Morpho-physical and Nutrient Properties of Soils in the Plantation Forest of Northwest Samar State University, San Jorge Campus (NwSSU-SJC), San Jorge Samar, Philippines

Jessie R. Sabijon[1]

10.18805/IJARe.AF-1021

ABSTRACT

Background: Understanding soil characteristics in plantation forests established on marginal lands is essential for evaluating productivity and ecological recovery. This study characterized the morpho-physical and nutrient properties of soils in the plantation forest of Northwest Samar State University-San Jorge Campus.

Methods: Four representative soil profiles along a slope gradient (summit, upper slope, middle slope, footslope) were examined through 1 m × 1 m soil pits. Morphological and physical properties were described following FAO guidelines. Horizon samples were analyzed for pH, organic matter (OM), total nitrogen (TN), available phosphorus (P) and exchangeable potassium (K).

Result: Soils derived from shale exhibited varying development influenced by topography and vegetation. Summit and footslope profiles were moderately to well developed (Ah-Bw-BC or Ah-AB-Cr), while upper slope soils showed moderate development. Textures were predominantly clayey with moderate bulk density (1.30-1.45 g cm^{-3}) and porosity (45-51%). Soils were moderately acidic (pH 5.0-6.2), with moderate surface OM (2.42-2.98%) and TN (0.15-0.24%), but low available P (1.83-2.24 mg kg^{-1}). Exchangeable K was relatively high in surface horizons (190-407 mg kg^{-1}). Nutrient concentrations declined with depth. Results indicate that plantation vegetation enhances organic inputs and structural development, promoting gradual soil recovery despite inherent acidity and low phosphorus. Continuous monitoring and nutrient-efficient enrichment planting are recommended to sustain long-term soil fertility and ecological resilience.

Key words: Degraded grassland restoration, Nutrient dynamics, Plantation forest, Soil morphology.

INTRODUCTION

A previous study in Samar documented that degraded soils are acidic, clay-rich, and low in organic matter, nitrogen, and available phosphorus, with variability in horizon development depending on landscape position (Sabijon and Asio, 2022). These characteristics constrain agricultural productivity and ecological stability.

Forest plantation establishment is widely used to rehabilitate such degraded grasslands because tree cover can modify microclimate, enhance litter deposition, stimulate biological activity and gradually improve soil properties. Evidence from forest shelterbelts shows that plantations reduce wind speed and conserve soil moisture, thereby improving land productivity (Vedeneeva *et al.,* 2025). The NwSSU-SJC plantation forest, established in 1989 and expanded in 2010, represents a local example of this ecological transition. Earlier observations indicated increasing floristic diversity, greater litter accumulation and surface soil pH within tolerable ranges for plant growth (Perocho *et al.,* 2018). However, these assessments were limited to surface soil properties and did not include detailed morpho-physical and chemical profile characterization.

A Previous study in Samar documented that degraded soils are acidic, clay-rich and low in organic matter, nitrogen and available phosphorus, with variability in horizon development depending on landscape position (Sabijon and Asio, 2022). In the NwSSU plantation, phosphorus was identified as the primary limiting nutrient in surface soils (Perocho *et al.,* 2018). Despite these insights, no study has yet conducted a comprehensive soil profile analysis within the NwSSU plantation forest to determine whether long-term forest establishment has improved morphological development, physical condition and nutrient status compared with its former grassland state.

Addressing this gap, the present study provides the first integrated characterization of the morphological, physical and chemical properties of soils in the NwSSU San Jorge Campus plantation forest. By evaluating whole-profile development rather than surface conditions alone, this study offers a more robust assessment of soil recovery

[1]College of Agriculture and Technology, Northwest Samar State University, Main Campus, Calbayog City, Samar 6710, Philippines.

Corresponding Author: Jessie R. Sabijon, College of Agriculture and Technology, Northwest Samar State University, Main Campus, Calbayog City, Samar 6710, Philippines.
Email: jessie.sabijon@nwssu.edu.ph

How to cite this article: Sabijon, J.R. (2026). Morpho-physical and Nutrient Properties of Soils in the Plantation Forest of Northwest Samar State University, San Jorge Campus (NwSSU-SJC), San Jorge Samar, Philippines. *Indian Journal of Agricultural Research.* **60(6):** 814-827. doi: 10.18805/IJARe.AF-1021.

Submitted: 09-01-2026 **Accepted:** 23-03-2026 **Online:** 07-05-2026

and the plantation's long-term effectiveness as a model for degraded land rehabilitation in Samar. Therefore, this study aims to characterize the morphological, physical and nutrient properties of soils in the plantation forest of NwSSU, San Jorge Campus.

MATERIALS AND METHODS

Study area

The study was conducted from January to September 2025 at the plantation forest of NwSSU-San Jorge Campus, Samar, Philippines (11°58′51″N, 124°49′26″E; Fig 1). The site was formerly degraded grassland prior to plantation establishment in 1989 and expansion in 2010. It includes summit, upper slope, middle slope and footslope positions. The climate is Type IV (no distinct dry season). Parent material consists of shale and shale-sandstone complexes. Soil description followed FAO (2006a) guidelines, documenting landform, slope, erosion, drainage, vegetation and parent material.

Soil profiling, collection, preparation and laboratory analysis

Four representative soil profile pits, one each in the summit (Soil profile 1), upper slope (Soil profile 2), middle (Soil profile 3) and footslope (Soil profile 4) positions were excavated to dimensions of approximately 1 m × 1 m and to depths of at least 1 m or until refusal (Fig 2). Although, having only four profiles is a limitation of the study, these profiles were carefully selected across the major physiographic positions and are considered sufficient to represent the variability and characteristics of soils within the plantation forest. The morphological characterization of each profile followed the FAO Guidelines for Soil Description (Jahn *et al.,* 2006) and the detailed procedures applied by Sabijon and Asio (2022). Each horizon was characterized in terms of depth, boundary distinctness, color, texture, structure, bulk density, porosity, moist and wet consistence, root distribution, mottling, rock fragments and other diagnostic features. These observations provided critical information on soil-forming processes and the degree of profile development.

Soil samples were collected from each identified horizon within the profiles using a quantitative approach, where three continuous and uniform slices were taken from the surface down to the deepest horizon and thoroughly mixed, following the method of Schlichting *et al.* (1995). For thinner horizons, wider slices were collected to ensure that the sample volume was comparable to that of thicker horizons. Each soil sample was placed in a properly labeled plastic bag, air-dried, crushed and passed through a 2-mm sieve in preparation for chemical analysis at Visayas State University-Central Analytical Service Laboratory (CASL). Subsamples designated for organic matter and total nitrogen analysis were further ground to pass a 0.425-mm sieve.

Chemical analyses of the soil included the determination of pH, organic matter, total nitrogen, available phosphorus and exchangeable potassium. Soil pH was measured potentiometrically in a 1:2.5 soil-to-water suspension following the procedures of ISRIC (1995). Organic matter content was determined using the Modified Walkley-Black method (Nelson and Sommers, 1982) and total nitrogen was analyzed by the Kjeldahl method. Available phosphorus was extracted using the Bray-2 method (Olsen and Sommers, 1982), while exchangeable potassium was measured using 1N ammonium acetate (NH_4OAc) at pH 7.0.

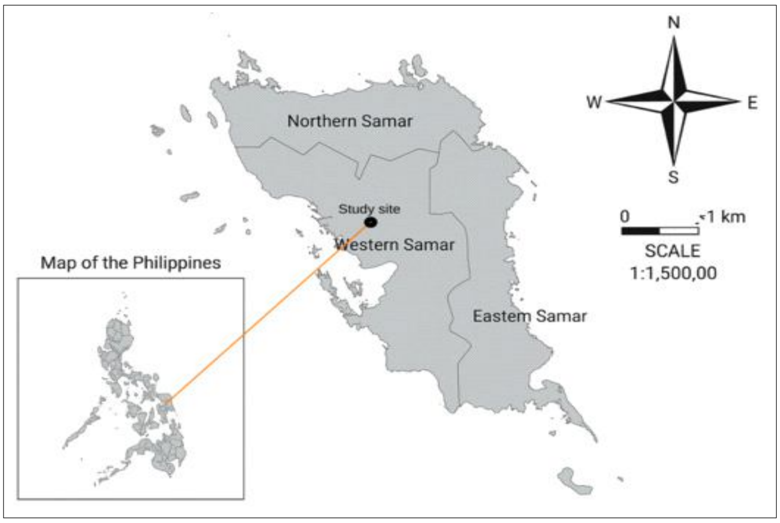

Fig 1: Map of the plantation forest at NwSSU-SJC, San Jorge, Samar, indicating the locations of the four representative soil profiles along the slope gradient.

RESULTS AND DISCUSSION

Site characteristics

The plantation forest exhibits heterogeneous site characteristics, reflecting complex interactions among topography, parent material, vegetation and land use history (Table 1). The four soil profiles (SP1-SP4) encompass a gradient of physiographic positions, ranging from the summit (SP1), upper slope (SP2), middle slope (SP3), to footslope (SP4). Such variation strongly influences soil development, erosion dynamics and vegetation succession. For instance, SP1, located at the summit, exhibits only slight erosion, consistent with the lower runoff potential of summit landscapes. In contrast, SP4, positioned on the footslope, shows evident erosion, reflecting the enhanced runoff accumulation typical of lower slope positions. Similar slope-dependent erosion patterns have been documented in Samar uplands, where even moderate slopes in humid tropical conditions are vulnerable to soil displacement when vegetation is disturbed (Sabijon and Asio, 2022; Asio *et al.,* 2009). All soil profiles are derived from shale, a parent material known for generating fine-textured, acidic and nutrient-poor soils. This is consistent with previous characterizations of shale-derived soils in Eastern Visayas, where strong acidity, limited phosphorus availability and high clay content present constraints to plant growth (Sabijon and Asio, 2022).

The uniformity of parent material across the study area suggests that the observed differences in soil behavior are primarily driven by topography, slope and vegetation cover rather than lithology. The study area is classified under an isohyperthermic, udic moisture and temperature regime, indicative of warm, humid tropical conditions. Such conditions accelerate weathering, organic matter decomposition and nutrient leaching, as observed in other Philippine reforested and grassland-converted landscapes (Asio *et al.,* 1998). Drainage in all profiles is generally good, attributed to moderate slopes and well-structured surface layers enhanced by litter accumulation in forested areas. Nonetheless, good drainage may increase nutrient leaching in humid tropical systems.

Erosion intensity varies across profiles: SP1 shows slight erosion, SP2 is relatively stable due to effective vegetation cover, while SP3 and SP4 display evident erosion, highlighting the vulnerability of mid- to lower-slope positions. These trends align with findings from Perocho *et al.* (2018), who observed that vegetation cover moderate erosion in newly established plantations but does not fully prevent soil loss on exposed slopes.

Vegetation composition across the soil profiles provides strong evidence of the site's current ecological condition and successional trajectory. In SP1, the persistence of *Imperata cylindrica*, together with *Chromolaena odorata* and other grassland species, clearly

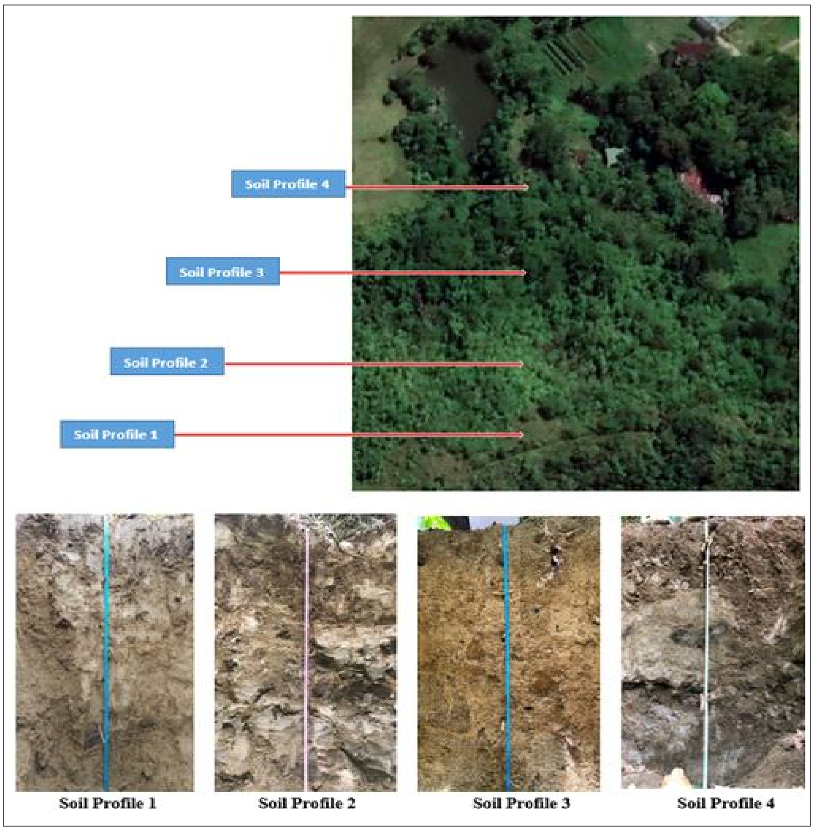

Fig 2: Location and photographs of the four representative soil profiles characterized in the plantation forest of NwSSU, San Jorge Campus.

reflects the legacy of disturbance and degradation. In the Philippines, *Imperata*-dominated grasslands are widely recognized as indicators of nutrient-poor, compacted and erosion-prone soils that develop following repeated burning and land clearing (Lasco and Pulhin, 2009). Its continued presence at the summit position suggests that despite plantation establishment, soil and microclimatic conditions in SP1 still favor grassland species, indicating incomplete ecological recovery from its former land-use state.

In contrast, SP2 to SP4 exhibit a marked shift toward tree-dominated vegetation, reflecting progressive forest succession along the slope gradient. The dominance of plantation species such as *Ficus spp*, *Swietenia macrophylla* and *Canarium luzonicum*, together with naturally regenerating species like *Macaranga*, *spp Pterocarpus spp* and understory components including *Piper spp* and *Urticularia spp*, indicates improving site conditions conducive to woody plant establishment. Likewise, the occurrence of native tree species such as *Canarium luzonicum* and *Pterocarpus indicus*, both listed among the threatened flora recorded in the area, highlights the site's increasing capacity to support ecologically valuable and conservation-significant woody species (Aureo and Reyes, 2023). Their persistence suggests that habitat conditions are suitable for the growth and long-term survival of late-successional forest trees.

The increasing structural and species diversity observed downslope (SP3 and SP4) further suggests enhanced soil moisture retention, reduced erosion and improved nutrient cycling associated with denser vegetation cover. Perocho *et al.* (2018) similarly reported increasing floristic diversity and vegetation complexity in the NwSSU plantation forest over time, attributing these trends to successful plantation establishment and natural regeneration. At the national scale, a study has consistently shown that reforestation and assisted natural regeneration promote higher organic matter inputs, increased soil biological activity and gradual improvements in soil structure and fertility compared with grassland-dominated systems (ViSCA-GTZ B, 1996).

Morphological and physical properties

The soil morphology of the plantation forest at NwSSU differed noticeably across physiographic positions (Table 2), highlighting the combined effects of slope processes, underlying parent material and plantation vegetation. The summit profiles (SP1 and SP3) exhibited moderately to well-developed soils with an Ah-Bw-BC-C horizon sequence. The development of Bw horizons at depths of 20-80 cm signals incipient cambic development, a hallmark of active pedogenesis stimulated by enhanced organic matter inputs, increased root penetration and higher biological activity under forest vegetation. Similar enhancements in horizon differentiation were reported by Sabijon and Asio (2022) in Samar uplands. This aligns with work by Navarrete *et al.* (2009), who observed that the soils are deep, clay-rich and reddish in color, suggesting an advanced stage of soil development under the rainforest environment. In the footslope profile (SP4), deeper soil formation with an Ah-AB-Cr1-Cr2 sequence reflects greater solum development typical of depositional environments. Similar patterns have been documented by Asio *et al.* (2014)

Table 1: Site characteristics of the plantation forest in NwSSU-SJC, San Jorge Samar.

Site characteristics	Soil profiles (SP)			
	SP1	SP2	SP3	SP4
Landform	Medium gradient hill	Medium gradient hill	Medium gradient valley	Plain
Physiographic position	Summit	Upper slope	Middle slope	Footslope
Coordinates	11°58′50″N 124°48′54″E	11°58′51″N 124°48′54″E	11°58′53″N 124°48′54″E	11°58′54″N 124°48′53″E
Elevation	38 masl	32 masl	25 masl	20 masl
Slope gradient	Gently sloping	Gently sloping	Gently sloping	Slightly sloping
Parent material	Shale	Shale	Shale	Shale
Soil moisture regime	Isohyperthermic	Isohyperthermic	Isohyperthermic	Isohyperthermic
Soil temperature regime	Udic	Udic	Udic	Udic
Erosion	Slight	Evident	Evident	Evident
Rock outcrops/stoniness	None	None	None	None
Drainage	Good	Good	Good	Good
Land use	Grassland/plantation	Plantation	Plantation	Plantation
Vegetation	*Imperata cylindrica*, *Chromolaena odorata*, *Saccharum spontauem* *Scleria scrobiculata*	*Ficus psedopalma* *Fagraea racemosa* *Leucosyke capitellata*	*Canarium lozunicum*, *Pterocarpus indicus*, *Utricularia volubilis* *Calamus merrillii* *Sweitenia macrophylla* *Piper interruptum*	*Sweitenia macrophylla* *Ficus nota* *Fagraea racemosa* *Ficus pseudopalma*

Table 2: Morpho-physical properties of soil in the plantation forest of NwSSU-SJC, San Jorge, Samar, Philippines.

Soil[A] horizon	Depth (cm)	Boundary[B]	Soil color (Munsell color-moist)	Texture[C]	Structure[D]	Bulk[E] density (g/cm^3)	Porosity[F] (%)	Consistence[G]		Roots[H]	Mottles[I]	Rock[J] fragments
								Moist	Wet			
Ah	0-20	cw	10YR 3/6 (dark yellowish brown)	SCL	2msbk	1.38	48	fr	s&p	fem	o	o
Bw1	20-50	di	10YR 5/6 (yellowish brown)	C	2csbk	1.45	45	f	s&p	vfem	o	o
Bw2	50-80	gw	10YR 5/6 (yellowish brown)	C	2csbk	1.45	45	f	s&p	o	o	o
BC	>80		10YR 5/6 (yellowish brown)	C	2msbk	1.40	47	fr	s&p	o	o	o
Ah	0-15	cw	10YR 3/6 (dark yellowish brown)	SC	1msbk	1.42	47	f	s&p	fem	o	o
AB	15-40	cw	10YR 3/6 (dark yellowish brown)	SC	1msbk	1.42	47	f	s&p	vfem	o	m
Cr	40-100		10YR 4/2 (dark grayish brown)	nd	3csbk	nd	nd	f	ss&sp	o	cm	m
Ah	0-20	cw	10YR 3/6 (dark yellowish brown)	CL	2mg-sbk	1.33	50	fr	s&p	cm	o	o
Bw1	20-50	di	10YR 5/6 (yellowish brown)	C	2csbk	1.42	47	f	s&p	cm	cfi	o
Bw2	50-75	cw	10YR 5/6 (yellowish brown)	C	2csbk	1.42	47	f	s&p	cm	cfi	o
BC	>75		10YR 5/6 (yellowish brown)	SC	2csbk	1.45	45	f	s&p	cm	vfefi	o
Ah	0-15	cs	10YR 4/3 (dark brown)	SiCL	2msbk	1.30	51	fr	ss&sp	cfi	o	vfe
AB	15-30	cw	10YR 4/2 (dark grayish brown)	SC	2fsbk	1.38	48	fr	ss&sp	cm	o	fe
Cr1	30-70	di	10YR 4/2 (dark grayish brown)	SC	2fsbk	1.5	43	f	ss&sp	vfevfi	cfi	m
Cr2	70-100		10YR 4/2 (dark grayish brown)	nd	nd	nd	nd	f	nd	cfi	cfi	m

[A]according to FAO (2006b); [B]- cw- Clear wavy, di- Diffuse, gw- Gradual wavy, cs- Clear smooth, [C]SCL- Sandy clay loam, C- Clay, SC- Sandy clay, CL- Clay loam, SiC- Silty clay loam; [D]1- Weak, 2- Moderate, 3- Strong, f- fine, m- Medium, c- Coarse, sbk- Sub-angular blocky; [E]fr- Friable, f- Firm, ss- Slightly sticky, s- Sticky, sp- Slightly plastic, p- Plastic; [F]vfevfi- Very few very fine, vfem- Very few medium, fem- Few medium, cm- Common medium, cfi- Common fine; [G]vfem- Very few medium, fem- Few medium , cfi- Common fine, cm- Common medium, o- None; [H]- vfe- Very few; fe- Few; m- Many; o- None; nd- Not determined.

for Leyte uplands and by Sun *et al.* (2019) in Southeast Asian tropical forests, where lower-slope soils under forest cover accumulated fine materials and organic matter transported downslope. Likewise, Koshelev *et al.* (2024) reported that the soil profile under the forest belt has an organogenic horizon A0 (forest floor) and the thickness of the humus horizon (A+B1) under the forest belt is 8-10 cm.

Soil color development further illustrates the strong influence of plantation vegetation on soil properties across the physiographic positions. The summit soils (SP1 and SP3) exhibited darker surface horizons (10YR 3/6) transitioning to yellowish brown (10YR 5/6) subsurface layers, indicating moderate organic matter accumulation coupled with iron oxide enrichment. This color differentiation reflects enhanced litter deposition, reduced surface disturbance and increased biological activity under plantation cover. Similar color patterns were documented by Perocho *et al.* (2018) in the NwSSU plantation forest, where the establishment and maturation of tree plantations resulted in darker surface horizons compared with adjacent cogon-dominated grasslands. They attributed these changes to increased organic inputs from leaf litter and improved soil microclimate conditions that favor humus formation and iron oxide stabilization. Comparable observations were also reported by Sabijon and Asio (2022) in degraded uplands over shale in Samar, further confirming surface darkening and horizon differentiation. In the upperslopes soils (SP2), the occurrence of grayish tones in the deeper horizons suggests periodic moisture accumulation and localized reduction conditions, which are typical of slope positions with impeded drainage and subsurface water movement. Similar moisture-related color expressions have been reported in tropical forest soils with high water retention capacities (Zanetti *et al.,* 2015).

Meanwhile, the footslope profile (SP4) displayed humus-rich dark grayish brown surface horizons (10YR 4/3), reflecting enhanced organic matter deposition associated with downslope transport and dense vegetation cover. Perocho *et al.* (2018) likewise observed darker surface colors in lower slope positions within the plantation forest, attributing these features to organic matter accumulation from both *in situ* litterfall and transported materials from upper slopes. These observations align with the classical interpretation of Shoji *et al.* (1993), who emphasized the combined influence of humus accumulation, parent material weathering and redox processes in governing soil color development in humid tropical environments.

Structural development varied across positions, with granular surface structure in SP1 and SP4 attributed to organic matter-driven aggregate formation and root activity. Subangular blocky structures in subsurface horizons indicate improved aggregation with depth, a common outcome of long-term vegetation cover that stimulates root-induced bioturbation and fungal hyphae binding (Baumert *et al.,* 2021). Comparable improvements in soil aggregation were reported in Philippine plantation soils on shale (Perocho *et al.,* 2018) and in temperate forestry plantations in China, where tree roots and litter contributed to stable aggregate formation (He *et al.,* 2023). The massive structural tendencies seen in some horizons of SP2 and SP3 likely reflect residual effects of past disturbance and slope compaction, as noted in degraded uplands transitioning to forest cover (Asio *et al.,* 2014).

Soil consistence across profiles revealed friable surface horizons and firm subsurface layers, with increasing stickiness and plasticity with depth typical of clay-rich, shale-derived soils. Similar consistence patterns have been documented in plantation forests in the Philippines (Asio *et al.,* 2015) and in tropical forest soils of Southeast Asia, where clay mineralogy influences physical behavior (Buol *et al.,* 2011). Root distribution ranged from medium to fine in the surface horizons and became very fine in the deeper layers, indicating increased soil density and reduced aeration with depth. The abundance of roots in surface and subsurface layers, particularly in SP3 and SP4, highlights vigorous biological activity under tree cover, which promotes pore formation, increases aggregate stability and enhances water infiltration (Huang *et al.,* 2024). Rock fragments were generally few in surface horizons but increased in deeper Cr horizons, typical of weathering shale bedrock as observed by Sabijon and Asio (2022).

Nutrient properties of soils

Soil pH

The chemical properties of soils across the plantation forest landscape of NwSSU-SJC show distinct variations influenced by physiographic position, vegetation cover and soil depth. The depth distribution of soil pH (H_2O) across the four soil profiles reveals clear differences associated with physiographic position and vegetation cover (Fig 3). The soils are moderately acidic, with pH values generally ranging from about 5.0 to 6.2, a condition typical of humid tropical upland soils derived from shale parent material. Despite this acidity, the relatively narrow pH range and gradual vertical trends indicate improving chemical stability under plantation forest cover. The summit profile under grassland-plantation transition (SP1) exhibited slightly more acidic conditions in the surface horizon, with pH values decreasing with depth. This pattern reflects the legacy of its former grassland condition, where repeated burning and limited organic matter inputs often lead to surface acidification and nutrient depletion. However, the relatively moderate acidity of SP1 compared with typical cogon grassland soils suggests that plantation establishment has begun to moderate soil chemical conditions through increased litter input and reduced disturbance. Similar observations were reported by Perocho *et al.* (2018) in the NwSSU plantation forest, where former grassland sites converted to plantations showed gradual increases in surface pH and improved nutrient status over time as forest vegetation matured. In contrast, the plantation forest profiles (SP2, SP3 and SP4) exhibited more stable pH values throughout the soil profile, with slightly higher pH in the subsurface horizons. The relatively uniform pH distribution in these profiles indicates enhanced buffering capacity associated with increased organic matter, base cation recycling and deeper root systems of plantation tree species. Perocho *et al.* (2018) similarly reported more stable and moderately acidic pH conditions in plantation forest soils compared with adjacent grassland areas, attributing this to continuous litterfall, root turnover and reduced leaching losses under forest cover. The slightly higher pH values observed in the middle slope (SP3) and footslope (SP4) profiles, particularly at depth, may be attributed to downslope movement and accumulation of basic cations such as Mg^{2+} and Ca^{2+}, as well as the influence of less weathered shale material in deeper horizons. This trend is consistent with findings in Leyte and Samar uplands, where lower slope positions under forest vegetation exhibited improved chemical properties due to sediment and nutrient redistribution (Sabijon and Asio, 2022; Asio *et al.,* 2015).

Perocho *et al.* (2018) also noted that lower slope plantation soils in NwSSU tended to maintain higher pH and nutrient availability relative to summit positions. From a biogeochemical perspective, plantation forests play a critical role in regulating soil acidity through nutrient cycling processes. Tree litter and root exudates contribute organic acids that initially lower surface pH, but these are counterbalanced by enhanced cation recycling from deeper soil layers *via* root uptake and litter return. Similar mechanisms have been widely documented in tropical plantation forests in Southeast Asia and Philippines, where forest cover reduces acidification by improving nutrient retention and minimizing leaching losses (Sun *et al.,* 2019; Navarrete *et al.,* 2018). Likewise, long-term plantation establishment has been shown to stabilize soil pH and improve overall soil chemical quality compared with degraded grasslands and abandoned agricultural lands (Duguma *et al.,* 2019).

Organic matter

The soil organic matter content across the four profiles (SP1-SP4) in Fig 4 shows a clear vertical decline with depth, with the highest values consistently observed in the surface horizons (Ah and AB) and progressively lower values in the subsurface horizons (Bw, BC and Cr). Surface OM ranges from 2.42 to 2.98%, reflecting moderate organic matter accumulation that can be attributed to continuous litterfall, root turnover and microbial activity associated with plantation forest vegetation and, in the case of SP1, the grassland-forest interface. This pattern is similar with the observation of Perocho *et al.* (2018) in a plantation forest of Northwest Samar, Philippines, who reported that surface horizons were enriched with humic materials and darker in color due to higher organic matter content, while subsurface horizons showed reduced organic matter as soil depth increased. Similar depth-dependent declines in OM have been documented in tropical forest and plantation soils in Leyte, Philippines, where organic matter was found to be concentrated in the upper horizons due to the accumulation of organic residues and greater biological activity near the surface soil (Asio *et al.,* 1998; Navarrete *et al.,* 2009). Variations in OM among physiographic positions further highlight the role of topography and landscape processes in organic matter distribution. The summit (SP1) and middle slope (SP3) profiles exhibit relatively higher surface OM (2.90-2.98%), suggesting favorable conditions for litter accumulation and organic matter stabilization under plantation forest cover. In contrast, the backslope profile (SP2) shows a sharper decrease from the Ah to the AB horizon, which may be influenced by erosion and downslope transport of organic materials.

Perocho *et al.* (2018) similarly emphasized that soil organic matter in plantation forests varies with slope

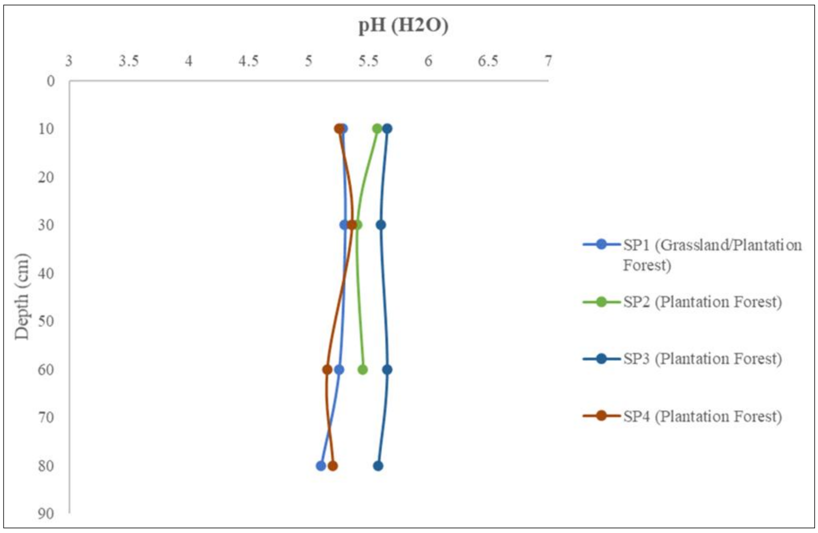

Fig 3: pH (H_2O) distribution by depth in the plantation forest of NwSSU-SJC, San Jorge, Samar, Philippines.

position, with landscape processes such as erosion, deposition and differences in vegetation density influencing OM content. At the footslope (SP4), moderately high OM values in the Ah and AB horizons (2.42-2.54%) may reflect depositional processes and accumulation of organic residues transported from upslope areas, while the very low OM value (0.7%) in the Cr horizon indicates minimal organic inputs and limited biological activity within the parent material. The observed OM values are comparable with those reported for other plantation forests and managed tropical forest soils in the Philippines, which generally contain moderate organic matter levels but lower than those of undisturbed primary forests (Asio *et al.,* 1998; Bobon-Carnice and Lina, 2021). This pattern is also consistent with earlier findings in Eastern Visayas, where forest vegetation significantly enhances soil organic carbon through abundant litterfall and root biomass (Navarrete *et al.,* 2009; Asio *et al.,* 2009). International studies further support these observations, showing that plantation forests typically maintain higher soil organic matter than agricultural lands but lower levels than natural forests, particularly in deeper horizons where organic inputs are limited (Laganière *et al.,* 2010). Forest soils exhibit a strong vertical stratification of organic matter, with surface horizons serving as the primary zone of carbon storage due to litter deposition and root activity, while subsoils contain smaller, more stable organic matter pools (Ahmed, 2018). Similarly, the forest shrub retama plays an important role in faunal diversity because it attracts insects; arthropods; invertebrates which participate in the process of chemical transformation of nutrients and recycling of organic matter as well as in the microbial activity of the soil (Djamel *et al.,* 2025).

Total nitrogen

As shown in Fig 5, soil total nitrogen (TN) displays a distinct vertical and topographic distribution that closely corresponds to the pattern of soil organic matter (OM) across all sampling points (SP1-SP4). In all profiles, TN is highest in the surface horizons (Ah and AB), with values ranging from 0.15 to 0.24% and decreases sharply with depth to as low as 0.04-0.08% in the Bw, BC and Cr horizons. This downward trend highlights the close relationship between nitrogen and soil organic matter, since most nitrogen in forest soils is organically bound within plant litter, root residues, microbial biomass and humified organic compounds (Ahmed, 2018; Xiong *et al.,* 2014). Consequently, horizons with higher OM contents also exhibit higher TN levels, confirming that nitrogen availability in these soils is largely regulated by organic matter accumulation and turnover. Similar depth-dependent decreases in TN have been widely documented in tropical forest and plantation soils, where diminishing organic inputs and reduced microbial activity limit nitrogen storage in deeper soil layers (Gou and Gifford, 2002).

Beyond its vertical distribution, the relatively moderate to low TN levels observed particularly in the subsurface horizons carry important implications for plantation productivity and long-term soil fertility. Nitrogen is a fundamental component of chlorophyll, amino acids and proteins; thus, inadequate nitrogen supply can directly restrict photosynthetic capacity, vegetative growth and biomass accumulation. The marked decline of TN with depth indicates that nitrogen reserves are largely concentrated in the biologically active surface horizons, making the system highly dependent on sustained litterfall, root turnover and microbial mineralization. Any disruption to these processes, such as reduced organic inputs, erosion, or intensive site disturbance, could accelerate nitrogen depletion and weaken nutrient cycling efficiency within the plantation ecosystem.

Variations in TN among physiographic positions further explain the role of landscape processes and vegetation cover in regulating nitrogen dynamics. The summit (SP1)

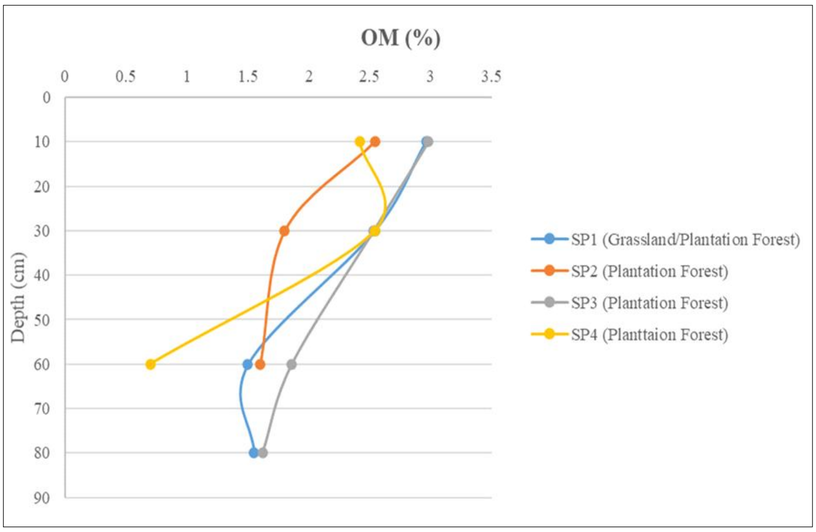

Fig 4: Organic matter (%) distribution by depth in the plantation forest of NwSSU-SJC, San Jorge, Samar, Philippines.

and middle slope (SP3) profiles exhibit moderate surface TN values (0.17-0.18%) that gradually decline with depth, a pattern typical of upland plantation forest soils influenced by leaching losses, erosion and limited nutrient recycling downslope. These findings align with Perocho *et al.* (2018), who observed that surface horizons in a plantation forest were enriched in organic matter and related nutrients, including nitrogen, whereas subsurface horizons were comparatively nutrient-poor due to limited organic inputs and greater degrees of weathering. Comparable trends were reported in forest soils of Leyte, Philippines, where nitrogen concentrations were strongly correlated with organic matter and declined rapidly below the surface horizons, particularly in sloping landscapes subjected to erosion and eluviation (Asio *et al.,* 1998). The progressive reduction of nitrogen in these upper landscape positions suggests heightened susceptibility to nutrient exhaustion over time if erosional losses persist without adequate replenishment from organic sources. Upperslope profile (SP2) shows a decline in TN from 0.15% in the Ah horizon to 0.10% in the AB horizon, reflecting possible nutrient depletion through surface runoff and soil redistribution. Such nutrient losses are commonly reported in tropical uplands, where steep slopes promote erosion of fine, organic-rich particles that carry both organic carbon and nitrogen (Lal, 2004; Asio *et al.,* 1998). This pattern underscores the risk of gradual nitrogen impoverishment in sloping areas, which may ultimately limit stand growth, reduce nutrient-use efficiency and constrain the regenerative capacity of the plantation if soil conservation and organic matter management practices are not sustained.

In contrast, the footslope profile (SP4) records the highest surface TN value (0.24%), closely associated with relatively higher OM content in the Ah and AB horizons. This enrichment likely results from depositional processes, downslope transport of organic residues and improved moisture conditions that favor organic matter preservation and nitrogen immobilization. Similar enrichment of OM and TN at lower slope positions has been reported in degraded soils in Samar by Sabijon and Asio (2022), who attributed higher nutrient contents in footslope soils to the accumulation of materials eroded from upslope areas. However, despite this surface enrichment, TN declines sharply to 0.04% in the Cr1 horizon, indicating that nitrogen accumulation remains largely confined to biologically active horizons and is minimal in parent material layers with low organic carbon content. This sharp decline reinforces the limited buffering capacity of deeper soil layers and highlights the dependence of the plantation system on continuous biological inputs to sustain nitrogen availability.

The close correspondence between OM and TN across all profiles highlights the strong coupling of carbon and nitrogen cycles of plantation forest soils. Studies in tropical and subtropical forests consistently demonstrate that increases in soil organic matter are accompanied by proportional increases in total nitrogen, resulting in relatively stable C:N relationships within surface horizons. Philippine studies likewise report strong positive correlations between OM and TN in forest and plantation soils, emphasizing the role of litter inputs and root turnover in sustaining nutrient availability (Asio *et al.,* 1998; Bobon-Carnice and Lina, 2021). International research further shows that plantation forests generally maintain moderate surface TN levels through continuous litterfall, but nitrogen stocks decline rapidly with depth and remain lower than those of undisturbed natural forests due to simplified vegetation structure and historical land-use effects (Guo and Gifford, 2002).

Available phosphorus

The available phosphorus (P) content of the plantation forest soils is generally low across all sampling points

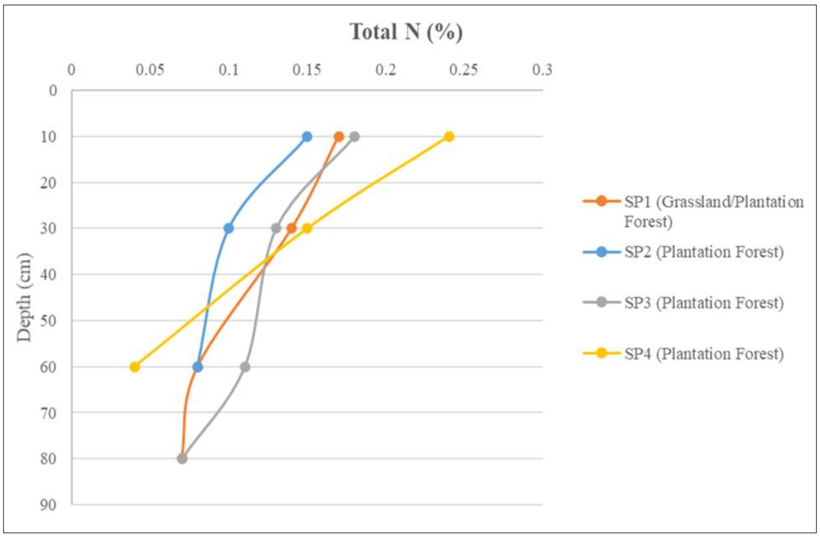

Fig 5: Total nitrogen (%) distribution by depth in the plantation forest of NwSSU–SJC, San Jorge, Samar, Philippines.

(SP1-SP4) and shows a clear decline with increasing soil depth, a pattern characteristic of highly weathered tropical soils (Fig 6). Surface horizons (Ah) exhibit the highest available P values, ranging from 1.83 to 2.24 mg/kg, while subsurface horizons (Bw, BC and Cr) show progressively lower concentrations, reaching as low as 0.7-0.9 mg/kg in deeper layers. This vertical distribution reflects the strong dependence of available phosphorus on biological cycling and organic matter inputs, which are concentrated near the soil surface due to litterfall, root activity and microbial mineralization processes. Similar depth-related decreases in available P have been widely reported in forest and plantation soils in the Philippines and other tropical regions, where phosphorus availability is largely confined to surface horizons (Asio *et al.,* 1998). The generally low values across profiles indicate that phosphorus may serve as a limiting nutrient in the plantation forest ecosystem, particularly for sustained biomass production and root development.

Across physiographic positions, the summit (SP1), backslope (SP2) and middle slope (SP3) profiles exhibit comparable surface available P values (approximately 2.23-2.24 mg/kg), suggesting a relatively uniform influence of plantation vegetation on P cycling in these areas. These values are indicative of low to very low phosphorus availability, which is typical of tropical Ultisols and highly weathered soils derived from old parent materials. In such soils, much of the phosphorus is strongly adsorbed or fixed by iron and aluminum oxides, rendering it unavailable to plants despite continuous inputs from litter decomposition (Lal, 2004). This condition highlights the limited pool of readily available phosphorus in the soil solution and underscores the dependence of vegetation on efficient biological recycling to meet nutrient demands. Perocho *et al.* (2018) reported similarly low available phosphorus levels in plantation forest soils in Northwest Samar and attributed these conditions to intense weathering, acidic soil reaction and strong P fixation, even under forest vegetation. The observed decline in available P with depth further emphasizes that phosphorus availability is largely confined to the biologically active surface horizon, with minimal contribution from deeper layers. Deeper horizons (BC and Cr) show very low P values (<1.0 mg/kg), indicating minimal phosphorus contribution from the parent material and limited downward movement of biologically cycled P.

In highly weathered tropical soils, primary P-bearing minerals have largely been depleted and remaining phosphorus is predominantly occluded within secondary minerals, making it inaccessible to plants (Lal, 2016). This explains why even in the footslope profile (SP4), where organic matter and total nitrogen are relatively higher in surface horizons due to depositional processes, available P remains low and declines sharply below the rooting zone. The persistence of low phosphorus availability across slope positions suggests potential long-term implications for nutrient sustainability, as continuous plant uptake without sufficient replenishment may further reduce labile P pools over time.

Vegetation plays a critical role in maintaining the modest levels of available phosphorus observed in surface horizons. Plantation forest species contribute organic inputs that temporarily increase P availability through litter decomposition and root exudation, which can mobilize phosphorus bound to soil minerals. However, in tropical plantation soils, inorganic phosphorus is strongly adsorbed, resulting in low levels of labile phosphorus and tree species have consequently developed various adaptations to acquire phosphorus under conditions of limited availability (Fox *et al.,* 2010). The relatively lower surface P value in the footslope (SP4; 1.83 mg/kg) compared with upper slope positions may reflect dilution effects from deposited mineral materials or differences in

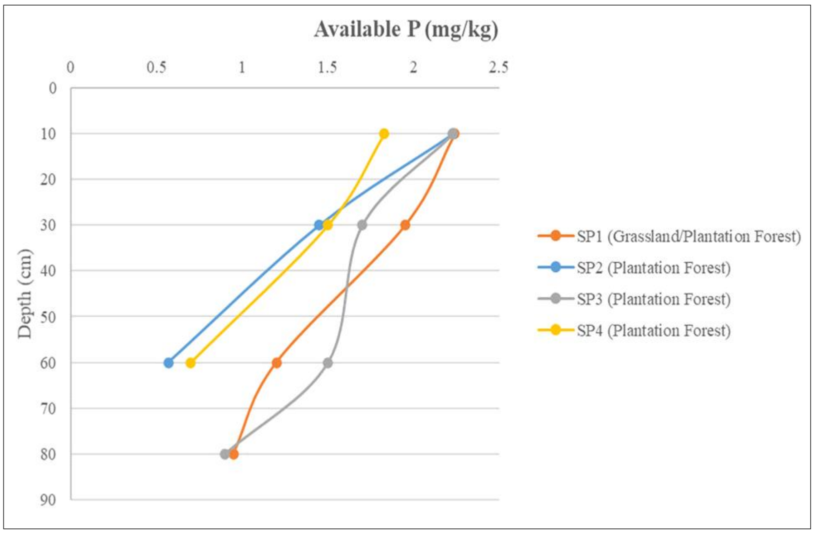

Fig 6: Available phosphorus (mg/kg) distribution by depth in the plantation forest of NwSSU-SJC, San Jorge, Samar, Philippines.

vegetation composition and litter quality, which influence phosphorus release during decomposition. Plantations of *Acacia mangium* and secondary forests exhibited a positive relationship between biomass production and favorable soil properties, including elevated levels of soil carbon, nitrogen and phosphorus (Sang *et al.,* 2013).

Exchangeable potassium

The distribution of exchangeable potassium (K) in the plantation forest soils reveals a distinct vertical and landscape pattern that reflects both biological cycling and soil physicochemical controls. As illustrated in Fig 7, exchangeable potassium (K) is greatest in the surface horizons (Ah), with values between 190 and 407.5 mg/kg and decreases with depth, reaching 110-180 mg/kg in the lower horizons (Bw, BC, Cr). In tropical forest and plantation soils, organic matter decomposition liberates exchangeable cations such as K^+, which are then adsorbed onto soil colloids in the upper horizons; with depth, the decline in organic inputs and root activity leads to reduced exchangeable cations.

The distribution of exchangeable potassium is also influenced by landscape position. The summit profile (SP1) shows the highest surface K concentration (407.5 mg/kg), which is likely attributed to limited erosion, accumulation of organic matter and inputs from grassland-forest litter. The upperslope (SP2; 300.57 mg/kg) and footslope (SP4; 256.88 mg/kg) also show relatively high surface K, possibly reflecting downslope deposition of K-rich organic materials mobilized from upslope. In contrast, the middle slope (SP3) displays the lowest surface K (190 mg/kg), suggesting enhanced leaching and soil redistribution common in sloping tropical landscapes (Lal, 2004). Similar topographic effects on exchangeable K were observed in Philippine forest soils by Asio *et al.* (1998), who reported higher K in surface horizons and lower values downslope or in eroded positions, reflecting both erosion and cation leaching.

Plantation forests influence soil K dynamics through litter return, root uptake and nutrient cycling. The presence of trees increases the input of K through litterfall and fine root turnover, which can elevate surface exchangeable potassium relative to degraded lands or agricultural systems. For example, research in dry land plantations showed that soils under plantation forests had higher exchangeable K due to continuous litter inputs and K recycling (Li *et al.,* 2022). In the Philippines, Bobon-Carnice and Lina (2021) found that upland Ultisols under forest cover retained greater exchangeable K than adjacent agricultural fields, attributing this to sustained litter inputs and Despite these positive effects of vegetation cover on surface K, the limited contribution of parent material and intense tropical weathering constrain deeper soil K reserves. In highly weathered soils, primary K-bearing minerals are depleted over time and potassium is often held in less available forms unless replenished by organic cycling (Yadav and Shidu, 2016). This explains why exchangeable K declines markedly below the rooting zone in all profiles, even where surface horizons are enriched.

Internationally, study on plantation forests also highlight that tree species influence soil K dynamics. K uptake and return differ among species depending on litter quality, root morphology and K demand (Augusto *et al.,* 2015). For instance, fast growing species with high biomass production often cycle more K, increasing its availability in the surface soil relative to slower growing species, an effect that has been documented in eucalyptus and acacia plantations (Cornut, 2022; Augusto *et al.,* 2015). This species effect may partly explain differences in exchangeable K observed among sampling points if species composition or stand age varies across the plantation.

Generally, the morpho-physical and nutrient characteristics of the plantation forest soils at NwSSU-SJC indicate a landscape undergoing gradual ecological recovery driven by plantation vegetation and internal

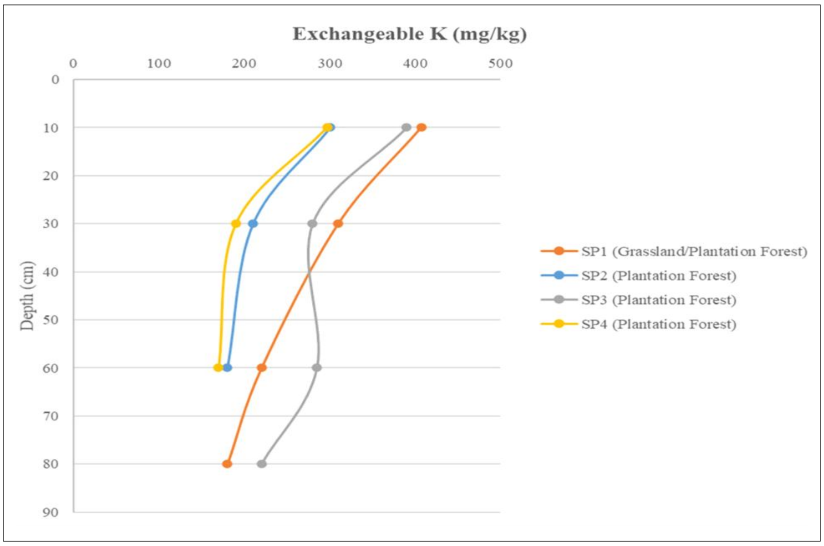

Fig 7: Exchangeable potassium (mg/kg) distribution by depth in the plantation forest of NwSSU-SJC, San Jorge, Samar, Philippines.

biogeochemical processes. The presence of Ah-Bw-BC horizon sequences in summit and middle slope positions, the development of cambic (Bw) horizons, granular surface structure, moderate bulk density (1.30-1.45 g/cm³) and relatively high porosity (45-51%) collectively reflect improving soil aggregation, enhanced root penetration and active pedogenesis, key indicators emphasized in soil restoration theory as signs of rebuilding soil structure and functionality. Darker surface colors and increased humus accumulation further confirm the restoration of organic-enriched topsoil layers, which serve as primary zones of biological activity and nutrient exchange.

From a nutrient cycling perspective, the clear vertical stratification of organic matter (2.42-2.98% at the surface), total nitrogen (0.15-0.24% in Ah horizons) and available phosphorus (1.83-2.24 mg/kg at the surface) demonstrates that nutrient availability is closely tied to litter deposition, microbial decomposition and root-mediated recycling processes. The strong coupling of OM and TN and the confinement of available P to surface horizons indicate that nutrient supply is largely sustained through rapid internal cycling rather than deep mineral reserves. Exchangeable potassium enrichment in surface soils (190-407.5 mg/kg) further illustrates the effectiveness of biological recycling under plantation cover. These findings align with restoration mechanisms where continuous organic inputs enhance microbial biomass, stimulate mineralization-immobilization dynamics and improve cation retention through increased cation exchange capacity associated with organic matter.

However, the sharp decline of nitrogen, phosphorus and potassium in deeper horizons, together with evidence of erosion in slope positions, highlights that nutrient capital remains shallow and vulnerable. This condition implies that long-term plantation sustainability depends on maintaining protective vegetation cover, minimizing soil disturbance and preventing topsoil loss, as the biologically active surface layer is the principal reservoir of fertility. Sustained litterfall, diversified root systems and improved aggregation must continue to reinforce nutrient retention and reduce leaching losses. In this context, the plantation forest is not only stabilizing soil structure but also progressively restoring nutrient cycling efficiency, thereby enhancing soil resilience, supporting continuous biomass production and strengthening the long-term ecological sustainability of the forest ecosystem.

CONCLUSION AND RECOMMENDATION

The soils of the plantation forest at NwSSU-San Jorge Campus were derived primarily from sedimentary rocks, particularly shale and exhibited moderately to well-developed profiles. Summit, middle slope and footslope positions displayed Ah-Bw-BC and Ah-AB-Cr horizon sequences, reflecting ongoing soil formation under forest vegetation. Texturally, the soils were predominantly clayey, with moderate bulk density and porosity. Surface horizons were friable when moist, whereas subsurface layers were sticky and plastic when wet, indicative of the clay-rich parent material. Chemically, the soils were moderately acidic, suggesting that acidity does not yet limit vegetation growth. Organic matter concentrations were moderate in the surface layers but declined sharply with depth. Total nitrogen and available phosphorus were relatively low, pointing to potential nutrient constraints for plant growth. Nevertheless, exchangeable potassium and base saturation levels were moderate, indicating that the soils have not undergone severe leaching.

In terms of soil development, the presence of distinct Bw and Cr horizons indicates moderate maturity, although the soils have not yet reached advanced stages of weathering due to their still relatively high base saturation levels. These characteristics reflect improving soil quality following the establishment of plantation forest vegetation, which has enhanced surface organic inputs and biological activity. Given the low nitrogen and phosphorus levels in the soils, it is advisable to carry out regular monitoring and implement suitable soil management practices, including organic fertilization, planting of leguminous cover crops, establishment of natural vegetative strips and enrichment planting with indigenous or nutrient-efficient species. These practices will help mitigate soil nutrient depletion, promote ecological restoration and support long-term soil fertility improvement across the plantation forest landscape.

ACKNOWLEDGEMENT

The author would like to acknowledge the Northwest Samar State University-San Jorge Campus for the financial support given to this research.

Conflict of interest

The author declares that he has no conflict of interest in relation to the publication of this article.

REFERENCES

Ahmed, I.U. (2018). Forest soil C: Stock and stability under global change. *New Perspectives in Forest Science.* **37:** 1-15. doi: 10.5772/intechopen.74690.

Asio, V.B., Demain, K.L.B., Olguera, D.T. and Villasica, L.J.D. (2015). Characteristics and nutrient status of two degraded upland soils in Samar, Philippines. *Annals of Tropical Research*. **37:** 142-166.

Asio, V.B., Jahn, R., Perez, F.O., Navarrete, I.A. and Abit, S.M.J. (2009). A review of soil degradation in the Philippines. *Annals of Tropical Research.* **31:** 69-94.

Asio, V.B., Jahn, R., Stahr, K. and Margraf, J. (1998). Soils of the Tropical Forests of Leyte, Philippines II: Impact of Different Land Uses on Status of Organic Matter and Nutrient Availability. In: Soils of Tropical Forest Ecosystems: Characteristics, Ecology and Management. Berlin, Heidelberg: Springer. pp. 37-44. doi: 10.1007/978-3-662-03649-5_4.

Asio, V.B., Lina, S.B., Maranguit, D.S., Bolledo, A.B., Doguiles, R.J.T., Quiñones, C.M.O., Sabijon, J.R. and Demain, K.L.B. (2014). Characteristics of soils in the marginal uplands of inopacan, leyte. *Annals of Tropical Research.* **36(Supplement):** 1-15. doi: 10.32945/atr36s1.2014.

Augusto, L., De Schrijver, A., Vesterdal, L., Smolander, A., Prescott, C. and Ranger, J. (2015). Influences of evergreen gymnosperm and deciduous angiosperm tree species on the functioning of temperate and boreal forests. *Biological Reviews.* **90:** 444-466. doi: 10.1111/brv.12119.

Aureo, W.A. and Reyes, J.T.D. (2023). Composition and community structure of plant species in a secondary growth forest in the central Philippines. *Journal of Biodiversity Conservation and Bioresource Management.* **9:** 13-28.

Baumert, V.L., Forstner, S.J., Zethof, J.H., Vogel, C., Heitkoetter, J., Schulz, S., Ingrid, K.K. and Mueller, C.W. (2021). Root-induced fungal growth triggers macroaggregation in forest subsoils. *Soil Biology and Biochemistry.* **157:** 108244. doi: 10.1016/j.soilbio.2021.108244.

Bobon-Carnice, P.A. and Lina, S.B. (2021). Changes in carbon and nutrient stocks of secondary forest transformations under Ultisol in Leyte Island, Philippines. *Mindanao Journal of Science and Technology.* **19:** 1-15. doi: 10.61310/mndjstecbe.0988.21.

Buol, S.W., Southard, R.J., Graham, R.C. and McDaniel, P.A. (2011). Soil Genesis and Classification. John Wiley and Sons.

Cornut, I. (2022). Assessing the Impact of the Potassium Cycle on Stand Growth and Resource-Use in Tropical Eucalypt Plantations: A Process-Based Modeling Approach (Doctoral dissertation, Université Paris-Saclay).

Djamel, B., Abdelkader, R. and Ahmed, Y. (2025). Combining dendrometric parameters and soil chemical properties: An useful tool for valorization of shrubs in forests. *Indian Journal of Agricultural Research.* **59:** 1920-1926. doi: 10.18805/IJARe.AF-951.

Duguma, L.A., Atela, J., Minang, P.A., Ayana, A.N., Gizachew, B., Nzyoka, J.M. and Bernard, F. (2019). Deforestation and forest degradation as an environmental behavior: Unpacking realities shaping community actions. *Land.* **8:** 26. doi: 10.3390/land8020026.

Farley, K.A. (2007). Grasslands to tree plantations: forest transition in the andes of ecuador. *Annals of the Association of American Geographers.* **97:** 755-771. doi: 10.1111/j.1467-8306.2007.00581.x.

Food and Agriculture Organization of the United Nations (FAO). (2006a). Guidelines for Soil Description (4th ed.). Rome, Italy: FAO.

Fox, T.R., Miller, B.W., Rubilar, R., Stape, J.L. and Albaugh, T.J. (2010). Phosphorus Nutrition of Forest Plantations: The Role of Inorganic and Organic Phosphorus. In Phosphorus in action: Biological processes in soil phosphorus cycling. Berlin, Heidelberg: Springer. pp. 317-338. doi: 10.1007/978-3-642-15271-9_13.

Guo, L.B. and Gifford, R.M. (2002). Soil carbon stocks and land use change: A meta analysis. *Global Change Biology*. **8:** 345-360. doi: 10.1046/j.1354-1013.2002.00486.x.

He, Y., Zhang, Q., Wang, S., Jiang, C., Lan, Y., Zhang, H. and Ye, S. (2023). Mixed plantations induce more soil macroaggregate formation and facilitate soil nitrogen accumulation. *Forests.* **14:** 735. doi: 10.3390/f14040735.

Huang, Y., Xiong, T., Zhao, M., Deng, Y., Yang, G., Ban, Y. and Huang, Y. (2024). Influence of soil properties and near-surface roots on soil infiltration process in short-rotation eucalyptus plantations in southern subtropical China. *Catena.* **234:** 107606. doi: 10.1016/j.catena.2023.107606.

International Soil Reference and Information Center (ISRIC). (1995). Procedures for Soil Analysis. Wageningen, The Netherlands.

Jahn, R., Blume, H.P., Asio, V.B., Spaargaren, O. and Schad, P. (2006). Guidelines for Soil and Description (4th ed.). Rome, Italy: FAO.

Koshelev, A.V., Shatrovskaya, M.O. and Kretinin, V. M. (2024). Influence of forest strips on changes in soil properties in the agrolandscape. *Indian Journal of Agricultural Research*. **58:** 323-330. doi: 10.18805/IJARe.AF-799.

Laganière, J., Angers, D.A. and Pare, D. (2010). Carbon accumulation in agricultural soils after afforestation: A meta-analysis. *Global Change Biology.* **16:** 439-453. doi: 10.1111/j.1365-2486.2009.01930.x.

Lal, R. (2004). Soil carbon sequestration in India. *Climatic Change*. **65:** 277-296. doi: 10.1023/B:CLIM.0000038202.46720.37.

Lal, R. (2016). Soil health and carbon management. *Food and Energy Security.* **5:** 212-222.

Lasco, R.D. and Pulhin, F.B. (2009). Carbon budgets of forest ecosystems in the Philippines. *Journal of Environmental Science and Management.* **12:** 1-13.

Li, Y., Dong, X., Yao, W., Han, C., Sun, S. and Zhao, C. (2022). C, N, P, K stoichiometric characteristics of the "leaf-root-litter-soil" system in dryland plantations. *Ecological Indicators.* **143:** 109371. doi: 10.1016/j.ecolind.2022.109371.

Navarrete, I.A., Peque, D.P. and Macabuhay, M.D. (2018). Soil Information as a Reforestation Decision-Making Tool and its Implication for Forest Management in the Philippines. In Environmental Resources Use and Challenges in Contemporary Southeast Asia: Tropical Ecosystems in Transition. Singapore: Springer Singapore. pp. 97-116. doi: 10.1007/978-981-10-8881-0_5.

Navarrete, I.A., Tsutsuki, K., Asio, V.B. and Kondo, R. (2009). Characteristics and formation of rain forest soils derived from late quaternary basaltic rocks in leyte, Philippines. *Environmental Geology.* **58:** 1257-1268. doi: 10.1007/s00254-008-1627-z.

Nelson, D.W. and Sommers, L.E. (1982). Methods of Soil Analysis (Part 2). Wisconsin, United States: American Society of Agronomy-Soil Science Society of America.

Olsen, S.R. and Sommers, L.E. (1982). Methods of Soil Analysis (Part 1). Wisconsin, United States: American Society of Agronomy-Soil Science Society of America.

Perocho, L.P., Sabijon, J.R. and Aquino, R.R. (2018). Floristic composition and soil characteristics of plantation forest in Northwest Samar State University, San Jorge Campus. *International Journal of Agriculture Forestry and Life Sciences*. **2:** 24-35.

Sabijon, J.R. and Asio, V.B. (2022). Morphophysical and nutrient characteristics of degraded soils in Sta. Rita, Samar, Philippines. *Mindanao Journal of Science and Technology.* **20:** 1-15. doi: 10.61310/mndjstea.0954.22.

Sang, P.M., Lamb, D., Bonner, M. and Schmidt, S. (2013). Carbon sequestration and soil fertility of tropical tree plantations and secondary forest established on degraded land. *Plant and Soil.* **362:** 187-200. doi: 10.1007/s11104-012-1281-9.

Schlichting, E., Blume, H.P. and Stahr, K. (1995). Bodenkundliches Practkum (2nd ed.). Berlin, Germany: Blackwell.

Shoji, S., Nanzyo, M. and Ahlgren, R.A. (1993). Volcanic Ash Soils: Genesis, Properties and Utilization. Developments in Soil Science 21. Amsterdam, Netherlands: Elsevier.

Sun, J., Huang, C.H., Han, G. and Wang, Y. (2019). Effects of cover on soil particle and associated soil nutrient redistribution on slopes under rainfall simulation. *Journal of Soils and Sediments*. **19:** 729-740. doi: 10.1007/s11368-018-2088-y.

Vedeneeva, V.A., Koshelev, A.V., Potashkina, Y.N. and Shatrovskaya, M.O. (2025). The influence of the depression zone of forest shelterbelts on the productivity and profitability of winter wheat. *Indian Journal of Agricultural Research*. **59:** 366-373. doi: 10.18805/IJARe.AF-909.

ViSCA-GTZ, B. (1996). Rehabilitation in Leyte, Philippines. Dipterocarp Forest Ecosystems. *Towards Sustainable Management.* **124:** 1-124.

Xiong, Y., Zeng, H., Xia, H. and Guo, D. (2014). Interactions between leaf litter and soil organic matter on carbon and nitrogen mineralization in six forest litter-soil systems. *Plant and Soil.* **379:** 217-229. doi: 10.1007/s11104-014-2033-9.

Yadav, B.K. and Sidhu, A.S. (2016). Dynamics of Potassium and Their Bioavailability for Plant Nutrition. In Potassium Solubilizing Microorganisms for Sustainable Agriculture. New Delhi: Springer India. pp. 187-201. doi: 10.1007/978-81-322-2776-2_14.

Zanetti, S.S., Cecílio, R.A., Alves, E.G., Silva, V.H. and Sousa, E.F. (2015). Estimation of the moisture content of tropical soils using colour images and artificial neural networks. *Catena.* **135:** 100-106. doi: 10.1016/j.catena.2015.07.015.