Industrial Crops and Products. 42. 70–77. 10.1016/j.indcrop.2012.05.009.

11) Brady NC, Weil RR (2008) The nature and properties of soils, 14th edn. Pearson Education Ltd, Harlow, Essex

12) Cardinael R, Hoeffner K, Chenu C, Chevallier T, Béral C, Dewisme A, Cluzeau D.(2019). Spatial variation of earthworm communities and soil organic carbon in temperate agroforestry. Biology and Fertility of Soils.55:171-183.

13) Chapagain, T., & Riseman, A., (2014). Barley–pea intercropping: effects on land productivity, carbon and nitrogen transformations. Field Crop Res. 166, 18–25.

14) Chaudhry AK, Khan GS, Ahmad I (2007). Effect of poplar tree intercropping at various densities on the post-harvest soil nutrient contents. Pakistani Journal of Agricultural Sciences.44(2):468-472.

15) Collignon, C.; Calvaruso, C.; Turpault, M.P. (2011). Temporal dynamics of exchangeable K, Ca and Mg in acidic bulk soil and rhizosphere under Norway spruce (Picea abies Karst.) and beech (Fagus sylvatica L.) stands. Plant Soil, 349, 355–366.

16) Costa, Eline & Landim, Marcelo & Marrocos, Paulo & Lobão, Dan & Silva, Daniela. (2018). Soil organic matter and CO2 fluxes in small tropical watersheds under forest and cacao agroforestry. PLOS ONE. 13. e0200550. 10.1371/journal.pone.0200550.

17) Department of Trade and Industry. (n.d.). PROFILE OF REGION 9. Retrieved April 10, 2024, from https://www.dti.gov.ph/regions/region-9/profile/

18) Dori, Tatek & Asefaw, Zebene & Kippie, Tadesse. (2022). Soil characteristics under dominant agroforestry systems along toposequence of Gedeo, Southeastern Ethiopia. Environmental and Sustainability Indicators. 15. 100191. 10.1016/j.indic.2022.100191.

19) Dyer, L., Oelbermann, M., Echarte, L., (2012). Soil carbon dioxide and nitrous oxide emissions during the growing season from temperate maize-soybean intercrops. J. Plant Nutr. Soil Sci. 175 (3), 394–400.

20) Fahad S, Chavan SB, Chichaghare AR, Uthappa AR, Kumar M, Kakade V, Poczai P. (2022). Agroforestry systems for soil health improvement and maintenance. Sustainability.14(22):14877.

21) Glaze-Corcoran, Samantha & Hashemi, Masoud & Sadeghpour, Amir & Jahanzad, Emad & Keshavarz Afshar, Reza & Liu, Xiaobing & Herbert, Stephen. (2020). Understanding intercropping to improve agricultural resiliency and environmental sustainability. 10.1016/bs.agron.2020.02.004.

22) Gill, A.S.; Burman, D. (2002). Production management of field crops in agroforestry systems. In Recent Advances in Agronomy; Singh, G., Kolar, J.S.W., Sekhon, H.S., Eds.; Indian Society of Agronomy: New Delhi, India, pp. 523–542.

23) Gonzal, Lelita. (2005). Integrating Abaca in a Mixed Forest Culture: A Livelihood Option for Smallholder Tree Farmers. Annals of Tropical Research. 10.32945/atr2932.2007.

24) Gupta MK, Sharma SD. (2008). Effect of tree plantation on soil properties, profile morphology and productivity index in Uttarakhand. Annuals of Forestry.16(2):209-224.

DOI: 10.5281/zenodo.14785040

25) Hailie, Shiferaw Wolle, Barberi, P., Carlesi, S., (2021). Effect of homegarden and parkland agroforestry practices in Ethiopia on selected soil properties. Afr. J. Food Agric. Nutr. Dev. 21 (5), 18115–18130. https://doi.org/10.18697/ajfand.100.19220.

26) Hammad, H.M., Fasihuddin Nauman, H.M., Abbas, F., Ahmad, Ashfaq, Bakhat, H.F., Saeed, S., Shah, G.M., Ahmad, Amjad, Cerd` a, A.,( 2020). Carbon sequestration potential and soil characteristics of various land use systems in arid region. J. Environ. Manag. 264, 110254 https://doi.org/10.1016/j.jenvman.2020.110254.

27) Hasan MK, Ashraful Alam AKM. (2006). Land Degradation Situation in Bangladesh and Role of Agroforestry. Journal of Agriculture and Rural Development.4(1 & 2):19-25.

28) Hombegowda, H.C. & Adhikary, Partha Pratim & Jakhar, Praveen & Madegowda, Madhu. (2022). Alley Cropping Agroforestry System for Improvement of Soil Health. 10.1007/978-3-031-09270-1_23.

29) Karki, H., Bargali, K. & Bargali, S.S. (2021). Spatial and Seasonal Pattern of Fine Root Biomass and Turnover Rate in Different Land Use Systems in Central Himalaya, India. Russ J Ecol 52, 36–48. https://doi.org/10.1134/S1067413621010070

30) Kelly, B. & Allan, C. & Wilson, Ben. (2009). Soil indicators and their use by farmers in the Billabong Catchment, southern New South Wales. Soil Research. 47. 234-242. 10.1071/SR08033.

31) Kumar K, Laik R, Das DK, Chaturvedi OP. (2008). Soil microbial biomass and respirationin afforested calciorthent. Indian Journal of Agroforestry.10(2):75-83.

32) Lacuna-Richman, Celeste. (2002). The Role of Abaca (Musa textilis) in the Household Economy of a Forest Village. Small-scale Forest Economics, Management and Policy. 1. 10.1007/s11842-002-0007-x.

33) Lal, R., (2004). Soil carbon sequestration impacts on global climate change and food security. Science 304, 1623–1627. https://doi.org/10.1126/science.1097396.

34) Lemmens, R.H.M.J. & Soerianegara, I. & Wong, W.C.. (1995). Timber Trees: Minor Commercial Timbers. Plant Resources of South-East Asia No 5(2). Backhuys Publishers, Leiden (1995) 655 pp.

35) Lorenz, Klaus & Lal, Rattan. (2014). Soil organic carbon sequestration in agroforestry systems. A review. Agronomy for Sustainable Development. 34. 443-454. 10.1007/s13593-014-0212-y.

36) Lucas, R.W.; Klaminder, J.; Futter, M.N.; Bishop, K.H.; Egnell, G.; Laudon, H.; Hogberg, P. (2011). A meta-analysis of the effects of nitrogen additions on base cations: Implications for plants, soils, and streams. For. Ecol. Manag. 262, 95–104.

37) Luo, X.X.; Liu, G.C.; Xia, Y.; Chen, L.; Jiang, Z.X.; Zheng, H.; Wang, Z.Y. (2017). Use of biochar-compost to improve properties and productivity of the degraded coastal soil in the Yellow River Delta, China. J. Soils Sediments, 17, 780–789.

38) Miah MG, Rahman MA, Haque MM, Ahmed NU, Islam MH. (2001). Crop productivity and soil fertility in Alley ropping system at different nitrogen levels in upland ecosystem. In “National workshop on Agroforestry research and development in Bangladesh” (M. F. Haq, M. K. Hasan, S. M. Asaduzzaman, and M. Y. Ali (Eds.), held on September, BARI, Gazipur.

39) Miller RW and Donahuer RL. (2001). Soils in our environment, Seventh edition. Prentice Hall, Inc. Upper Saddle River, New Jersey.

40) Minasny, B., Malone, B.P., McBratney, A.B., Angers, D.A., Arrouays, D., Chambers, A., Chaplot, V., Chen, Z.S., Cheng, K., Das, B.S., Field, D.J., Gimona, A., Hedley, C.B., Hong, S.Y., Mandal, B., Marchant, B.P., Martin, M., McConkey, B.G., Mulder, V.L., O’Rourke, S., Richer-de-Forges, A.C., Odeh, I., Padarian, J., Paustian, K., Pan, G.X., Poggio, L., Savin, I., Stolbovoy, V., Stockmann, U., Sulaeman, Y., Tsui, C.C., Vågen, T.G., van Wesemael, B., Winowiecki, L., (2017). Soil carbon 4 per mille. Geoderma 292, 59–86. https://doi.org/10.1016/j.geoderma.2017.01.002.

41) Newaj, Ram & Dar, Ahmad & Bhargava, M.K. & Yadav, Ram & Gupta, Ajit. (2007). Effect of management practices on growth of white siris (Albizia procera), grain yield of intercrops, weed population and soil fertility changes in agrisilviculture system in semi-arid India. Indian Journal of Agricultural Sciences. 77. 403-407.

42) Niu, X., Liu, C., Jia, X., & Zhu, J. (2021). Changing soil organic carbon with land use and management practices in a thousand-year cultivation region. Agriculture, Ecosystems & Environment, 322, 107639. doi:10.1016/j.agee.2021.107639

43) Oelbermann, M., Regehr, A., Echarte, L., (2015). Changes in soil characteristics after six seasons of cereal-legume intercropping in the Southern Pampa. Geoderma Reg. 4, 100–107.

44) Ogunkunle, Ayoade. (2010). Effect of Land Use on Soil Degradation and Soil Productivity Decline on Alfisols and Ultisols in Ogun State in South Western, Nigeria. Agriculturae Conspectus Scientificus (ACS) (acs@agr.hr); Vol.75 No.1. 75.

45) Okalebo, J.R. & Gathua, K.W. & Woomer, P.L. (2002). Laboratory Methods of Soil and Plant Analysis. A Working Manual. Soil Science Society of East Africa. Technical Publication No. 1.

46) Osman KT, Rahman MM, Barua P. (2001). Effects of some forest tree species on soil properties in Chittagong University Campus, Bangladesh. Indian Forester. 127(4):431-442.

47) Philippine Fiber Industry Development Authority. (2019). The-Philippine-Abaca-Industry-Roadmap-2021-2025. Retrieved August 16, 2023, from https://philfida.da.gov.ph/images/the-philippine-abaca-industry-roadmap/the-philippine-abaca-industy-roadmap-2021-2025.pdf

48) Phogat, V.K. & Tomar, V.S. & Dahiya, Rita. (2015). Soil Physical Properties. https://www.researchgate.net/publication/297737054_Soil_Physical_Properties

49) Rawat, Indra & Rawat, Pravin & Kumar, Amit & Bhatt, Parul. (2018). Soil physico-bio-chemical properties under different agroforestry systems in Terai region of the Garhwal Hiamalayas. 2813-2821.

50) Reichert, J. M., Suzuki, L. E. A. S., Reinert, D. J., Horn, R., & Håkansson, I. (2009). Reference bulk density and critical degree-of-compactness for no-till crop production in subtropical highly weathered soils. Soil and Tillage Research, 102(2), 242–254. doi:10.1016/j.still.2008.07.002

51) Rhoades, C., & Binkley, D. (1996). Factors influencing decline in soil pH in Hawaiian Eucalyptus and Albizia plantations. Forest Ecology and Management, 80(1-3), 47–56. doi:10.1016/0378-1127(95)03646-6

52) Sanderman, J., Hengl, T., Fiske, G.J., (2017). Soil carbon debt of 12,000 years of human land use. Proc. Natl. Acad. Sci. USA 114, 9575–9580. https://doi.org/10.1073/ pnas.1706103114.

53) Sarkar, Sudip & Das, Dipty & Singh, Abhinandan. (2020). Soil micronutrients status of different agroforestry systems in north Bihar. 10.13140/RG.2.2.30637.51687.

54) Schoenholtz, S.., Miegroet, H. V., & Burger, J. (2000). A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. Forest Ecology and Management, 138(1-3), 335–356. doi:10.1016/s0378-1127(00)00423-0

55) Scholberg, J. & Morgan, Kelly. (2012). Nutrient Use Efficiency in Citrus. Advances in Citrus Nutrition. 10.1007/978-94-007-4171-3_15.

56) Sileshi, Gudeta & Mafongoya, Paramu & Nath, Arun. (2020). Agroforestry Systems for Improving Nutrient Recycling and Soil Fertility on Degraded Lands. 10.1007/978-981-15-4136-0_8.

57) Singh, Yadvinder-Singh & Singh, Bijay & Timsina, Jagadish. (2005). Crop Residue Management for Nutrient Cycling and Improving Soil Productivity in Rice-Based Cropping Systems in the Tropics. Advances in Agronomy - ADVAN AGRON. 85. 269-407. 10.1016/S0065-2113(04)85006-5.

58) Singh DP and Rathore MS. (2013). Available nutrient status and their relationship with soil properties of Aravalli Mountain ranges and Malwa Plateau of Pratapgarh, Rajsthan, India.African J. of Agric.Res.8(41),5096- 5103.

59) Six J, Conant RT, Paul EA, Paustan K.(2022). Ssailization mechanism of soil organic matter, implication for carbon saturation in soil. Plant and Soil. 241:155-176.

60) Solanki HA and Chavda NH, (2011). Physicochemical analysis with reference to seasonal changes in soils of Victoria park reserve forest, Bhavnagar (Gujarat).Life sciences Leaflets,62-68.

61) Sousa DMG, Miranda LN, Oliveira SA. (2007). Soil acidity and its correction. In: Novais RF, Alvarez VH, Barros NF, Soil fertility. Sociedade Brasileira de Ciencia do Solo, Vicosa, MG, Brazil, pp. 205-275.

62) Srivastava, A.K. & S. K. Malhotra (2017): Nutrient use efficiency in perennial fruit crops—A review, Journal of Plant Nutrition, DOI: 10.1080/01904167.2016.1249798

63) Thiago, Almeida Vieira, Leonilde, dos Santos Rosa, Maria Marly, de Lourdes SilvaSantos, Clodoaldo Alcino Andrade, dos Santos, Denise, Castro Lustosa1, Alan P´ericles Amaral, dos Santos, (2016). Chemical properties of soils in agroforestry homegardens and other land use systems in Eastern Amazon. Brazil 11 (29). https://doi.org/ 10.5897/AJAR2016.11036.

64) Thomas, G.V., Krishnakumar, V., Dhanapal, R., Srinivasa Reddy, D.V. (2018). Agro-management Practices for Sustainable Coconut Production. In: Krishnakumar, V., Thampan, P., Nair, M. (eds) The Coconut Palm (Cocos nucifera L.) - Research and Development Perspectives. Springer, Singapore. https://doi.org/10.1007/978-981-13-2754-4_7

65) Tshepiso, Seobi & Anderson, Stephen & Udawatta, Ranjith & Gantzer, Clark. (2005). Influence of Grass and Agroforestry Buffer Strips on Soil Hydraulic Properties for an Albaqualf. Soil Sci. Soc. Am. J.. 69. 893-901. 10.2136/sssaj2004.0280.

66) Viji, R., & Rajesh, P. (2012). Assessment Of Water Holding Capacity Of Major Soil Series Of Lalgudi , Trichy , India.

67) Wagh GS, Chavhan DM and Sayyed MRG. (2013). Physicochemical Analysis of Soils from Eastern Part of Pune City.Uni.J.of Env.Res.and Tech.,3(1),93-99.

68) Xiong, Yanmei & Xia, Hanping & Li, Zhi An & Cai, Xi-an & Fu, Shenglei. (2008). Impacts of litter and understory removal on soil properties in a subtropical Acacia mangium plantation in China. Plant and Soil. 304. 179-188. 10.1007/s11104-007-9536-6.

69) Yadav RS, Yadav BL, Chhipa BR. (2008). Litter dynamics and soil properties under different tree species in a semi-arid region of Rajasthan, India. Agroforestry Systems. 73:1-12.

70) Yengwe, J. (2017). Soil carbon and nitrogen dynamics, soil quality and crop yield levels in Faidherbia-maize agroforestry systems in Zambia. Ghent University. Faculty of Bioscience Engineering, Ghent, Belgium.

71) Zebene, Asfaw. (2016). Woody species composition and soil properties under some selected trees in parkland agroforestry in central Rift Valley of Ethiopia. Int. J. Dev. Res. 10150–10156.

72) Zebene, Asfawran, Go, gren, I.A., (2007). Farmers' local knowledge and topsoil properties of agroforestry practices in Sidama. Southern Ethiopia. https://doi.org/10.1007/ s10457-007-9087.0.

73) Zhi, C., Shuoshi, M., Guisheng, F., Yonglai, Z., (2007). Effect of wind erosion resistance of soil for wheat and potato strip intercropping farmland. Trans. Chin. Soc. Agric. Eng. 23 (3), 51–54.