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Soil quality assessment on coffee (*Coffea* spp.) farms in Pigtauranan, Bukidnon, Philippines

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Abstract. *Francisco JMS, Labajo JRN, Ebuna RM. 2022. Soil quality assessment on coffee (*Coffea *spp.) farms in Pigtauranan, Bukidnon, Philippines. Intl J Trop Drylands 6: 56-62.* A study was conducted from September to March 2019 with the following objectives: (i) to determine the physical and chemical properties of soil grown with coffee, (ii) to generate a soil nutrient map of the coffee farm; and (iii) to provide fertilizer recommendations based on the result of analysis of chemical properties. The following criteria for the selection of farm sites were: (i) 1-2 hectares of coffee farm area, (ii) 3-5 years of land use for coffee production; and (iii) the variety of the coffee grown is Robusta (*Coffea canephora* Pierre ex A.Froehner). Twenty-two (22) farms fit the criteria, and a survey questionnaire was disseminated to gather information. Soil samples were collected, and each was replicated and analyzed at the Soil and Plant Analysis Laboratory CMU. The coffee farms were identified as mostly medium acidic in their pH ranging from 5.6 to 6, marginal in organic matter (2.1 to 3.5%), very deficient in their extractable phosphorus (<9.0 mg dm^{-3}), and very high in exchangeable potassium (167.70 to 245.70 mg dm^{-3}). Most coffee farms were clayey soil texture, the water holding capacity was mostly 50-59%, and most bulk densities were categorized as ideal bulk density with values ranging from (1.0 to 1.3 Mg m^{-3}). The recommended rate of fertilizer were (0.030 to 0.115 g/tree) for Nitrogen, (0.165 to 0.500 g/tree) for Phosphorus, and (0 to 0.090 g/tree) for Potassium. The fertilizer rate of 16-20-0 and 18-46-0, and 0-0-60 will be used to satisfy the nutrient deficiency in the soil, and it is highly recommended to follow the correct application of fertilizer and apply an organic fertilizer to obtain good productivity and higher yield for the coffee farms, though this still needs further studies.

Keywords: Assessment, Bukidnon, *Coffea*, Pangantucan, physical-chemical properties, soil fertility mapping

INTRODUCTION

Coffee is one of the most important commercial crop-plant and the most widely traded commodity in the world. After cocoa, coffee is the second most important agricultural product for export (Núñez et al. 2011). The genus Coffea has several species of coffee plants. Still, the two most commonly grown species are *Coffea arabica* L. or the Arabica coffee and *Coffea canephora* Pierre ex A.Froehner or the Robusta coffee (Nelson 2011). Coffee is the most important non-alcoholic beverage in the world trade (Nair 2010). Aside from other products, many Bukidnon coffee brands are produced in the province's different municipalities.

Furthermore, the mission of the DTI concerning the coffee industry is to increase productivity and make it self-sufficient and globally competitive. To date, Bukidnon has 100 coffee farmers; most of them are indigenous community members. Bukidnon province has some 2,000 hectares of cultivated land for coffee, mostly in the highlands. In Bukidnon, the dominant coffee variety is Robusta, followed by Arabica (Sablad and Enerio 2017).

Soil plays an important role in our natural resources because it can produce food and fiber for humans. It maintains terrestrial ecosystems and serves as plant growth, a sink for heat, water, and chemicals, and a filter for water. In addition, it is the biological medium for the decomposition of wastes. Soil quality is defined as a specific kind of soil's capacity to sustain plant productivity. It comprises soil's physical, chemical, and biological properties (Zhan-Feng et al. 2006). Coffee trees are tolerated in a wide range, provided with deep and porous soils and well balanced for their texture. The ideal coffee can be grown in a fertile volcanic red earth, deep sandy loam, or lateritic soil (Titus and Pereira 2017). Coffee trees perform well in organic matter rich soil, producing a better leaf area to fruit ratio and better quality. Ideally, coffee is grown in moist, fertile, well-drained soil under a shaded canopy that receives a healthy dose of sunlight daily (DaMatta 2004; Mighty 2015). Those containing nitrogen and potassium are most predominant in the bean, usually followed by calcium, magnesium, phosphorus, and sulfur. The right balance of nutrients found in soil with good soil management improves bean quality. Cooler temperatures or higher altitudes produce bigger and better beans because it leads to slower photosynthesis, allowing the plant to metabolize nutrients gradually (Aprile 2015).

The health of the soil is the primary concern to farmers because their livelihoods depend on well-managed agriculture. However, one of the farmer’s problems is the poor bean type which will lead to low coffee yield affected by low nutrient availability, not being well managed and poor knowledge about the kind of soil or the ideal soil quality of the coffee farms. The main reservoir of mineral nutrients for plants is the soil. Therefore, good production needs good soil nutrients and fertility depending on a crop. Complex interactions of biological, chemical, and physical quantities take place in the soil in which all of these components and properties are included in the concept of soil quality. The chemical properties of the soil are the pH, organic matter, and cation exchange capacity, which are important factors in determining how well the crop will grow. The good quality of the soil and availability of nutrients in the soil requires special attention from the grower because it affects the bean size. Objectives of the Study: Evaluating the soil health in coffee farms since the soil quality cannot be measured directly, assessing the soil quality of the farms grown with coffee crops is important to measure and analyze. Specifically, the study aimed to answer the following objectives: (i) to determine the physical and chemical properties of some soil grown to coffee, (ii) to generate a soil nutrient map of the coffee farm; and (iii) to provide fertilizer recommendation to the soil grown to coffee based on the result of analysis of the soil pH, organic matter content, extractable phosphorus, and exchangeable potassium.

MATERIALS AND METHODS

Study area

The study was focused only on the assessment of physical and chemical properties of soil-grown coffee those with 1-2 hectares of coffee farm area, 3-5 years of land use for coffee production; and the variety of the coffee grown is Robusta (*C. canephora*) in Barangay Pigtauranan, Pangantucan, Bukidnon, Philippines.

Survey and farm selection procedure

A survey was conducted on the selected farms grown coffee (Coffea spp.) in Barangay Pigtauranan, Pangantucan, Bukidnon, Philippines (Figure 1). To ensure a manageable number of surveyed farms, the farmers that were selected possessed the following criteria: (i) 1-2 hectares of coffee farm area, (ii) 3-5 years of land use for coffee production; and (iii) the variety of the coffee grown is Robusta (*C. canephora*).

Collection, preparation, and analysis of soil sample

The owner of the farms was interviewed first using the questionnaire that was given. After the interview, the soil samples to a depth of 40-60 cm were collected from the farmer's field covered in the survey. The collected samples were air dried and pulverized using a screen or 2 mm sieve and then it was stored in plastic jars for the determination of the physical and chemical properties of the soil. Analysis was performed at the Soil and Plant Analysis Laboratory, Department of Soil Science, College of Agriculture, Central Mindanao University, University Town, Musuan, Maramag, Bukidnon, Philippines. Methods used in the Analyses of Soil's Physical and Chemical properties are presented in Table 2. The sampled area is presented in Figure 2.

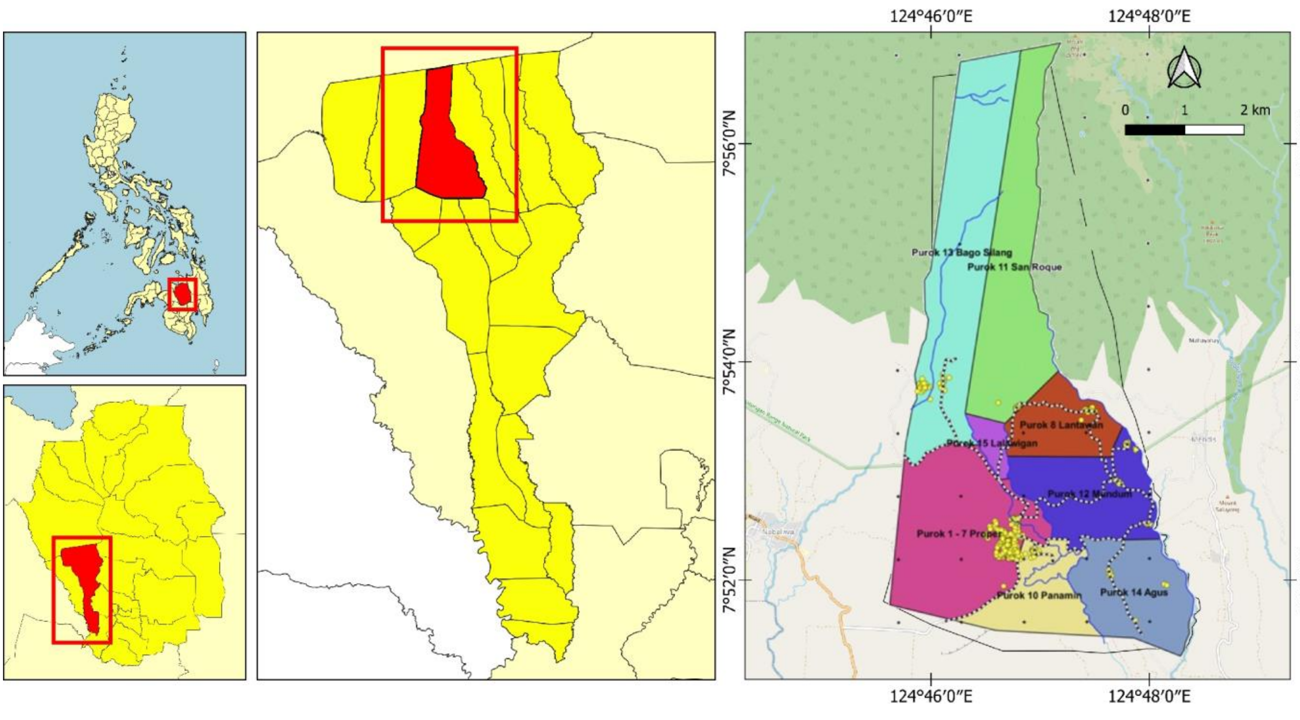

Figure 1. Location map of the study Barangay Pigtauranan, Pangantucan, Bukidnon, Philippines

Table 1. Soil test values and a nutrient recommendation rate of coffee (kg/tree)

Category	Recommended Rate (kg/tree)												
	Organic matter, (%) Nitrogen, kg/tree				Phosphorus (mg dm^{-3}) P_2O_5, kg/tree					Potassium (mg dm^{-3}) K_2O, kg/tree			
Soil test values	0-2	2.1-3.5	3.6-4.5	>4.5	0.9	10-15	16-22	23-30	>30	0-35	36-55	56-75	>75
New plant	0.003	0.002	0.001	0.000	0.004	0.003	0.002	0.001	0	0.003	0.002	0.001	0
1 year old	0.04	0.025	0.015	0.010	0.115	0.070	0.040	0.010	0	0.045	0.030	0.012	0
2 year old	0.055	0.035	0.020	0.015	0.125	0.075	0.045	0.020	0	0.048	0.032	0.018	0
3 year old	0.070	0.040	0.025	0.020	0.135	0.085	0.050	0.025	0	0.060	0.040	0.270	0
4 year old	0.085	0.050	0.030	0.025	0.500	0.095	0.055	0.025	0	0.075	0.050	0.030	0
5 year old	0.115	0.070	0.045	0.030	0.165	0.105	0.060	0.030	0	0.090	0.060	0.045	0
6-10 years old	0.160	0.100	0.070	0.050	0.130	0.080	0.045	0.020	0	0.390	0.120	0.060	0
11-15 years old	0.230	0.145	0.090	0.070	0.145	0.090	0.050	0.025	0	0.450	0.300	0.090	0
>15 years old	0.165	0.100	0.070	0.050	0.100	0.065	0.040	0.020	0	0.300	0.200	0.060	0

Note: PCARRD (1991)

Table 2. Methods used in the analysis of the physical and chemical properties of soil

Property	Methods of analysis	Reference
Physical properties		
Soil texture	Pipette method	PCARRD (1991)
Water holding capacity	Wire gauze method	Lal and Shukla (2004)
Bulk density	Core method	Blake (1965)
Chemical properties		
Soil pH	Potentiometric method (1:5 soil water ratio)	Biddle (1997)
Organic matter content	Walkley-Black method	FAO GLOSOLAN (2020)
Extractable phosphorus	BrayP$_2$ (o.1N HCl + 0.03N NH_4F)	Landon (1984)
Exchangeable potassium	1N NH_4OAc extraction/Flame photometer	Landon (1984)
Lime requirement	Veitch Method	Hoskins (1997)

Procedures

Preparation of soil physical and chemical fertility map

Generating the soil fertility map of each coffee farm in Pigtauranan, Pangantucan, Bukidnon was the first to be categorized using the soil test values for pH, exchangeable phosphorus, and extractable potassium (Hoskins 1997), and soil organic matter soil test values of PCARRD (1991) and was assigned with designated color for identification as presented in Figure 2. The soil fertility map of pH, organic matter content, extractable phosphorus, and exchangeable potassium was mapped and generated using ArcGIS software by Esri.

Computation for fertilizer and lime recommendations

Fertilizer recommendations are computed using the nutrient recommendation rate developed by PCARRD (1991) for coffee in the Philippines, presented in Table 1. Soil test values are the result of the conducted soil chemical analysis of OM, extractable phosphorus, and exchangeable potassium and matched with the recommended rate of fertilizer per coffee tree at a different age to derive the amount of fertilizer recommended per tree. The lime recommendation was based on the result of the Veitch method (Hoskins 1997) with the amount of lime on the x-axis and pH on the y-axis and was computed based on the desired pH for coffee which is 5.5.

RESULTS AND DISCUSSION

Soil chemical properties

The soil pH value of coffee farms in Barangay Pigtauranan, Pangantucan, Bukidnon is shown in Table 3. Six (6) coffee farms (27.27%) were characterized as strongly acidic, having a soil pH value of 5.1 to 5.5. Twelve (12) coffee farms (54.54%) were categorized as medium acidic, having a soil pH value of 5.6 to 6.0. Meanwhile, there were only three (3) coffee farms (13.64%) identified as slightly acidic, where the pH values ranged from 6.1-6.9, and only one (1) coffee farm was categorized as neutral, having a soil pH value of 7.0 (4.54%). Therefore, it was observed that most of the coffee farms in Barangay Pigtauranan fell on medium acidic, where according to (PCARRD 1991), the soil pH requirement of coffee ranges from 5.5-to 7.0. Based on the result, most coffee farms were suited for their production.

The percent organic matter of the coffee farms was identified as deficient in the organic matter having a value of <2.0% or five (5) of the coffee farms (22.73%). Ten (10) coffee farms (45.45%) fell on a marginal amount of organic matter having a value of 2.1 to 3.5%, five (5) categorized (22.73%) on the adequate amount with a value of 3.6 to 4.5%, and only two (2) had a highly adequate amount of organic matter having a value of >4.5% (9.09%). Based on the results, most of the coffee farms in Barangay

Pigtauranan were categorized as marginal because most farmers applied organic fertilizer to their coffee farms.

Table 3 also shows that all twenty-two (22) coffee were deficient in extractable phosphorus, with twenty-one (21) coffee farms (95.45%) recognized as very deficient in phosphorus content having <9.0 mg dm^{-3} and one (1) or 4.55% with deficient status which is 10-15 mg dm^{-3} (PCARRD 1991). Based on the results, extractable phosphorus of the coffee farms was very low because only a few farmers applied complete fertilizer and phosphorus-containing fertilizer to their farms; thus, farms were recommended to apply phosphorus-containing fertilizer to satisfy the said nutrient in the soil. According to Sage (2014), phosphorus will provide the coffee trees' roots and bearing wood development, early berry maturity, and increase the bean's density.

The exchangeable potassium content of coffee was Six (6) coffee farms (27.27%) identified as low in exchangeable potassium with a value of <74.10 mg dm^{-3}, as well as in the medium category having a value of 0.19-0.29 cmol kg-1. On the other hand, two (2) of the coffee farms (9.09%) were categorized as high in exchangeable potassium with a value of 0.29-0.38 mg dm^{-3}, and eight (8) or 36.36% of the farms fell into the category of very high in exchangeable potassium, with a value of >148.20 mg dm^{-3} (PCARRD 1991). Based on the results, most coffee farms in Barangay Pigtauranan had high exchangeable potassium. In contrast, other farms were still recommended to apply potassium-containing fertilizer to obtain enough potassium for berry development and for the crop to grow efficiently (Sage 2014). This is because; most farmers used potassium-containing fertilizer on their farms, such as muriate of potash. The result of the soil's chemical properties was presented in the fertility map presented in Figure 2.

The productivity of coffee production is affected by soil and environmental factors, in which soil pH is the biggest factor in determining the availability of the soil's chemical nutrients. Strongly acidic soil conditions may limit the availability of phosphorus and potassium; thus, excessive application of inorganic fertilizer without the knowledge of the right amount and the right timing of the application may contribute to soil acidification. Between July 2008 and June 2009, (Saroj and Dilip 2014) worked on the investigation of physicochemical factors such as pH, specific conductivity, chloride, total alkalinity, calcium, magnesium nitrate, sulfate, phosphate sodium, and potassium. Several characteristics fluctuated for the research year. The soil was alkaline throughout the research year, according to the findings. The quality of the soil determines an ecosystem's productivity. Some metrics were over the allowed range, while others were below it, affecting pond soil quality and productivity. Several factors influence the number of plant nutrients required by coffee trees. These include seasonal change, terrain, soil type, and dominant cultural techniques; the amount and distribution of rainfall; the species and number of other plants planted in combination with the coffee trees; because it impacts bean size (grade), bean quality, and the overall productivity of the crop, which determines marketability, proper coffee nutrition demands specific attention from the grower. Nutrients are given to replace those lost due to tissue formation, yields, leaching, and substances that are difficult to obtain by roots (Melke and Ittana 2015).

Soil physical properties

Table 3 shows the bulk density of selected coffee farms in Pigtauranan, Pangantucan, Bukidnon. Five (5) of the farms were categorized as very loose, which has a value of <1.0 Mg m^{-3} (22.73%). There were sixteen (16) categorized as ideal soil (72.73%), with a value of 1.0-1.3 Mg m^{-3}. Only one (1) farm falls on compacted bulk density (4.54%), with a value of >1.3 Mg m^{-3}, which is expected to restrict root growth, and poor movement of air and water through the soil. Due to the very loose and compact soil, it was not expected to obtain a higher yield for the farm. In a similar study conducted by Labajo and Pabiona (2022), most of the soil in Mt. Nebo, Valencia City, Bukidnon planted with sugarcane has bulk density values ranging from 1.0 Mg m^{-3} to 1.3 Mg m^{-3}, which is the ideal bulk density for growing crops, because it is not too loose and compacted.

The soil texture of the selected coffee farms. Twenty-one (21) among the farms were classified as clayey (95.45%), while only one (1) or 4.55% coffee farm was identified as clay loam. Most coffee farms were identified as clayey soil, in which coffee soil needs deep and porous soils and is well balanced for their texture. Since it influences nutrient and water retention, the soil texture will also affect the yield (Titus and Pereira 2017). Clayey soil texture holds very much water when wet and is highly compacted when dry. Application of organic manures and organic fertilizer increase soil aggregation and improves soil structure, thus influencing water holding capacity

The water holding capacity of selected coffee farms, out of twenty-two farmers, eleven (11) or 50% of which can hold water for about 50-59%, in which organisms suffered from dryness. The other eleven (11) farms (50%) can hold water for about 60-80%, which is the normal field soil that corresponds to optimal biological activity for water holding capacity.

In a similar study conducted in Krakow, Poland, by Kormanek et al. (2015), the results demonstrate that most of the growth characteristics of the studied seedlings were considerably impacted by the change in dry bulk density soil. The length and dry bulk of the root system showed particularly strong negative relationships. It was shown that the dry bulk density variant substantially impacted all of the growth characteristics of Scots pine seedlings and a few characteristics of European beech. Obviously, an increase in soil bulk density also contributed to a decline in the quality of European beech seedlings. Reichert et al. (2009) also concluded that the bulk density is highly correlated to the clay content, and soil ecological properties are affected before compaction restricts plant growth and yield.

Table 3. Physical and chemical properties of the soil in the selected coffee farms in Pigtauranan, Pangantucan, Bukidnon, Philippines

Farm code	Soil pH	% OM	Exchangeable phosphorus mg dm^{-3}	Extractable potassium mg dm^{-3}	Bulk density mg m^{-3}	Water holding capacity, %	Soil texture class
F1	5.92	2.19	3.26	245.70	1.22	53.17	Clayey
F2	5.70	5.81	6.87	62.40	0.93	68.60	Clayey
F3	5.46	2.36	2.57	167.70	0.83	54.95	Clayey
F4	5.28	4.88	13.29	89.70	1.09	58.71	Clayey
F5	5.48	4.21	6.93	136.50	1.12	59.33	Clayey
F6	5.63	1.85	1.39	183.30	1.19	60.35	Clayey
F7	5.60	3.28	2.17	101.40	1.11	61.20	Clayey
F8	5.45	2.69	2.43	187.20	1.12	58.84	Clayey
F9	5.32	3.62	3.83	105.30	0.97	65.38	Clayey
F10	6.31	4.12	6.35	214.50	0.97	72.38	Clay Loam
F11	6.28	2.78	6.59	237.90	1.19	60.05	Clayey
F12	5.90	4.38	2.19	191.10	1.25	50.63	Clayey
F13	6.00	1.85	0.85	136.50	0.93	66.56	Clayey
F14	5.64	2.69	1.24	54.60	1.07	62.25	Clayey
F15	5.80	0.76	0.99	50.70	1.20	55.30	Clayey
F16	5.74	1.60	1.06	245.70	1.18	70.77	Clayey
F17	5.49	2.61	0.96	93.60	1.06	57.13	Clayey
F18	5.87	3.62	1.66	78.00	1.11	65.68	Clayey
F19	5.60	1.60	3.37	74.10	1.05	66.68	Clayey
F20	6.02	2.19	1.47	39.00	1.15	54.58	Clayey
F21	7.04	3.53	1.85	31.20	1.13	50.16	Clayey
F22	5.66	3.45	2.09	35.10	1.31	54.28	Clayey

Table 4. Fertilizer recommendation of coffee farms in Pigtauranan, Pangantucan, Bukidnon, Philippines

Farmers code	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Lime recommendation (mg ha^{-1})
F1	140	400	200	6.28
F2	110	300	200	6.27
F3	140	200	200	6.46
F4	80	400	200	4.71
F5	80	200	200	1.84
F6	80	400	200	3.96
F7	140	200	200	1.87
F8	80	400	200	3.57
F9	200	200	200	4.51
F10	110	500	200	3.68
F11	110	300	200	1.64
F12	110	400	170	6.96
F13	110	400	200	4.64
F14	140	400	200	3.29
F15	170	400	200	5.99
F16	80	400	200	5.95
F17	170	300	170	3.62
F18	140	400	200	4.46
F19	110	400	200	8.68
F20	110	400	200	4.79
F21	80	400	200	2.14
F22	110	400	200	4.34

Fertilizer recommendation

The fertilizer recommendation of coffee farms in Barangay Pigtauranan, Pangantucan, Bukidnon is presented in Table 4. There were fourteen (14) different sets of recommendation rates distributed on different coffee farms. The nitrogen recommendation ranges from 0.03-0.115 kg/tree, and the phosphorus recommendation ranges from 0.165-0.500 kg/tree, which needs 0.825 kg/tree of ammonium phosphate (16-20-0), while other farms are recommended to use the 0.207-1.090 kg/tree of diammonium phosphate (18-46-0) to satisfy the recommended rate in a lower amount. The potassium recommendation ranges from 0-0.09 kg/tree, which needs to apply 0.083-0.150 kg/tree of muriate of potash (0-0-60). The lime recommendation was computed based on the result of the Veitch method analysis of soil with the amount of lime on the x-axis and pH on the y-axis on the desired pH for coffee which is 5.5. Therefore, twelve (22) sets of lime recommendations were distributed on different coffee farms in Pigtauranan, Pangantucan, Bukidnon, Philippines.

A similar study was conducted in Oromia Region, Ethiopia, by Chimdi et al. (2012); soil acidity is one of the major limiting factors to acid-sensitive crop production in the western areas of the Oromia Region, Ethiopia. Soil acidity is one of the main problems restricting the cultivation of acid-sensitive crops. Increasing lime rates for both lime particle sizes raised soil pH, and exchangeable bases reduces the magnitude of soil acidity, exchangeable acidity, and Al saturation. The acid saturation percentage significantly decreased when 10 Mg ha-1 of lime was given to the soil. This resulted in lower soil acidity, which raised the pH and accessible P in the soils.

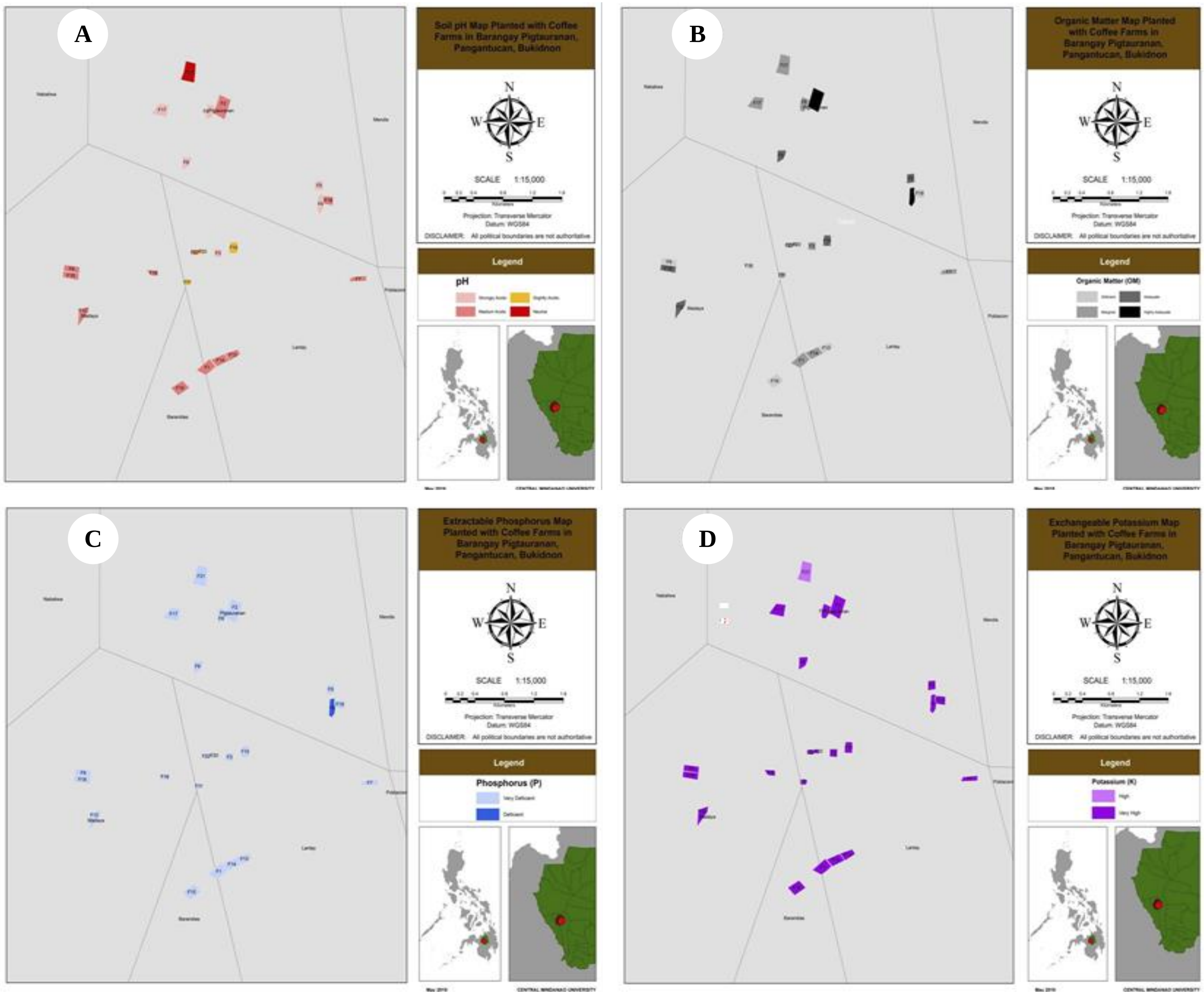

Figure 2. Soil chemical fertility map of selected coffee farms in Pigtauranan, Pangantucan, Bukidnon, Philippines: A. Soil pH, B. Organic matter content, C. Exchangeable phosphorus, D. Extractable potassium

In conclusion the soil quality of the farms grown coffee crops must be measured and analyzed since the soil quality cannot be measured directly. The soil chemical properties of the coffee farms were analyzed, such as pH, in which, among the 22 farms, most of them (54.54%) were categorized as medium acidic, having a value of 5.6-6.0. The organic matter content of coffee farms was mostly categorized as marginal, with a range of 2.1-3.5 (45.45%). The extractable phosphorus of the coffee farms was very deficient with a value of <9.0 mg dm^{-3} (95.45%), and the exchangeable potassium was categorized as very high with a value of >148.20 mg dm^{-3} (36.36%). The soil's physical properties in most coffee farms were categorized as clayey in soil texture (95.45%), holding the water with a capacity of 50-59% (50%), then the bulk density was categorized as ideal soil (72.73%) which have a value of 1.0-1.3 Mg m^{-3}. There were 14 different sets of recommendation rates distributed in different coffee farms derived from the analysis. The NPK recommendation was 0.03-0.115 kg/tree N, 0.165-0.500 kg/tree P, and 0-0.09 kg/tree K. It is recommended that selected coffee farms need to apply fertilizer to satisfy the nutrient deficiency in the soil; however, it is highly recommended to apply organic fertilizer since based on the analysis of the correlation between soil parameters and the yield, organic matter content is the only factor that can sustain good productivity and higher yield for the coffee farms, which still needs further studies.

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