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Soil characterization of selected Pili (*Canarium Ovatum*, Engl.) farms from top producing Municipalities in Sorsogon, Philippines

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ABSTRACT

Sorsogon province is considered as the top producer of Pili (*Canarium ovatum*, Engl.) fruits contributing to more than half of the country production. Believed to be indigenous in the province, the soil properties were examined to know what type of soils Pili trees naturally thrive on. Relief of the land, moisture content, soil color, soil pH, level of Nitrogen, Phosphorus and Potassium were investigated through various procedures such as ocular inspection, gravimetric method, and utilization of Munsell Color Chart and Soil Test Kit. There were 19 sampling areas selected from the Pili farms of Irosin, Bulusan, Gubat, and Prieto Diaz. A total of 38 composite soil samples were collected from topsoil and subsoil from each sampling area. The general relief of the Pili farms selected are hilly or mountainous. Moisture content ranges from 1.37% to 14.38% in the topsoils and from 7.33% to 24.37% in the subsoils. The predominant color in the topsoil is brown while for subsoil is olive brown and light olive brown at different landscape positions. The soils of the Pili Farms can be generally described as acidic. pH of 5.8 was predominant for the topsoil and subsoil regardless of landscape positions. Medium nitrogen was commonly detected in the topsoil and low nitrogen in the subsoil. Low phosphorus and sufficient potassium were all evident at both depths in all Pili farms from the four municipalities.

Key words: *Pili (Canarium ovatum, Engl.) Soil properties, Indigenous*

Introduction

Pili (*Canarium ovatum*, Engl.) is considered as the "tree of hope" due to its numerous uses derived from almost all of its parts such as food and pastries out of its kernel, animal feeds and versatile oil from its pulp, handicrafts, fashion accessories, activated carbon and biofuel from its shells (Baleza, 2018). As a result, Pili has become a valuable commodity creating a continuous increasing market demand not just locally but also globally resulting to 7, 649 mt of production in 2018 (PSA, 2018). From the data on national production, the province of Sorsogon remains to be at the top contributing 54.9% or 4, 199. 30 mt of fruit production and 60.7% or 1, 373.03 hectares area of production in 2018 (PSA, 2018). With the majority of the fruit-bearing Pili trees being found in Sorsogon, it is believed that the region is the crop's center of genetic diversity (Coronel, 1996).

A great number are indigenous which means they are not intentionally planted and cultivated by farmers and do not require human intervention (Coronel, 1996). Several factors can be attributed to the indigeneity of Pili in the province of Sorsogon namely soil characteristics, climate, topography, and agricultural practices. In this study, some physical and chemical characteristics of the soils in the province of Sorsogon were examined in order to assess the properties of soil where Pili is currently cultivated and to assess the current nutrient status of the selected Pili Farms. This study can serve as baseline data for the farmers and Pili stakeholderswho have little knowledge regarding the condition of the soils of their Pili farms and apply possible necessary soil management practice to sustain or improve their yield.

Objectives

The purpose of this study was to characterize the physical and chemical properties of the soils in Pili farms in Sorsogon. Specifically the study aimed to: (1) Identify the characteristics of the soils planted with Pili in study sites in terms of relief of land, soil moisture content, soil color, pH, and N-P-K; and (2) Compare soil characteristics of Pili farms from the top producing municipalities.

Indigenous and Endemic Species

A species is considered indigenous or native to a certain region if its existence in that region is the result of only natural processes without any human intervention (Executive Order No. 13,112, 1999). They are well adapted to the soil conditions, climate, light, and topography of that region that characterize their ecosystem. On the other hand, a species is considered endemic when the species is exclusively found or restricted in a particular place (Endemic, n.d.). Moreover, an indigenous crop may not necessarily mean that it is endemic since indigenous crops can be found in other areas.

The Philippines belongs to the world's 25 recognized biodiversity hotspots and the world's 17 mega diversity countries(Altoveros and Borromeo, 2007). It also places seventh in terms of species diversity and endemism or number of endemic species. From the 57, 177 species of flora and fauna identified in the country, 67% are endemic. And from the 8, 120 species of flowering plants, 40% are endemic to the country. 3, 000 of these plant species are utilized for food, fiber, essential oils, medicine, commercial timber and ornamentals (Altoveros and Borromeo, 2007).

One example of a plant that is endemic to the Philippines is the Manila hemp which is also locally known as abaca (*Musa textilis*) (USDA, 2020). The Abaca plant belongs to the Musaceae family and closely related to the wild seeded bananas. An immense majority of cultivars found in the country are traditional varieties. 773 accessions of Manila hemp in one ex situ collection in the country consists of traditional cultivars or landraces, wild types, breeding lines, and improved cultivars (Altoveros and Borromeo, 2007). The modern abaca is believed to have their ancestry coming from the Eastern Philippines and the wild varieties can still be found in the virgin forests of Catanduanes away from cultivated areas. Abaca has great economic value being harvested for its fiber extracted from the leaf-stem. Of all the natural fibers, it is considered the strongest allowing it to be used in making ropes for ship's lines and fishing nets (Wood and Roberts, 2005). Due to its flexibility and durability it can also be made into handcrafts, teabags, furniture, clothing and banknotes. When it comes to cultivation, the crop is normally grown in well-drained loamy soil through rhizomes planted at the onset of the rainy season but they can be propagated through seeds (Hoiber, 2010).

An example of a plant that is indigenous or native to the Philippines but not endemic since it can also be found in Southeast Asia, East Asia and other Pacific regions is the *Pterocarpus indicus* locally known as the Narra tree. From Thomson's publication "*Pterocarpus indicus* (narra)" in 2006 the following information on the said plant were described. It belongs to the Fabaceae family under the subfamily Faboideae. It is a deciduous tree that typically grows to 25-35 meters in height. Their best development was observed in riverine, tropical, closed and secondary forests including near the coasts. This is due to their adaptability to subtropical and tropical conditions with mean annual temperature of 22-32 °C and annual rainfall of 1300-1400 mm. Narra is also well-adapted to strong winds and usually stands up even in storms and suffers only branch breakage When it comes to soil conditions, it can survive in a very wide range of soils but it is normally located in well drained, sandy to clay loams of mildly acidic to mildly alkaline pH. In addition, it is considered a multipurpose tree species because of its utilization for timber, medicine, reforestation, village-level woodlots, live-fencing landscaping. Narra tree was declared the national tree of the Philippines in 1934 through Proclamation No. 652(PH National Tree: Narra, n.d.)because it symbolizes the Filipino people's indomitable spirit and strength of character.

Indigeneity of Pili in Sorsogon

The Philippines is home to a number of species that thrive naturally and represent how diverse the country is. One of which is Pili or *Canarium ovatum* that belongs to the Burseraceae family (*Canarium ovatum* Engl, n.d.). This crop's center of genetic diversity is in the Bicol region possibly in the rainforests of the municipality of Bulusan in Sorsogon (Coronel, 1996). Century old trees were sighted in the said province with height measuring more than 50 meters. From Sorsogon, the trees have spread naturally through fruits dispersed by hornbills, monkeys, wild pigs and deer. The trees have spread northward to Albay, Camarines Sur, Camarines Norte, and have spread further to island provinces of Catanduanes and Masbate. The trees were also distributed to the Province of Quezon and Southern Tagalog region by means of man-made efforts. Pilidid not spread much to other countries because historically there is little interest in the pili nut due to its thick shell and small kernel. In addition, other countries have their own important species (Coronel, 1996).

According to Coronel (1996) in his book "Pili nut. *Canarium Ovatum* Engl.", about 53 species of Canarium were believed to be found in the Philippines but was later reduced to nine species as studied by Leenhouts in 1956 and four of these are endemic.

Pili is primarily utilized for its edible nut and pulp. The nut is a source several essential nutrients such as Na, Fe, Al, Zn, Mn, Cu, Ni, and Cr (Millena and Sagum, 2018).The high oil percentage and the fatty acid profiles of the oil samples of the pulp and the nuthave potential for high-value specialty oil products (Pham and Dumandan, 2015). Another economically valuable species is *Canarium luzonicum. Canarium luzonicum* is primarily utilized for its oily resin or more commonly known as Manila elemi that is obtained from its bark and are utilized as ingredient in making varnishes, paints, lacquers, and printing inks (Manalo and West, 1949). Pharmacological actions including antioxidant, antimicrobial, anti-inflammatory, hepatoprotecttive, and antitumor activities from *Canarium* L. also increase its potential for medicinal use (Rajagopal and Wiart, 2011).

Geography of Sorsogon

The province of Sorsogon is located at the southeastern tip of Bicol Peninsula with a total land area of 211, 901 hectares (PSA, 2019). It has 14 municipalities and one city with Sorsogon city as the capital. It is bordered by Albay on the north, by San Bernardino Strait on the south, by Ticao on the west and by the Philippine Sea on the east.

The topography of the province is irregular (Arostorenas, 1963). The relief ranges from narrow

Fig. 1. Map of the Province of Sorsogon showing the general relief of the land. (http://www.maphill.com/philippines/region-5/sorsogon/3d-maps/satellite-map/)

coastal plains and valleys to undulating, gently rolling, steep slopes, rugged hills and mountains. The highest elevation is Mt. Bulusan at 1,565 meters. The coastline is also very irregular marked with several indentures. In the southern part of the province, early and middle tertiary volcanic and intrusive rocks are found while tertiary and quarternary volcanic rocks are prevalent in the eastern and northwestern sections. Quarternary alluvium of terraces, flood plains, deltaic and litoral deposits are found along Sorsogon Bay together with tuffaceous rocks and limestones (Arostorenas, 1963).

In 1963, Aristorenas and company of the Department of Agriculture and Natural Resources published a soil survey report of the Sorsogon province that presented the characteristics and classifications of the soils in Sorsogon. The report described that Sorsogon has three general groups namely: i. soils of the plains and valleys; ii. soils of the flat upland, undulating, rolling hills and mountains and iii. Miscellaneous land types.

The soils that represent the plains and valleys are Bascaran, Sorsogon, Macabare, Donsol, Silay, Irosin and Panganiran series. These are alluvial soils well adapted to crops grown in the locality. The soils that represent the flat upland, undulating, rolling hills and mountains are Bolinao, Castilla, Ubay, Annam, Luisiana, Casiguran, Bulusan, and Series with one soil complex: Castilla-Bolinao complex. Lastly the miscellaneous land types consist of hydrosol and beach sand. The secondary soils of the province developed from recent and older alluvial deposits while the primary soils have originated from the weathered products of different country rocks such as basalt. Andesite, shale, sandstone, limestone, tuff conglomerate and agglomerate (Arostorenas, 1963). Radial pattern characterizes the drainage of the whole province. The big rivers that constitute the province are Donsol, Putiao, Hipanao, Dalagnan, Casiguran, Cadacan, Banuangdaan, Fabrica, Irosin, Ogod, and Buhang Rivers.

In the Modified Corona's classification of Climate, the province of Sorsogon falls under Type II (Climate Projections for Provinces, n.d.). It has no dry season with a very pronounced maximum rain period from December to February with an annual average rainfall of 152.42 mm. Much of the cyclonic rains occurs from July to February. There is not a single dry month and the minimum monthly rainfall occurs during the period from March to May. The average temperature is 24 degrees Celsius (low) and 34 degrees Celsius (high). The relative humidity gradually increases from September to December with an annual average of 81.5%. The high humidity can be attributed to: the high evaporation rate form surrounding bodies of water, richness of vegetation, different prevailing winds occurring in different seasons of the year, and the abundant rains present throughout the year (Aristorenas, 1963). The province experiences 5-10 typhoons every year as a result of its geographical location being located near the equator and the Pacific Ocean.

Soil Properties and Soil Testing

Soil is one of the vital components for plant growth. It is a natural dynamic body composed of minerals and organic materials and living forms in which plants grow (Brady and Weil, 1999). The physical and chemical properties of the soil constitute to reaching the optimum growth and yield of crops.

The physical properties of the soil include soil color, soil texture, soil structure, soil moisture, particle density, bulk density, porosity, consistency, and others (FAO, 1987). Soil color is described by its hue, value and chroma. The combination of the three can pertain to the distinct mineral material composition, and water state or drainage of the soil. Soil texture refers to the relative proportion of sand, silt and clay. It has an effect on porosity, ease of water movement, water holding capacity, internal drainage and nutrient retention. Soil structure is when sand, silt, clay, and organic-matter particles in a soil combine with one another to form larger particles of various shapes and sizes. A structure of the soil can be platy, blocky, prismatic, columnar, granular, and structureless. The structure of soil is usually determined per layer horizon identified.

Soil moisture serves as the primary source of water for terrestrial plants. It is important for soils to store sufficient amount of water and release it to the crop at the time of need. The availability of water to plants is affected by different forces measured in soil moisture tension (SMT) which is measured in atm or bar (FAO, 1987). The higher the SMT the more difficult it is for plants to acquire the water. Field capacity is the estimate of the upper limit of the available moisture while Permanent Wilting Point is for the lower limit. Another determinant for soil moisture is the moisture content usually measured using the Gravimetric Method. This is done by subtracting the oven dried weight of the soil to its fresh weight then divided by the oven dried weight and multiplying it by 100 for the result to be expressed in percent by mass.

The chemical properties of the soil can be assessed through soil pH, cation exchange capacity (CEC), percent base saturation, and buffering capacity (FAO, 1987). Soil pH is the expression of acidity or alkalinity of the soil by measuring the concentration of H+ ions in the soil. It can indicate nutrient availability to plants. Cation exchange capacity (CEC) is the sum of adsorbed cations expressed in me/100 g soil or cmolc/kg. CEC indicates soil fertility since it shows capacity of soils to retain nutrients. Percent base saturation is the percentage of CEC that are represented by exchangeable basic cations such as Ca^{2+}, Mg^{2+}, K^{2+}, NH_4^+, Na^+. It is an important soil property as it has an inverse relationship with soil acidity. Buffering capacity is the resistance of the soil to drastic changes in pH. The higher the buffering capacity of the soil, the higher the amount of lime needed to neutralize its acidity.

Soil testing or soil analysis is one of the quick and precise methods in evaluating the fertility status of the soil. The principle behind this is that the amount of nutrient extracted by the chemical reagents at any one time is the amount available throughout the growth period of the crop. The general step in soil analysis are i. soil sampling, ii. Analysis and interpretation of results iii. Formulation of fertilizer recommendation. The accuracy of soil analysis can only be as good as the soil sampling. In the analysis part, the general procedure is for the soil to undergo different chemical tests for soil pH, soil nitrogen and organic matter content, phosphorus, and potassium if exact quantitative data is required. For qualitative data, a soil test kit can be utilized.

In a study by Brye and Sherman in 2019, soil analysis was done to determine the changes the chemical properties of the soil in response to long-term pineapple cultivation in Costa Rica. Through soil analysis, the study identified that "soil organic carbon was lower under pineapple cultivation than in an adjacent pasture and secondary forest; soil pH and base cations were lower in a 20 than in a 7 yrold pineapple field, pasture, and forest; Pineapple cultivation may require increased liming rates to help maintain longterm soil quality" (Brye and Sherman, 2019).

In another study, by Adhikari and company in 2018, soil analysis was also utilized to determine soil nutrient variations by topographic controls in a silvopasteur system in a research site at the University of Arkansas Agricultural Research and Extension Center. The study collected a total of 51 topsoil samples from different topographic positons and was able to affirm the "topographic influences on soil nutrient distribution; terrain attributes identified topographic functional units as management zones; level of soil nutrients in topographic functional units were different" (Adhikari et al, 2018).

Agro-Climatic Conditions for Crop Production

The condition of the soil greatly influence the productivity of the cultivated crops for the reason that it can pose as a constraint to the growth of the crops (Vogt *et al.*, 2012). This means that different crops require different type of soils that will sustain and nurture their growth. Its physical, biological, and chemical properties are taken into account when cultivating a certain crop is initiated.

From the study of Adornado and Yoshi in 2008 titled "Crop Suitability and Soil Fertility Mapping using Geographic Information System", the characteristics of the soil required by certain crops were discussed. For rice (*Oriza sativa*), pH of 5.5 to 6 and heavier soils are preferred. It will be suitable in broad alluvial plains and collu-alluvial terraces with 0-8% slope. The agro climatic condition suitability is 20 to 30 ^oC and evapotranspiration is between 450 to 700 mm.

For pineapple (*Ananas comosus*), pH of 4.5 to 6.5, sandy loam and well-drained soils are ideal. Pineapple is suitable for broad alluvial plains and collu-alluvial terraces, sedimentary hills and volcanic foot slopes with 0-25% slope. The agro climatic condition suitability is 22 to 26 ^oC mean daily temperature and evapotranspiration is between 700 to 1000 mm (Adornado and Yoshi, 2008).

Another crop discussed is the coconut (*Cocos nucifera*) that prefers soil with enough Potassium content, pH of 5-8, freely drained and volcanic ash soils. It is usually planted in estuarine soils and alluvial river but it can also survive in areas below 500 above sea level. It can also grow in broad alluvial plains and collu-alluvial terraces with slope 0-8%. Coconut can tolerate hot and dry temperature but must not exceed 45 ^0C. It requires 500-800 mm of rainfall (Adornado and Yoshi, 2008).

The paper also presented the soil properties and agro climatic conditions suitable for banana (*Musa sapientum).* Banana must have an optimum pH of 5-7 and must be planted in deep and well drained loam soil with high water holding capacity, humus content, nitrogen, and potassium. It can thrive in for broad alluvial plains and collu-alluvial terraces, sedimentary hills and volcanic foot slope and alluvial plains to inland latosols of tropics. 2000-2500 mm of water is needed in rained production. Temperature suitability ranges from 16 to 38 ^{o}C and prefers 60% humidity (Adornado and Yoshi, 2008).

Materials and Methods

The Study Area

Two farms were selected from each of the following municipality: Irosin (12° 41' 59.99" N, 124° 01' 60.00" E), Bulusan (12° 45' 28.80" N, 124° 08' 6.00" E), Gubat (12°55’15.60" N 124°07’22.80" E), and Prieto Diaz (13°01’60.00" N 124°11’60.00" E). These four municipalities were identified as the top pili producing municipalities together with Sorsogon City in the Province of Sorsogon, Philippines. Farms were selected based on the greatest number of fruit bearing trees and ease of accessibility as identified by each of the municipal agriculture office. Selected farms were assessed how many sampling areas were needed depending on the topography and the cropping management of the farms. One sampling area did not exceed five hectares.

Soil Sampling and Relief Determination

Five to ten random spot samples were collected from each sampling area. From each of the spot sample, the topsoil (20 cm depth) and subsoil (40 cm depth) were collected using the soil auger. Composite soil samples were collected from spot samples of the topsoil and subsoil from each sampling area. In Irosin, six sampling areas were identified from the two farms which means 12 composite samples (topsoil and subsoil) were collected. In Bulusan, five sampling areas where identified from the two farms or 10 composite samples were collected. In Gubat, four sampling areas were identified from the two farms or eight composite samples were collected. Lastly, for Prieto Diaz, four sampling areas were also identified so eight composite samples were collected. A total of 19 sampling areas or 38 composite soil samples were identified from the four municipalities. The sampling areas were primarily selected based on the relief of the land which was identified by ocular inspection.

From the composite samples, soil moisture content, soil color, pH status and the level of Nitrogen, Phosphorus and Potassium were examined.

Moisture content determination

Moisture content was computed by gravimetric method. Around 30 g of air-dried composite sample were oven dried at 105 ^{o}C for 24 hours. The oven-dried weight of the soil samples were acquired and the percent moisture content by mass were computed.

Formula:

$$\%mc = \frac{\text{Fresh weight of soil} - \text{oven dried weight of soil}}{\text{Oven dried weight of soil}} \times 100$$

Soil color determination

The soil color were identified through the Munsell Color Chart. A moist soil ped was acquired from each composite sample and matched with the colors on the Munsell color chart. The corresponding hue, value, and chroma were recorded. Percent distribution of soil color from the topsoil and subsoil were presented in a chart.

pH, NPK determination

pH status and level of nitrogen, phosphorus and potassium were obtained through the Soil Test Kit. Around 5 g of composite samples were subjected to analyses. Upon reaction with the formulated solutions, the resulting color were matched on the charts and recorded. Appropriate charts were used to show the visual representation of the least and greatest results.

Statistical Analysis

One-way analysis of variance (ANOVA) were performed to test the significant differences in the meansof the following: 1. moisture content between top soil and sub soil of Pili Farms. 2. soil moisture content by relief. 3. Soil moisture content among municipalities 4. pH level between top soil and sub soil. 5 pH level by relief. 6. pH level of soil among municipalities.

Results

Irosin Pili Farms

In the municipality of Irosin, the selected Pili Farms have three soil sampling areas identified based on the relief of the land namely foot slope, back slope, and summit (Table 2). The pH of the soil samples are less than 6.0 which indicates that they are acidic.

Medium nitrogen, low phosphorus, sufficient potassium were identified in all of the soil samples regardless of its relief and soil depth.

In the two depths of soil from different relief of land in Pili Farm 1, pH of 5.8 were determined identifying the farm as moderately acidic. The topsoil from the foot slope of Pili Farm 1 is dark yellowish brown and has 7.38% moisture content while its subsoil is olive brown and has a higher moisture content equal to 9.26%. The topsoil from the back slope is brown has 9.94%% moisture content while its subsoil is olive brown and has a higher moisture content equal to 13.28%. The topsoil from the summit is brown and has 13.16% moisture content while its subsoil is dark grayish brown but has a lower moisture content equal to 9.26% (Table 2).

For Pili Farm 2, the two depths from different relief are generally strongly acidic with very strongly acidic condition observed in the back slope while one extremely acidic condition coming from the topsoil of the foot slope. The topsoil from the foot slope of Pili Farm 2 is light brown and has 9.97% moisture content while its subsoil is brown and has a higher moisture content equal to 12.82%. For the topsoil in the back slope, grayish brown color is observed with 13.53% moisture content while the subsoil is light yellowish brown with lower moisture content of 11.32%. The topsoil from the summit is light pale brown with 11.08% while the subsoil is olive with a higher moisture content of 13.47% (Table 2).

Bulusan Pili Farms

The selected Pili farms in Bulusan have different numbers of identified sampling areas (Table 2). Pili farm 1 has shoulder and summit as sampling areas while Pili farm 2 has foot slope, shoulder, and summit. All of the sampling areas from the two depths have low phosphorous and sufficient potassium. However, the nitrogen levels vary from farm to farm and at different depths. The topsoils of the shoulder and summit of Pili Farm1 have medium nitrogen while the subsoils have low nitrogen. For Farm 2, both depths of the foot slope have medium nitrogen while both depths of the shoulder have low nitrogen. Lastly, the summit of Farm 2 has medium nitrogen in the top soil and low phosphorous in the subsoil.

Majority of the sampling areas are moderately acidic. Extremely acidic conditions were observed in Pili farm 1 specifically the subsoils of shoulder and submit and the topsoil of the shoulder (Table 2). Very mildly alkaline condition was detected in the subsoil of foot slope of Pili farm 2 and slightly acidic condition in the topsoil of the foot slope of Pili Farm 2.

The topsoil from the shoulder of Farm 1 is brown and has 5.51% moisture content while its subsoil is olive brown with a significantly higher moisture content of 24.37%. The summit's topsoil is also brown colored with 5.77% moisture content while its subsoil is olive brown with significantly higher moisture content of 19.54%. Farm 2's topsoil from the foot slope is brown with 1.37% moisture content while the subsoil is olive brown with a higher moisture content of 11.91%. Both of the depths from shoulder of Farm 2 are olive brown but the topsoil has a slightly higher moisture content of 13.00% compared to the 12.03% of the subsoil. Lastly, the summit of Farm 2 has a gray topsoil with 14.09% moisture content while it has an olive subsoil with 9.70% moisture content (Table 2).

Gubat Pili Farms

The sampling areas for Gubat are foot slopes for Farm 1 while foot slope and summit for Farm 2 (Table 2). All of the sampling areas in different depths have low nitrogen, low phosphorous, and sufficient potassium. The sampled areas can be described as moderately acidic since most of these have 5.8 pH.

Most of the soil samples of Farm 1 is brown with the topsoil of the foot slope 2 as the exception having weak red coloration. The moisture content from different depths of the sampling areas are roughly on same level (22-24%).

Farm 2's topsoil from the foot slope is light olive brown with 14.49% mc and a gray subsoil with 14.12% mc. Its summit has a light reddish brown topsoil with 17.60% mc and a light olive brown subsoil with 12.97% mc (Table 2).

Prieto Diaz Pili Farms

Sampled areas for both farms are foot slopes and shoulders (Table 2). All sampled areas have low

Table 2. Initials

Acronym	Description
PF1	Pili Farm 1
PF2	Pili Farm 2
1PF1	Pili Farm 1 found at footslope 1
2PF1	Pili Farm 1 found at footslope 2

phosphorous, and sufficient potassium. Most of the sampled areas have low nitrogen except for the medium nitrogen of the topsoil of the shoulder of Farm 2. The areas sampled from different depths are mostly moderately acidic (5.8 pH).

The two farms selected have similar colors exhibiting gray coloration. The topsoil of foot slope of Farm 1 is gray with 14.42% mc while its subsoil is reddish grays with 17.78% mc. Its shoulder's topsoil is gray with 12.93% mc while the subsoil is light olive brown with a 20.49% mc (Table 2).

For Farm 2, all sampling areas from different depths are grayish brown. The topsoil of foot slope has 13.99% mc while the subsoil has 17.02% mc. For the shoulder, 13.53% mc was computed for the top soil and 19.50% mc for the subsoil.

Discussion

Topography/Relief of Pili farms among Municipalities

Relief or topography is defined as the elevation difference over a predetermined area or inferred length scale (Goudie, 2004). The overall relief or topography of the Pili farms selected are mountainous or hilly. These areas exhibit different slope positions as shown by the Hillslope-Profile Position (Figure 2).

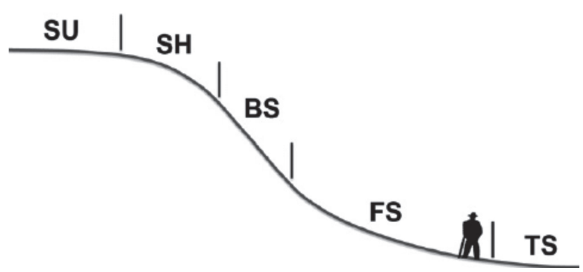

Fig. 2. Hillslope-Profile Position: SU-summit, SH-shoulder, BS-Back slope, FS-Foot slope, TS-Toe slope. (Wysocki *et al.*, 2000 and Schoeneberger *et al.*, 2012)

All of the four municipalities have Pili farms located at foot slopes. Resulting for it to have the highest frequency in terms of sampling areas (Figure 3). It is followed by summit then closely by shoulder and lastly by back slope. Only one farm from Irosin was found at a back slope. Bulusan and Prieto Diazhave farms located at the shoulder. Farms in Irosin, Bulusan, and Gubat were found at the summit.Based on the data gathered, the Pili trees in the selected areas naturally grow in sloping lands. However, it can be observed that the back slope

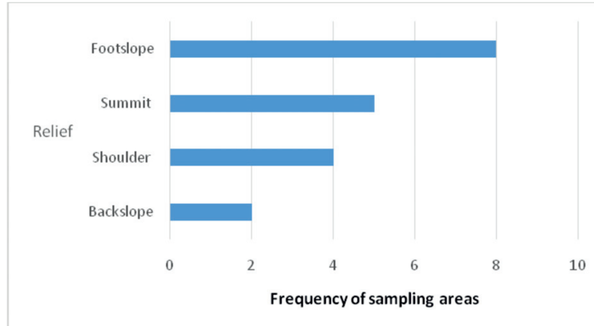

Fig. 3. Distribution of sampling areas based on relief.

which has the steepest slope among the positions has the least number of sampling areas. This can be attributed to the fact that these Pili trees are naturally grown which means that fruits that have fallen from trees will naturally settle and germinate in least sloping areas due to the action of gravity.

Moisture Content

Moisture content of soil is affected by a number of factors such as period of year when soil is gathered, depth of soil, soil texture, and topography of the land (Gwak, 2016). From Figure 4. Moisture content of soil from varying depth along the foot slopes is presented. For the topsoil, lowest moisture content of 1.37% was detected in Bulusan PF2 while the highest moisture content of 24.38% was from Gubat 2PF1. The topsoil has an average of 13.64% moisture along the foot slopes. For the subsoil, lowest moisture content of 9.26% was detected in Irosin PF1while the highest moisture content of 23.94% was from Gubat 1PF1. The subsoil has an average of 16.12% from the foot slopes. Moisture content was higher in the subsoils than in the topsoils along the foot slopes in most of the farms. Only in Gubat 2PF1 and Gubat PF2, where the topsoil has a higher mois-

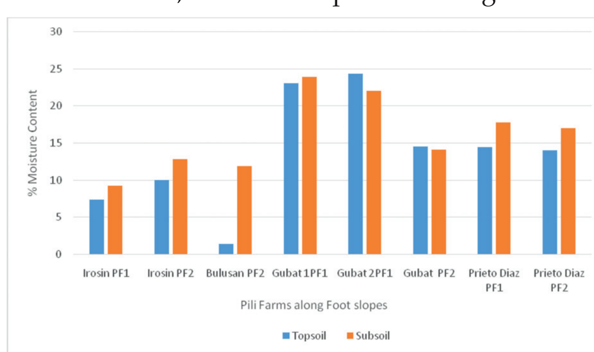

Fig. 4. Comparison of % moisture content between topsoil and subsoil from foot slopes

ture content but the difference is very minimal.

There were only two Pili sampling areas found along the back slope and these were both from Irosin (Table 2). The subsoil of Irosin PF1 is higher than its topsoil while the subsoil in Irosin PF2 is lower than its topsoil in moisture content. The topsoil can sometimes have same or higher moisture content with the subsoil when amount of clay particles are the same or drainage is similar across the soil horizons. Still on average, the subsoil has a higher moisture content equal to 12.3% compared to the 11.73% from the topsoil.

Figure 5 shows how moisture content vary between topsoil and subsoil in sampling areas along shoulders. Higher moisture content was observed in three out of four sampling areas namely Bulusan PF1, Prieto Diaz PF1, and Prieto Diaz PF2. Only Bulusan PF2 has higher moisture content in the topsoil compared to the subsoil which can be attributed to the difference in clay content and drainage at different depths.

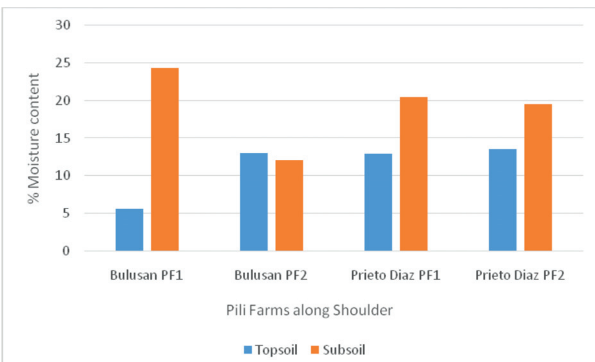

Fig. 5. Comparison of % moisture content between topsoil and subsoil from shoulder

Three out five sampling areas at the summit have higher moisture content in the topsoil than in the subsoil by an average of 4.96% (Figure 6). This could be the result of higher amount of clay from topsoil than in the subsoil. However, when taking the average of moisture content from all the sampling areas at the summit, the subsoil is almost the same amount as the topsoil.

The general characteristic of soil in an area is to have higher moisture content in the subsoil than in topsoil (Soils, Crops and Fertilizer Use: A Field Manual for Development Workers, 1986). This is due to the higher clay content in the subsoil transported from the topsoil (Adams *et al.,* 2015) and it is deeper than the topsoil preventing easy loss of water through evaporation. This soil characteristic was also evident in most of the sampling areas from the different Pili farms of the four municipalities. However using one-way ANOVA, at $\alpha = 0.05$, there was no significant difference in means of the moisture content between the topsoil and subsoil in all of the Pili farms (Appendix 5). When grouped by relief, there was also no significant difference in the means of moisture content in the Pili farms (Table 6). Significant difference among the means in the moisture content was only observed between municipalities at $\alpha = 0.05$ (Table 8) with Gubat as the highest while Irosin and Bulusan with least moisture content.

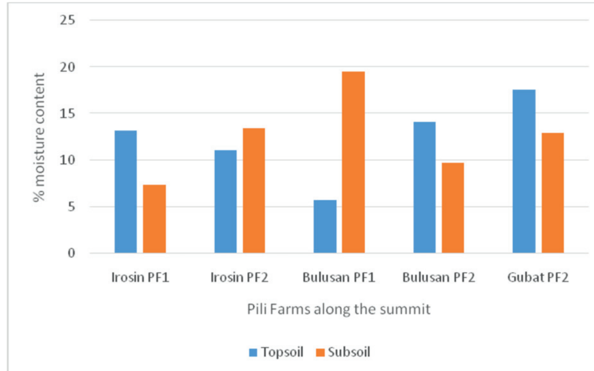

Fig. 6. Comparison of % moisture content between topsoil and subsoil from summit.

Moisture content ranged from 1.37% to 14.38% in the topsoils and from 7.33% to 24.37% in the subsoils from different landscape positions. The wide range of moisture content in the topsoil and subsoil is a primary indicator of differences in distribution of sand, silt, and clay (Gupta and Larson, 1979). Sandy soils tend to have lower moisture content and clayey soils tend to have higher (USDA, 1979). Other factors also affect moisture content such as the immediate weather conditions. In this result, the Pili farms exhibited dry to moderate moisture conditions and support the notion that Pili can thrive on wide range of soil type and over a wide range of climatic conditions in the locality (Coronel, 1996).

Soil Color

As shown in Figure 7, the most dominant color shown by topsoil was brown having 26% of the sampling sites (5 out of 19). It was followed by gray and grayish brown, both having 16%. Other colors are variations of brown. The dark color of the topsoil indicates high organic matter content derived from decaying plant matter and incorporation of other

Table 2. Summary of Soil Characteristics of Pili Farms from the four Municipalities

Municipality	Pili Farm Number	Location/ Description	Soil Depth A=0-20cm B= 20-40cm	Soil Color	Soil Moisture (%mc)	N	P	K	pH
IROSIN	Farm 1	Foot slope	A	10YR 3/6 Dark Yello wish Brown	7.38	Medium	Low	Sufficient	5.8
			B	2.5Y 4/4 Olive Brown	9.26	Medium	Low	Sufficient	5.8
		Back slope	A	7.5YR 4/3 Brown	9.94	Medium	Low	Sufficient	5.8
			B	2.5Y 4/4 Olive Brown	13.28	Medium	Low	Sufficient	5.8
		Summit	A	7.5YR 5/3 Brown	13.16	Medium	Low	Sufficient	5.8
			B	10YR 4/2 Dark Grayish Brown	7.33	Medium	Low	Sufficient	5.8
	Farm 2	Foot slope	A	7.5YR 6/4 Light Brown	9.97	Medium	Low	Sufficient	4.4
			B	10YR 5/3 Brown	12.82	Medium	Low	Sufficient	5.4
		Back slope	A	2.5Y 5/2 Grayish Brown	13.53	Medium	Low	Sufficient	5
			B	10YR 6/4 Light Yello wish Brown	11.32	Medium	Low	Sufficient	5
		Summit	A	10YR 6/3 Pale Brown	11.08	Medium	Low	Sufficient	5.4
			B	5Y 5/6 Olive	13.47	Medium	Low	Sufficient	5.4
BULUSAN	Farm 1	Shoulder	A	10YR 4/3 Brown	5.51	Medium	Low	Sufficient	6.0
			B	2.5Y 4/4 Olive Brown	24.37	Low	Low	Sufficient	4.4
		Summit	A	2.5Y 4/3 Olive Brown	5.77	Medium	Low	Sufficient	4.4
			B	2.5Y 4/3 Olive Brown	19.54	Low	Low	Sufficient	4.4
	Farm 2	Foot slope	A	7.5YR 5/2 Brown	1.37	Medium	Low	Sufficient	6.4
			B	2.5Y 5/3 Light Olive Brown	11.91	Medium	Low	Sufficient	7.2
		Shoulder	A	2.5Y 5/3 Light Olive Brown	13.00	Low	Low	Sufficient	6.0
			B	10YR 5/2 Light Olive Brown	12.03	Low	Low	Sufficient	6.0
		Summit	A	5YR 5/1 Gray	14.09	Medium	Low	Sufficient	5.8
			B	5Y 4/4 Olive	9.70	Low	Low	Sufficient	5.8

Table 2. *Continued ...*

Municipality	Pili Farm Number	Location/ Description	Soil Depth A=0-20cm B= 20-40cm	Soil Color	Soil Moisture (%mc)	N	P	K	pH
GUBAT	Farm 1	Foot slope 1	A	7.5YR 5/2 Brown	**30.47**	Low	Low	Sufficient	5.8
			B	7.5YR 5/2 Brown	**29.98**	Low	Low	Sufficient	5.8
		Foot slope 2	A	2.5YR 5/2 Weak Red	**30.01**	Low	Low	Sufficient	5.8
			B	7.5YR 5/3 Brown	**28.69**	Low	Low	Sufficient	5.8
	Farm 2	Foot slope	A	2.5Y 5/3 Light Olive Brown	**23.06**	Low	Low	Sufficient	5.4
			B	10YR 5/1 Gray	**21.25**	Low	Low	Sufficient	5.8
		Summit	A	5YR 6/4 Light Reddish Brown	**24.13**	Low	Low	Sufficient	5.8
			B	2.5Y 5/3 Light Olive Brown	**23.90**	Low	Low	Sufficient	5.4
PRIETO DIAZ	Farm 1	Foot slope	A	10YR 5/1 Gray	14.42	Low	Low	Sufficient	5.8
			B	5YR 5/2 Reddish Gray	17.78	Low	Low	Sufficient	5.4
		Shoulder	A	10YR 5/1 Gray	12.93	Low	Low	Sufficient	5.8
			B	2.5Y 5/3 Light Olive Brown	20.46	Low	Low	Sufficient	5.8
	Farm 2	Foot slope	A	10YR 5/2 Grayish Brown	13.99	Low	Low	Sufficient	5.4
			B	2.5Y 5/2 Grayish Brown	17.02	Low	Low	Sufficient	5.8
		Shoulder	A	2.5Y 5/2 Grayish Brown	13.52	Medium	Low	Sufficient	5.8
			B	2.5Y 5/2 Grayish Brown	19.50	Low	Low	Sufficient	5.8

organic matter in the soil (Meenakshi, 2012). Another factor that contributes to the color of soil is the parent material. Soils tend to become reddish or yellowish when oxidized ferric iron oxides are present (Jackson, 2008). Soil color also indicates its drainage. Brown and red colors of soil are most common in well drained soils while grayish coloration develops in poorly drained soils (Hillel, 2005).

Table 3. Moisture content of topsoil and subsoil summary

Groups	Count	Sum	Average	Variance
Top Soil	19	267.3207	14.06951	61.11621
Sub Soil	19	323.6026	17.03172	43.55922

In the subsoil, lighter color was observed as shown in Figure 8. Olive brown and light olive brown altogether constitutes 42% of the subsoil from all of the sampling sites (8 out of 19). It was followed by brown with 16%. Lighter color of soil was generally observed in the subsoil because of the lower organic matter content compared to the topsoil (Soils,

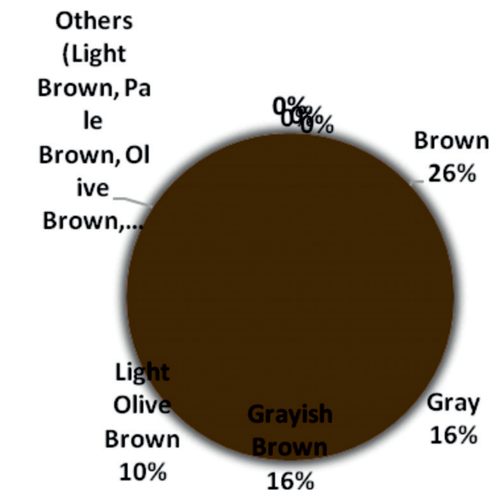

Fig. 7. Percentage distribution of soil color in the topsoil

Crops and Fertilizer Use: A Field Manual for Development Workers, 1986). The gray color in the subsoil can indicate poor aeration and drainage as a result of soil compaction.

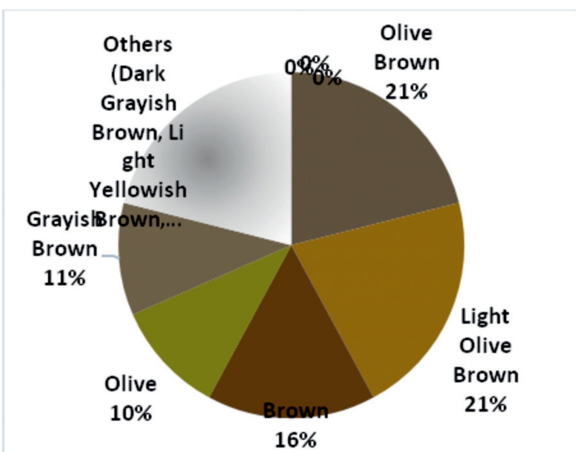

Fig. 8. Percentage distribution of soil color type in the subsoil.

Soil pH

Ten out of nineteen sampling areas hadpH of 5.8 in the topsoil indicating moderate acidity (Figure 9.) it was followed by pH of 5.4 with 3 sampling sites. All of the other pH were also acidic ranging from extremely acidic to slightly acidic. One of the causes of acidity of soil in the tropics is acidic deposition or whenacid rain is formed by excess presence of sulfur dioxide and oxides of nitrogen by reacting with rainwater (Mohajan, 2019). In addition, water increases the rate of decline of basic cations and increased concentration of aluminum in soil solution making the soil acidic. Soil acidity can also happen when plant residues decomposed to organic acids (Fageria and Nascente, 2014). Since the Pili Farms are mostly covered with decaying organic matter and are intercropped with other plants, acidity of soil is bound to increase.

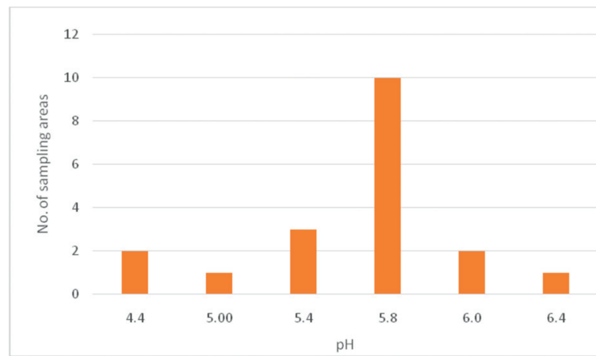

Fig. 9. Distribution of the sampling sites based on pH of topsoil.

For the subsoil, ten out of nineteen sampling areasalso had a pH of 5.8 indicating moderate acidity (Figure 10). It was followed by pH of 5.4 with four sampling areas. Most of the subsoil were acidic with one sampling area exhibiting very mild alkalinity. Commonly, subsoils have similar pH with the topsoil and can also be a bit more alkaline. However, From the ANOVA conducted, at á= 0.05, there was no significant difference in the ph level between top soil and sub soil in all municipalities (Table 10) as well as the pH level when grouped by relief (Table 12). Furthermore, there was also no significant difference in the pH level of soil between municipalities (Table 13).

Nitrogen, Phosphorous, Potassium

Using a soil test kit, the status of nitrogen, phospho-

Table 4. One way ANOVA of soil moisture content between topsoil and subsoil

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	83.35924	1	83.35924	1.592718	0.215054	4.113165
Within Groups	1884.158	36	52.33771			
Total	1967.517	37				

Table 5. Moisture content between reliefs summary

Groups	Count	Sum	Average	Variance
Footslope	16	279.3648	17.4603	80.89016
Shoulder	8	121.3287	15.16608	35.27951
Summit	10	142.1662	14.21662	41.2451
Backslope	4	48.06364	12.01591	2.898937

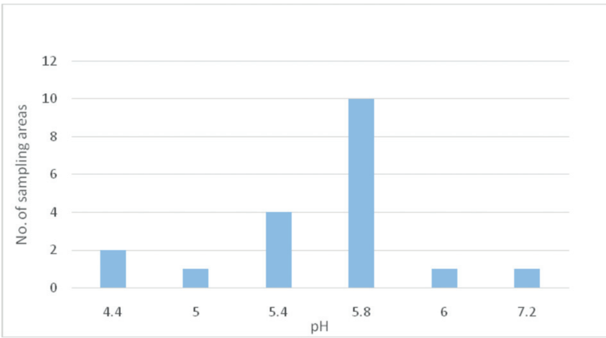

Fig. 10. Distribution of the sampling areas based on pH of subsoil

rous, and potassium from the 19 sampling areas from four municipalities were determined. Nitrogen is a macro element essential for plant growth specifically in the development of protein wherein it is a vital component (Shah Jahan *et al.,* 2016). For the topsoil, medium nitrogen was detected in 10 sampling areas while there are 8 sampling areas with low nitrogen (Figure 11). Nitrogen is one of the nutrients that is easily lost from the soil due to volatilization, leaching, and denitrification (Smil, 1999). These processes are accelerated by frequent and intense rainfall due to surface runoff and interflow (Wang *et al.,* 2019).

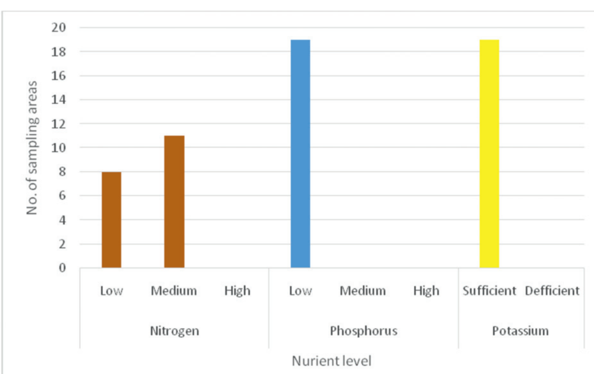

Fig. 11. NPK levels from the topsoil in all sampling areas

Table 7. Moisture content between municipalities summary

Groups	Count	Sum	Average	Variance
IROSIN	12	132.5067	11.04222	5.238494
BULUSAN	10	117.2957	11.72957	45.97011
GUBAT	8	211.4913	26.43642	13.80897
PRIETO DIAZ	8	129.6297	16.20371	8.310128

Phosphorus is an important nutrient responsible root development and early maturity of plants (Malhotra *et al.,* 2018). All sampling areas have low level of phosphorous. Although total soil phosphorus is generally high in soils, most of it is not readily available for plant uptake (Yadav *et al.,* 2012). And when they are available, they are easily lost through surface run-off which carries away soluble phosphorous. In addition, iron oxides which are predominant in tropical soils bind to phosphorous making it unavailable for plant uptake (Fink *et al.,* 2016).

Another vital nutrient is potassium which increases vigor and disease resistance of plants (Amtmann *et al.,* 2008). It also involved in other essential metabolic processes. From tests conducted, results show that all sampling areas have sufficient level of potassium. This could be attributed to the abundance of forest litter in all of the Pili farms. The biogeochemical weathering of litter deposited though annual cycles of litter fall in the forests results to the high levels of potassium in the soil solution and the exchangeable solution (Tripler *et al.,* 2006).

The predominant nitrogen level in the subsoil is low as detected in 12 sampling areas (Figure 12). Since the subsoil is less exposed to the atmosphere compared to the topsoil, this occurrence was observed. It is followed by medium level from seven sampling areas.

Similarly with the topsoil, all sampling areas have low phosphorous. Even if the moisture content of

Table 6. One way ANOVA of soil moisture content between reliefs

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	127.3053	3	42.43511	0.784037	0.511148	2.882604
Within Groups	1840.212	34	54.12387			
Total	1967.517	37				

Table 8. One way ANOVA of soil moisture content between municipalities

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1341.329	3	447.1096	24.27661	1.4E-08	2.882604
Within Groups	626.1882	34	18.4173			
Total	1967.517	37				

Table 9. pH between topsoil and subsoil summary

Groups	Count	Sum	Average	Variance
Top Soil	19	106.4	5.6	0.262222
Sub Soil	19	106.6	5.610526	0.362105

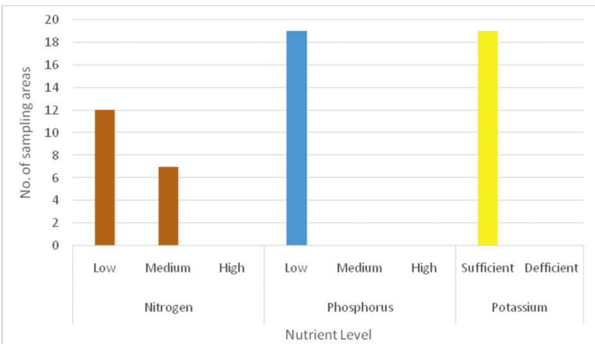

Fig. 12. NPK levels from the subsoil in all sampling areas.

subsoil is higher and less prone to surface run off, the predominant pH of soil is 5.8 which is below the 6.0-7.0 pH range for P availability.

The potassium level in the subsoil from all sampling areas are sufficient. This is the same with the topsoil since organic matter residues from forest litter and deep roots from trees are found in the subsoil.

The most significant result in the NPK levels of the sampling areas irrespective of depth is the low phosphorus and sufficient potassium. In addition, higher level of nitrogen are found in the topsoil. The sufficient level of potassium both in the topsoil and subsoil possibly plays a great role to why Pili trees thrive naturally in Sorsogon without application of inorganic fertilizers since it is involved in disease prevention, maintaining plant vigor, and fruit development.

Acknowledgement

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Table 10. One way ANOVA of pH between topsoil and subsoil

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.001053	1	0.001053	0.003372	0.954015	4.113165
Within Groups	11.23789	36	0.312164			
Total	11.23895	37				

Table 11. pH between reliefs summary

Groups	Count	Sum	Average	Variance
Footslope	16	91.8	5.7375	0.323833
Shoulder	6	34	5.666667	0.394667
Summit	10	54	5.4	0.311111
Backslope	4	21.6	5.4	0.213333

Table 12. One way ANOVA of pH between reliefs

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.888056	3	0.296019	0.922281	0.441188	2.90112
Within Groups	10.27083	32	0.320964			
Total	11.15889	35				

Table 13. One way ANOVA of pH between municipalities

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.444947	3	0.148316	0.46718	0.707104	2.882604
Within Groups	10.794	34	0.317471			
Total	11.23895	37				

least, the researchers would like to recognize the co-operation of all the Pili stakeholders namely the Provincial Government of Sorsogon under the leadership of Gov. Francis Escudero, the municipal agriculture offices, and most especially the Pili farmers and producers.

References

Adams, C. R., Bamford, K. M., Brook, J. and Early, M. P. 2015. *Principles of Horticulture.* London: Routledge, Taylor & Francis Group.

Adhikari, K., Owens, P., Ashworth, A.J., Sauer, T.J., Zamir, L., Richter, J. L. and Miller, D.M. 2019. Topographic Controls on Soil Nutrient Variations in a Silvopasture System. *Retrieved February.* 15 : 2020 from https://acsess.onlinelibrary.wiley.com/doi/10.2134/age2018.04.0008.

Adornado, H. and Yoshida, M. 2008. Crop Suitability and Soil Fertility Mapping using Geographic Information System. Retrieved February 15, 2020 from https://www.jstage.jst.go.jp/article/air/17/2/17_2_60/_pdf.

Altoveros, N.C. and Borromeo, T.H. 2007. Country Report on the State of Plant Genetic Resources for Food and Agriculture:Philippines. Retrieved February 10, 2020 from http://www.fao.org/3/i1500e/Philippines.pdf.

Amtmann, A., Troufflard, S. and Armengaud, P. 2008. The effect of potassium nutrition on pest and disease resistance in plants. *Physiologia Plantarum.* 133. 682-91. 10.1111/j.1399-3054.2008.01075.x.

Baleza, A. 2018. Scientific studies show 'tree of hope's' pharmaceuticals and cosmeceuticals potentials. Retrieved from http://bicol.da.gov.ph/rfo5newweb/scientific-studies-show-tree-of-hopes-pharmaceuticals-and-cosmeceuticals-potentials/

Brady, N.C. and Weil, R. 1990. *The Nature and Properties of Soils.* 15th edition. Retrieved February 14, 2020 from https://www.researchgate.net/publication/301200878_The_Nature_and_ Properties_of_ Soils_15th_edition.

Brye, KR. and Sherman, L.A. 2019. Soil Chemical Property Changes in Response to Long Term Pineapple Cultivation in Costa Rica. Retrieved February 15, 2020 from https://acsess.onlinelibrary.wiley.com/doi/10.2134/age2019.07.0052

Canarium ovatum Engl. (n.d.). Retrieved July 14, 2020, fromhttps://plants.usda.gov/core/profile?symbol=CAOV7.

Climate Projections for Provinces. (n.d.). Retrieved July 29, 2020, from https://www1.pagasa.dost.gov.ph/index.php/93-cad1/472-climate-projections

Coronel, R.E. 1996. Pili nut. Canarium ovatum Engl. Promoting the conservation and use of underutilized and neglected crops. 6. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy.

Exec. Order No. 13, 112, Vol. 64. No. 25 Fed. Reg. 99-3184. Page 6183-6186. (February 8, 1999).

Fageria, N. and Nascente, A. 2014. Management of Soil Acidity of South American Soils for Sustainable Crop Production. *Advances in Agronomy.* 129 : 221-275. https://doi.org/10.1016/B978-0-12-802139-2.00006-8.

Fink, J. R., Inda, A. V., Tiecher, T. and Barrón, V. 2016. Iron oxides and organic matter on soil phosphorus availability. *Ciência e Agrotecnologia.* 40(4) : 369–379. Doi:10.1590/1413-70542016404023016

Food and Agriculture Organization 1987. Soil Quality Considerations in the Selection of Sites for Aquaculture. Retrieved February 15, 2020 from http://www.fao.org/3/AC172E/AC172E00.htm#TOC.

Goudie, A. (2004). Encyclopedia of geomorphology: Volume 2: J-Z. London: Routledge.

Gwak, Y. and Kim, S. 2016. Factors affecting soil moisture spatial variability for a humid forest hillslope. *Hydrological Processes.* 31(2) : 431-445. doi:10.1002/hyp.11039

Gupta, S. C. and Larson, W. E. 1979. Estimating soil water retention characteristics from particle size distribution, organic matter percent, and bulk density. Water *Resources Research.* 15(6) : 1633–1635. doi:10.1029/wr015i006p01633

Hoiberg, D. H. ed. 2010. Sbaca". *Encyclopædia Britannica.* 1: A –AK Bayes (15th ed.). Chicago, Illinois: Encyclopædia Britannica Inc.

Hillel, D. 2005. *Encyclopedia of Soils in the Environment.* Amsterdam: Elsevier.

Jackson, R. S. 2008. *Wine Science: Principles and Applications, A volume in Food Science and Technology,* 3rd Edition.

Manalo, G. and West, A. 1949. Analysis and Composition of Manila Elemi. *The Philippine of Journal of Science.* 111-124.

Millena, C. G. and Sagum, R. S. 2018. Philippine Pili (Canarium ovatum, Engl.) varieties as source of essential minerals and trace elements in human nutrition. *Journal of Food Composition and Analysis.* 69 : 53–61. doi:10.1016/j.jfca.2018.02.008

Malhotra, H., Vandana, Harma, S. and Pandey, R. 2018. Phosphorus Nutrition: Plant Growth in Response to Deficiency and Excess. 10.1007/978-981-10-9044-8_7.

Meenakshi, P. 2012. *Elements of Environmental Science and Engineering.* New Delhi: Prentice-Hall of India.

Merriam-Webster. (n.d.). Endemic. In Merriam-Webster.com dictionary. Retrieved July 13, 2020, from https://www.merriam-webster.com/dictionary/endemic.

Mohajan, H. 2019. Acid Rain is a Local Environment Pollution but Global Concern. 3. 47-55. Retrieved July 9,2020 from https://www.researchgate.net/publication/330506420_Acid_Rain_is_a_Local_Environment_Pollution_but_Global_Concern.

Peace Corps. 1986. Soils, Crops and Fertilizer Use: A Field Manual for Development Workers.

PH National Tree: Narra. (n.d.). Retrieved July 14, 2020, from https://ncca.gov.ph/about-culture-and-arts/culture-profile/philippine-fast-facts/national-tree-narra/.

Pham, L. J. and Dumandan, N. G. 2015. Philippine Pili: Composition of the lipid molecular species. *Journal of Ethnic Foods.* 2(4) : 147–153. doi:10.1016/j.jef.2015.11.001

Philippine Statistics Authority. (2018). 2018 Commodity Fact Sheets. ISSN-2012-0427.

Philippine Statistics Authority. 2019. Countryside in Figures, Sorsogon, 2019 Edition. Retrieved July 15, 2020 fromhttp://rsso05.psa.gov.ph/sites/default/files/content/Sorsogon%202019%20 Countryside%20in%20%20Figures.pdf

Rajagopal, M. and Wiart, C. 2011. Canarium L. : A Phytochemical and Pharmacological Review. Journal of Pharmacy Research. *Journal of Pharmacy Research* 2011. 2482-2489.

Shah, J., Wahocho, N., Laghari, G., Laghari, A. and Bhabhan, G., Hussain Talpur, K. and Ahmed, T., Wahocho, S. and Lashari, A. 2016. Role of Nitrogen for Plant Growth and Development: A review. *Advances in Environmental Biology.* 10 : 209-218.

Thomson, L.A.J. 2006. Pterocarpus indicus (narra), ver. 2.1.In: Elevitch, C.R.(ed.). Species Profiles for PacificIsland Agroforestry. Permanent Agriculture Resources (PAR), Hôlualoa, Hawai75 ,"l?
i. <http://www.traditionaltree.org>.

Tripler, C. E., Kaushal, S. S., Likens, G. E. and Walter, M. T. 2006. Patterns in potassium dynamics in forest ecosystems. *Ecology Letters.* 9(4) : 451–466. https://doi.org/10.1111/j.1461-0248.2006.00891.x

USDA, Agricultural Research Service, National Plant Germplasm System. 2020. Germplasm Resources Information Network (GRIN-Taxonomy). National Germplasm Resources Laboratory, Beltsville, Maryland. Retrieved from https://npgsweb.ars-grin.gov/gringlobal/taxonomydetail.aspx?id=24742. Accessed 14, July 2020.

USDA, United States Bureau of Chemistry and Soils, United States. Bureau of Plant Industry, United States. Bureau of Plant Industry, Soils, and Agricultural Engineering, United States. Soil Conservation Service, United States. *Natural Resources Conservation Service.* (1979). Soil Survey, United States Bureau of Chemistry and Soils. Michigan.

Vogt, K. A., Patel-Weynand, T., Shelton, M., Vogt, D., Gordon, J., Mukumuto, C., Suntana, A. and Roads, P. 2012. Sustainability Unpacked: Food, Energy and Water for Resilient Environments and Societies. Routledge.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Smil, V. 1999. Nitrogen in crop production: An account of global flows. *Global Biogeochemical Cycles.* 13(2) : 647-662. doi:10.1029/1999gb900015

Yadav, R. S., Meena, S. C., Patel, S. I., Patel, K. I., Akhtar, M. S., Yadav, B. K. and Panwar, J. 2012. Bioavailability of Soil P for Plant Nutrition. *Farming for Food and Water Security*. 177–200. doi:10.1007/978-94-007-4500-1_8

Wang, S., Feng, X., Wang, Y., Zheng, Z., Li, T., He, S. and Lin, C. 2019. Characteristics of nitrogen loss in sloping farmland with purple soil in southwestern China during maize (*Zea mays* L.) growth stages. *Catena,182*, 104169. doi:10.1016/j.catena.2019.104169

Wood, F.A. and Roberts, George, A. F. 2005. Prance, Ghillean; Nesbitt, Mark (eds.). *The Cultural History of Plants.* New York, NY: Routledge.