ASIAN JOURNAL OF AGRICULTURE
Volume 6, Number 2, December 2022
Pages: 79-86
E-ISSN: 2580-4537
DOI: 10.13057/asianjagric/g060204

Physical and chemical properties of soil on selected sugarcane farms in Mt. Nebo, Valencia City, Bukidnon, Philippines

JOHN REY N. LABAJO[1], MYRNA G. PABIONA[2,♥]
[1]Soil and Plant Analysis Laboratory, Central Mindanao University. University Town, Musuan, Maramag, Bukidnon, Philippines
[2]Department of Soil Science, College of Agriculture, Central Mindanao University. University Town, Musuan, Maramag, Bukidnon, Philippines.
Tel.: +63-88-356-1910, ♥email: johnreylabajo7@gmail.com

Manuscript received: 26 March 2022. Revision accepted: 17 July 2022.

Abstract. *Labajo JRN, Pabiona MG. 2022. Physical and chemical properties of soil on selected sugarcane farms in Mt. Nebo, Valencia City, Bukidnon, Philippines. Asian J Agric 6: 79-86.* The study was conducted to determine soil's physical and chemical properties on selected sugarcane farms in Mt. Nebo, Valencia City, Bukidnon, Philippines. Soil samples were collected from 24 different sugarcane farms planted with sugarcane following Sloven's Formula for farm selection. Soil samples were collected from August 2018 to April 2019, and the physical and chemical properties of the soil were determined at SPAL, CMU, Musuan, Maramag, Bukidnon, Philippines. Soil texture and percent Water Holding Capacity (%WHC) soil of the sugarcane farms were clayey textured, with %WHC ranging from 54.24-76.30% and bulk Density (BD) and Particle Density (PD) values ranging from 1.05-1.31 Mg m^{-3} (BD) and 2.28-2.41 Mg m^{-3}, which is ideal for growing sugarcane. Soil samples collected were categorized as medium acidic, marginal in soil organic matter content (SOMC), extractable phosphorus (P) was very deficient, and low on exchangeable potassium (K). That implies these sugarcane farms need soil amendments to meet sugarcane's desired nutrient and pH requirements. Therefore, the sugarcane farms in Mt. Nebo, Valencia City, Bukidnon are required to apply 1.64-7.04 Mg ha^{-1} of lime and a recommendation rate of 80-200 kg ha^{-1} Nitrogen (N), 200-500 kg ha^{-1} of Phosphorus (P), and 170-200 kg ha^{-1} potassium (K). Moreover, a soil fertility map is necessary to classify and group the delineated soils into map units and capture soil property information to interpret and depict soil spatial distribution on a map.

Keywords: Assessment, Bukidnon, physical-chemical properties, *Saccharum officinarum*, soil mapping, Valencia City

Abbreviations: BD: Bulk Density, PD: Particle Density, SMOC: Soil Organic Matter Content, WHC: Water Holding Capacity

INTRODUCTION

The soil's physical and chemical characteristics regulate the number of nutrients available to plants. Their relevance in nutrient supply to crops must be regularly checked for long-term development and increased crop production to achieve optimal crop production (Suleiman et al. 2017). Soil nutrient availability is the adequacy with which soil supplies the plant needed nutrients. With the complex availability of the nutrient and incompletely understood, plant response remains the only reliable basis for diagnosing nutrient deficiencies. To maintain the sustainability of sugarcane production, soil management practices that can increase soil fertility and quality should be employed (Wakgari et al. 2020; Abdullah et al. 2022). Sugarcane (*Saccharum officinarum* L.) belongs to the family Gramineae and is a raw material for everyday use in sugar and bioethanol production. Like most crops, they cannot grow without the important natural resources, soil, and water. As a medium for plant growth, the soil must be properly managed to attain a higher production yield.

To understand the growth requirement of sugarcane and how to achieve the desired yield, the soil's chemical and physical properties must be considered. Fertile soil is critical to our ability to achieve food security, but inadequate management exacerbates soil degradation (such as acidification). Liming affects all soil elements, resulting in several simultaneous changes in soil processes that affect plant nutrient uptake (Holland et al. 2018). The application has benefited humans for centuries in ameliorating acidic soil conditions. One of the major keys to food security for future food production is healthy soil for the plant to grow. The efficient use of inorganic and organic fertilizers is the most important aspect of a sustainable agriculture farming system. Ensuring the health of the soil and correct agricultural practices and preventing the loss and damage to the soil, correct fertilizer management of 4R Principles (right source, right rate, right time, and right place), nutrient stewardship, increased crop production, and sustainable farming will be achieved.

The rising soil erosions, land degradation, and nutrient depletion in the Philippines are problems to the region, with yearly visits by typhoons and hurricanes a serious threat to the agriculture sector in the country. The soil nutrient maps and physical property maps are effective strategies for ensuring precise evaluation of the area. The development of maps is crucial in site-specific soil physical and chemical management for sustainable agricultural practices (Verma et al. 2018).

The Philippines is a sugar-producing country, growing mainly on the Island of Negros, Western Visayas, Bukidnon in Northern Mindanao, and the CALABARZON Region (PSA 2019). Although in Northern Mindanao, sugarcane can only be found in Bukidnon, the sugar industry in the province formally started in 1975 when it was discovered that Bukidnon's wide lands are suitable for sugarcane. Recently its contribution to the national production was 3,068,055 metric Mg in 2018. This study was conducted with the following objectives: (i) to determine the chemical and physical properties of soil on selected sugarcane farms in Mt. Nebo, Valencia City, Bukidnon; (ii) to formulate lime and fertilizer recommendations based on the data gathered and results of analysis; and (iii) to generate nutrient fertility map based on soil pH, soil organic matter content, extractable phosphorus, and exchangeable potassium.

MATERIALS AND METHODS

Study area

The soil quality assessment was conducted in Mt. Nebo, Valencia City, Bukidnon, on the Island of Mindanao, Philippines (Figure 1). With an altitude of 896.5 meters above sea level, located at the foot of Mt Kalatungan Range. Its latitude is 7.9728, 124.9866 (7°58' North, longitude 124°59' East), which has a diversity of plantation crops and is identified as adtuyon clay soil series.

Survey and farm selection procedure

Each sugarcane farm in Mt. Nebo, Valencia City, Bukidnon had an equal probability of being selected in the sampling selection. Due to the numerous sugarcane farms, a survey questionnaire was formulated and distributed to the farmers, including interviews done during the study. Sloven's formula was used to secure a randomly selected sugarcane farm. The following criteria were imposed to minimize the number of farmers. (i) The farmer must have at least 1.5-4 ha of sugarcane farm; (ii) must have at least five years of sugarcane operation; and (iii) did not practice burning sugarcane residue. If one of the farmers cannot meet at least two of the following criteria, the farm will be disregarded for being part of the study.

$n = N/(1+Ne^2)$

Where: n = sample size, N = population size, e = margin of error

Given: N = 26 total number of sugarcane farms fit the criteria

$e = 0.05$ or 5%

$n = 26/(1+26x0.05^2)$

Furthermore, a total number of 24 sugarcane farms from the 26 sugarcane farms fits the criteria used for the survey.

Collection and preparation of soil sample

A survey questionnaire was provided to the randomly selected farmer in the area. The area was inspected first, and the land feature, coordinates, and farmer's profiles were collected before sampling the area for analysis. The was collected in a zigzag pattern, with a composite sample of 15-20 per area with a 10-15cm soil depth. Soil samples were air-dried and pulverized. Then sieved and stored in a clean plastic container.

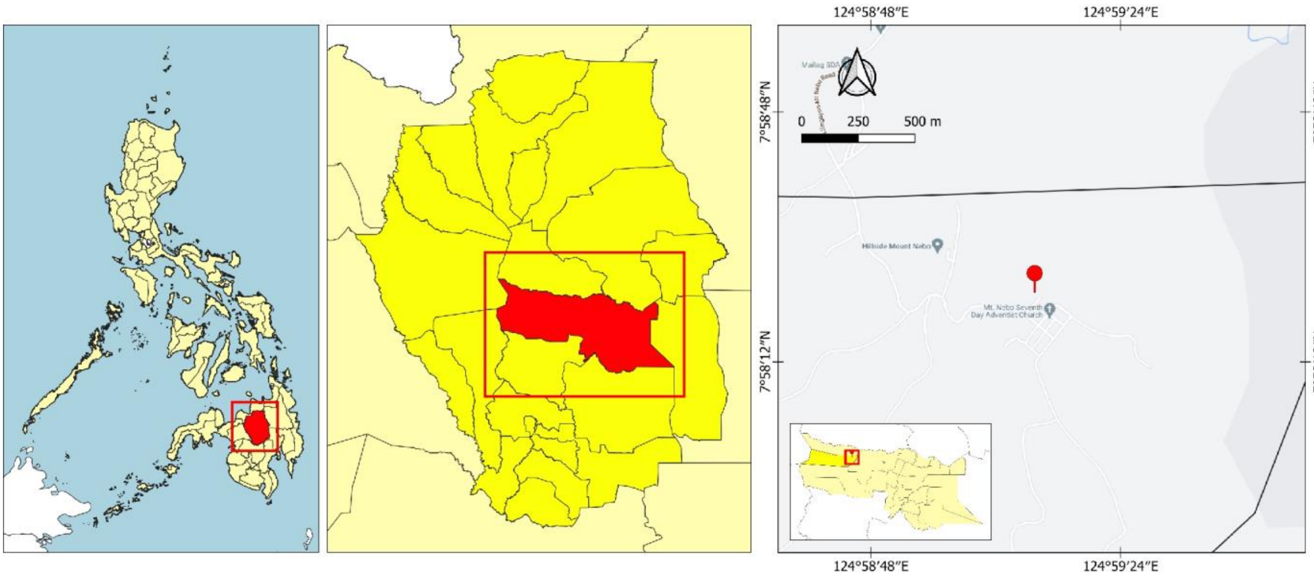

Figure 1. Location map of Mt. Nebo, Valencia City, Bukidnon, Philippines

Table 1. Soil test values and a nutrient recommendation rate of sugarcane

Category	Soil test values			Recommendation (kg ha^{-1})		
	% Nitrogen	Phosphorus (ppm)	Potassium (ppm)	N	P_2O_5	K_2O
Very Low	<0.05	<5	<25	200	200	600
Low	0.05-0.09	5-9	25-49	170	170	500
Medium Low	0.10-0.14	10-14	50-74	140	140	400
Average	0.15-0.19	15-19	75-99	110	110	300
Medium High	0.20-0.24	20-24	100-124	80	80	200
High	0.25-0.29	25-29	125-149	40	40	100
Very High	>0.29	>29	>149	20	20	50

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)
Particle Density	Pycnometer 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	BrayP2 (o.1N HCl + 0.03N NH_4F)	(Landon 1984)
Exchangeable Potassium	1 N NH_4OAc extraction/Flame photometer	(Landon 1984)
Lime Requirement	Veitch Method	(Hoskins 1997)

Preparation of soil physical and chemical fertility map

Mapping of each sugarcane farm in Mt. Nebo, Valencia City, Bukidnon was the first to categorize using the soil test values for pH, exchangeable phosphorus, and extractable potassium (Hoskins 1997). Also, tests for soil organic matter and soil text values of PCARRD (1991) were assigned with designated colors for identification, as presented in Figure 2. The development of soil fertility, soil texture, pH, organic matter content, extractable phosphorus, and exchangeable potassium was mapped using ArcGIS software by Esri.

Computation for fertilizer and lime recommendations

The fertilizer recommendation of sugarcane was based on the nutrient recommendation rate developed by PCARRD (1991), presented in Table 1. Soil test values result from the conducted analysis of OM, extractable phosphorus, and exchangeable potassium. The result of OM was multiplied by the conversion factor of 0.05 to convert OM to (%) Nitrogen, and extractable potassium was multiplied by 390 to convert mg dm^{-3} to ppm potassium. The lime recommendation was based on 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 sugarcane being 6.5.

Laboratory work

Soil samples collected in the sampling sites were replicated during the analysis to ensure the correct analysis of the samples. Analysis of Physical and chemical properties of the selected sugarcane farms in Mt. Nebo, Valencia City, Bukidnon, Philippine soil 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.

RESULTS AND DISCUSSION

Soil chemical properties

Soil pH values of farms grown to sugarcane in Mt. Nebo, Valencia City, Bukidnon is presented in Table 3. Fifteen (15) sugarcane farms (62.50%) were identified as medium acidic with soil pH values of 5.6-6.0. Seven (7) farms (29.16%) farms were categorized as strongly acidic, having pH values of 5.1-5.5. One (1) sugarcane farm (4.17%) was slightly acidic with soil pH values of 6.1-6.9, and only one (1) sugarcane farm (4.17%) was found to be very strongly acidic with soil pH values of 4.5-5.0. Therefore, it was observed that most and the optimum soil pH are about 6.5. Considerably, sugarcane can tolerate a degree of soil acidity and alkalinity. Soil reaction refers to the degree of acidity or alkalinity and is expressed in terms of pH units (Braddy and Weil 1999), as cited by Daquiado and Pabiona (2017).

The soil organic matter content of sugarcane is presented in Table 3. The analysis showed seventeen (17) or 70.83% of sugarcane farms have a marginal amount of organic matter (Walkley-Black 1934). Four (4) or 16.67% of sugarcane farms are deficient in organic matter. Lastly, three (3) or 12.50% are adequate in organic matter content (FAO GLOSOLAN 2020). The results show that sugarcane farms' percent organic matter content is marginal.

The extractable phosphorus of sugarcane farms is presented in Table 3. Twenty-four (24) or 100%, whose extractable phosphorus ranged from <4.1 mg dm^{-3}, were classified as very deficient. Based on the result, the extractable phosphorus of sugarcane farms is very low, and it is recommended to apply phosphorus-containing fertilizer. Proper management of phosphorus on the farm will lead to higher crop production and sustainability for sugarcane production (Arruda et al. 2016). P application, especially in P-deficient soils, promotes root growth, stimulates tillering, influences better growth, and thus increases yield and juice quality. P availability in the soil is influenced by various factors such as soil texture, clay content, clay type, and soil organic matter (Gichangi et al. 2009).

The exchangeable potassium (K) of sugarcane farms is presented in Table 3. There were eight (8) farms 33.33% categorized as a medium in exchangeable K content with values ranging from 78.0 to 109.59 mg dm^{-3}, and seventeen (17) or 70.83% farms were categorized as low in exchangeable K with values less than 78.0 mg dm^{-3} (FAO GLOSOLAN 2020). Plant requirement for this element is quite high, and increased potassium availability in the soil promotes higher absorption of nutrients by plants (Pancelli et al. 2015). Therefore, sugar utilizes a large amount of K. Deficiencies are commonly observed on well-drained, coarse, sandy soils. Furthermore, compared to other nutrients, sugarcane's response to potassium fertilization is usually the most immediate (Rice et al. 2010). Therefore, K often increases the percentage of sugar in the cane and juice recovery even when there is no increase in cane yield, particularly when the harvest is delayed. The nutrient map for pH, organic matter content, phosphorus, and potassium of the sugarcane farms is presented in Figure 2.

The soil quality assessment will help the farmers apply the 4R nutrient stewardship to their soil. Rajendran and Shanmuganathan (2019) observed diverse roles that soils provide as the cornerstone for sustainable land management were demonstrated using evaluation tools for indexing soil quality at various scales. Shivanna and Nagendrappa (2014) investigated the soil fertility status in Selected Command Areas of Three Tanks in Tiptur Taluk of Karnataka, India. The factors examined were pH, OM, N, P, and K. The pH of the soil samples ranged from 7.07 to 7.87, indicating that they were somewhat alkaline but within the ideal range of 6.5-7.5 for crops. The OM concentration of the samples ranged from 0.86 percent to 1.15 percent, all rated as medium. Nitrogen availability ranged from 54.825 kg/ha to 54.825 kg/ha. Available phosphorous ranged from 5.33 kg/ha to 10.79 kg/ha; the samples were nitrogen and phosphorus deficient. Potassium levels ranged from 156.18 kg/ha to 434.38 kg/ha, except for one sample with a high potassium level. A similar study was conducted by (Wagh et al. 2013) in Mula, Mutha, India. Moreover, because most farmers use excessive chemical fertilizers, the amount of phosphorus and potassium in the soil is higher than the usual range, and inferior drainage characteristics in this area, making the soil alkaline. As a result, Wagh et al. (2013) suggested that the additional fertilizers during crop formation may be responsible for varying concentrations of various parameters and irregular macronutrient distributions.

Table 3. Physical and chemical properties of the soil in the selected sugarcane farms in Mt. Nebo, Valencia City, Bukidnon, Philippines

Farm code	Soil pH	% OM	Exchangeable phosphorus mg dm^{-3}	Extractable potassium mg dm^{-3}	Bulk density Mg m^{-3}	Particle density Mg m^{-3}	Water holding capacity (%)	Soil texture class
F1	5.33	2.32	1.48	67.47	1.22	2.31	70.54	Clay
F2	5.38	3.30	2.02	78.00	1.11	2.36	65.96	Clay
F3	5.42	2.70	2.87	106.47	1.05	2.33	71.08	Clay
F4	5.67	4.58	4.91	65.91	1.17	2.38	73.68	Silty Clay
F5	5.89	4.88	1.59	104.91	1.21	2.32	65.23	Clay
F6	5.77	4.05	1.43	65.91	1.28	2.40	67.34	Clay
F7	5.86	2.85	1.79	108.03	1.22	2.39	59.47	Clay
F8	5.82	4.58	3.25	69.03	1.23	2.31	69.58	Clay
F9	5.72	1.05	1.70	113.88	1.10	2.30	82.90	Clay
F10	5.73	3.15	1.42	49.53	1.23	2.33	63.55	Silty Clay
F11	6.38	3.00	1.42	79.56	1.19	2.28	71.66	Clay
F12	5.28	3.45	6.58	51.09	1.31	2.38	69.69	Clay
F13	5.68	3.00	1.87	72.15	1.21	2.32	76.30	Clay
F14	5.82	1.95	3.37	64.35	1.29	2.28	63.68	Clay
F15	5.29	1.72	1.14	55.38	1.26	2.30	75.94	Clay
F16	5.59	4.20	1.79	55.38	1.23	2.31	68.12	Clay
F17	5.77	1.58	5.18	90.09	1.31	2.28	70.35	Clay
F18	5.64	2.85	1.70	61.62	1.21	2.35	65.00	Clay
F19	5.08	3.00	4.25	73.32	1.25	2.24	65.48	Clay
F20	5.49	3.22	1.53	56.94	1.13	2.39	74.44	Clay
F21	5.86	4.42	2.12	55.38	1.22	2.31	69.74	Clay
F22	5.62	3.15	2.25	52.65	1.15	2.31	65.27	Clay
F23	5.47	3.00	2.24	109.59	1.18	2.37	70.26	Clay
F24	5.71	3.82	1.31	61.62	1.23	2.41	54.24	Silty Clay

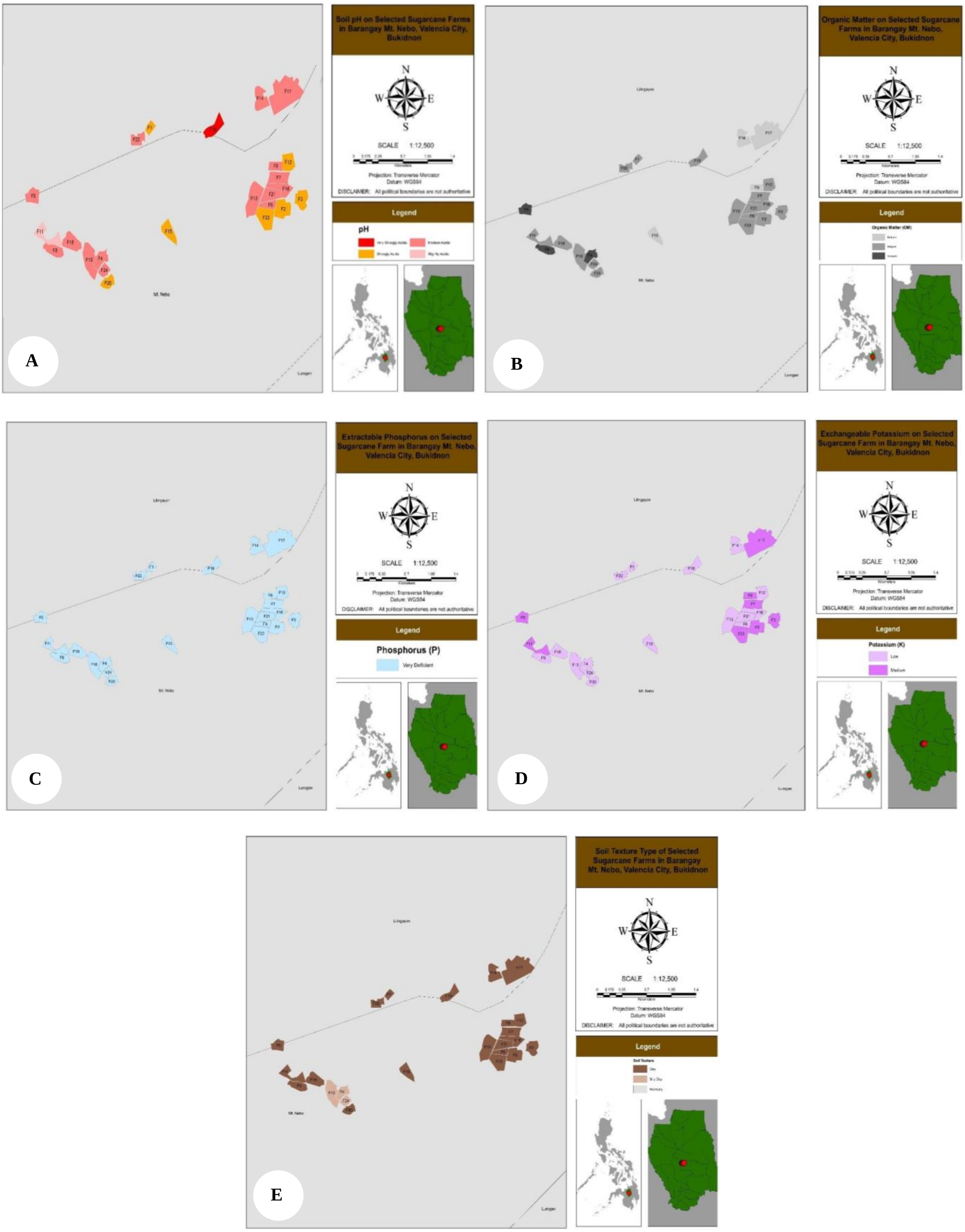

Figure 2. Soil physical and chemical fertility map of selected sugarcane farms in Mt. Nebo, Valencia City, Bukidnon, Philippines. A. Soil pH, B. Organic matter content, C. Exchangeable phosphorus, D. Extractable potassium, E. Soil texture

Soil physical properties

The bulk density of sugarcane farms in Mt. Nebo, Valencia City, Bukidnon showed in Table 3. There were twenty-two (22), or 91.67%, whose values ranged from 1.0-1.3 Mg $m^{-3,}$ and only two (2), or 8.33%, with values greater than 1.3 Mg m^{-3}. This area was a well-drained, deep, loamy soil with a bulk density of 1.1 to 1.2 Mg m^{-3} (and 1.3-1.4 Mg m^{-3} in sandy soils). The critical value of Bulk density for restricting root growth varies with soil type (Hunt and Gilkes 1992). Still, bulk densities greater than 1.6 Mg m^{-3} tend to restrict root growth (McKenzie et al. 2004). Sandy soils usually have higher bulk densities (1.3-1.7 Mg m^{-3}) than fine silts and clays (1.1-1.6 Mg m^{-3}) because they have larger but fewer pore spaces. In clay soils with good soil structure, there is a greater amount of pore space because the particles are very small, and many small pore spaces fit between them. Soils rich in organic matter (peaty soils) can have densities of less than 0.5 g Mg c^{-3}. Most of the sampling area planted with sugarcane is considered favorable for planting sugarcane.

Particle density values ranging from 2.24 Mg c^{-3} to 2.40 Mg m^{-3} were determined from the sugarcane farms, as shown in Table 3. Typical particle densities for soils range from 2.60 to 2.75 Mg m^{-3} for mineral particles. However, they can be as high as 3.0 Mg m^{-3} for very dense particles and as low as 0.9 Mg m^{-3} for organic particles. Particle density measurements provide information about the kinds of material present in the soil. If the particle density is high, we know that the soil's parent material consists of high-density minerals. This information provides insight into the geologic history of the soil. On the other hand, a low particle density (<1.0 Mg m^{-3}) indicates high organic matter content. It also provides information about the potential release of carbon from the soil into the atmosphere as the organic matter decomposes over time (Globe 2014).

Twenty (20), or 87.50%, sugarcane farms were classified as optimal soil in terms of water holding capacity, with values ranging from 60-80%. Only two (2), or 8.33%, have values ranging from 55-to 60%. And only one (1) or 4.17% whose value is greater than 80% and categorized as saturated. Available water holding capacity of 15% or more (15 cm per meter depth of soil is considered ideal for sugarcane cultivation (Gliński and Lipiec 2018). Daquiado (2018) states that the higher the percentage of silt and clay-sized particles, the higher the water-holding capacity. As presented in Table 3, Twenty (20), or 87.5% of sugarcane farms, have clayey textured soil, and three (3), or 12.50%, are silty clay textured soil. Most sugarcane farms in Mt. Nebo, Valencia City, Bukidnon had clayey soil and less silty clay soil texture suitable for growing sugarcane. The soil texture will affect the yield since it influences nutrient and water retention (Gerpacio et al. 2004).

An important finding was the investigation by Campos et al. (2020), which established the soil's physical properties in plantations of lacustrine soils in Venezuela. These location does not favor the rapid movement of water; such is the case of the high values of BD observed in some plots associated with their lake origin, which can affect the normal development of plant roots. Likewise, Rondon et al. (2021) indicated that the physical variables of these soils of lacustrine origin, such as texture class, apparent density, porosity, and moisture retention capacity, were related to banana yield and productivity.

The results of Olivares et al. (2022) agree with our results, which indicate that bananas show a high sensitivity to cycles of fertilization and a decrease in yields due to soil compaction; thus, the weight of the roots and shoots of the banana decreases significantly as the BD of the soil increases.

Lime and fertilizer recommendation

The lime recommendation of the sugarcane farm in Mt. Nebo, Valencia City, Bukidnon is presented in Table 4. All twenty-four (24) or 100% sugarcane farms must apply lime. Fourteen (14), or 58.33%, required up to 3-6 Mg ha^{-1}. Another six (6), or 25% of farms, required 6-9 Mg ha^{-1}, while only four (4), or 16.67% of farms, required 1-3 Mg ha^{-1}. Lime is usually added to acid soil to increase soil pH. Adding lime can eliminate most of the major problems associated with acid soils by replacing hydrogen ions and raising soil pH. It can also provide calcium and magnesium to the soil. Lime also makes phosphorus more available for plant growth and increases nitrogen availability by hastening the decomposition of organic matter in the soil.

The lime recommendation was based on the result of the Veitch method. The lime mounted on x-axis and pH on y-axis was computed based on the desired pH for sugarcane which is 6.5. There were twelve (12) different sets of recommendation rates distributed on different sugarcane farms. The recommended rate for nitrogen ranges from 80 to 140 kg ha^{-1}, which needs 0-5.29 bags of urea (46-0-0) ha^{-1}. The recommended rate of phosphorus ranges from 200-500 kg ha^{-1}, which needs 8.70 to 21.74 bags of ammonium phosphate (16- 20-0) ha^{-1}. For potassium, the recommendation rate ranges from 170-200 kg ha^{-1}, which needs 4 to 5.67 bags of muriatic potash (0-0-60) ha^{-1}. Fertilizers used for recommendations were based on the farmer's choice of fertilizers.

Also, the studies by Olivares et al. (2021) and Paredes et al. (2021) establish that the crops with an important demand for water and chemical products for conventional management, with the majority of plantations of more than ten years planted, generate inconveniences in the filtration and movement of water in the soil coupled with the absence of soil and water conservation practices in the plots, with the improvement of irrigation depending on the planting age of the banana plantation strictly necessary to avoid infiltration problems of the underground water. Finally, these studies in tropical territories (Olivares and Hernandez 2020; Olivares 2022) imply that these farms of sugarcane, bananas, and other tropical crops need soil amendments to meet the desired nutrient requirement and good physical soil conditions.

Table 4. Fertilizer and Lime recommendation of sugarcane farms in Mt. Nebo, Valencia City, 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
F23	110	200	200	7.06
F24	110	400	200	4.15

In conclusion, the result of the study indicated that most of the selected sugarcane farms were affected by heavy cultivation over the past decades without proper management and are expected to affect the yield. The soil texture in the sampling sites is clayey soil. Bulk density and particle density values were recommended for optimum sugarcane cultivation sugarcane. This location was within the ranges of (BD) and (PD) values for clayey textured soil, and the water-holding, capacity was at the optimum values. The medium acidic pH values in the selected sugarcane farm Mt. Nebo are required to apply liming material to achieve the required pH values for growing sugarcane. The marginal organic matter, very deficient extractable phosphorus, and low exchangeable potassium contents indicate that soil fertility is among the major constraints for sustainable sugarcane production in the area. Moreover, to maintain and ensure sustainable sugarcane production, good soil management should be practiced to ensure good soil pH, increase soil organic matter content, extractable phosphorus, and exchangeable potassium.

ACKNOWLEDGEMENTS

To the people behind this success, the author would like to express his gratitude and thanksgiving to all who willingly assisted in making this study possible. His parents are their inspiration and support him financially. To the member of his Thesis Advisory Committee, Prof. Editha L. Agus and Prof. Cyd Cherisse U. Gayonan, for the time, advice, kindness, and suggestions they shared and provided to the author, the faculty of the Soil Science Department, and the staff of SPAL. To Jewel Marie Francisco, who helped him throughout the study and partnered in the conduct of the analysis. To the farmers who gave their effort and support to the author.

REFERENCES

Abdullah UH, Sufardi S, Syafruddin S, Arabia T. 2022. Soil organic carbon of grassland and bush forest on dryland in Aceh Besar District, Indonesia. Biodiversitas 23: 2594-2600. DOI: 10.13057/biodiv/d230541.

Arruda B, Rodrigues M, Soltangheisi A, Richardson AE, Andreote FD, Pavinato PS. 2016. Biological and morphological traits of sugarcane roots in relation to phosphorus uptake. J Soil Sci Plant Nutr 16 (4): 901-915. DOI: 10.4067/S0718-95162016005000064.

Biddle DL. 1997. A Compilation of Selected Methods for Soil and Plant Chemical Analysis. Department of Agriculture, University of Queensland, Australia, St Lucia.

Blake GR. 1965. Bulk density. In: Black CA (eds). Methods of Soil Analysis: Part 1 Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling. ASA-SSSA, Agronomy Monograph. DOI: 10.2134/agronmonogr9.1.c30.

Brady NC, Weil RR. 1999. The Nature and Properties of Soils. 12th edition. Prentice-Hall Inc., New Jersey. DOI: 10.1046/j.1365-3091.2000.0376c.x.

Campos O, Araya-Alman M, Acevedo-Opazo C, Cañete-Salinas P, Rey JC, Lobo D, Landa B. 2020. Relationship between soil properties and banana productivity in the two main cultivation areas in Venezuela. J Soil Sci Plant Nutr 20 (3): 2512-2524. DOI: 10.1007/s42729-020-00317-8.

Daquiado NP, Pabiona MG. 2017. Soil fertility Evaluation: Laboratory Manual. Department of Soil Science, Central Mindanao University, Musuan, Maramag, Bukidnon. [Philippines]

Daquiado NP. 2018. Soil Physics: Laboratory Manual. Department of Soil Science, Central Mindanao University, Musuan, Maramag, Bukidnon. [Philippines]

FAO GLOSOLAN. 2020. Standard Operating Procedures for Soil Organic Carbon: Walkley and Black Method. GLOSOLAN's Best Practice Manual. GLOSOLAN-SOP-02, Rome.

Gerpacio RV, Labios JD, Labios RV, Diangkinay EI. 2004. Maize in the Philippines: Production Systems, Constraints, and Research Priorities. Cimmyt (p. 36). Retrieved from http://books.google.com/books?hl=en&lr=&id=bZ-t7dHwvHAC&pgis=1

Gichangi EM, Mnkeni PNS, Brookes PC. 2009. Effects of goat manure and inorganic phosphate addition on soil inorganic and microbial biomass phosphorus fractions under laboratory incubation conditions. Soil Sci Plant Nutr 55 (6): 764-771. DOI: 10.1111/j.1747-0765.2009.00415.x.

Gliński J, Lipiec J. 2018. Soil Physical Conditions and Plant Roots. CRC Press, Boca Raton. DOI: 10.1201/9781351076708.

Globe GV. 2014. Soil (Pedosphere). In Soil Particle Density Protocol. www.globe.gov

Holland JE, Bennett AE, NewMg AC, White PJ, McKenzie BM, George TS, Pakemanb RJ, Baileyc JS, Fornara DA, Hayes RC. 2018. Liming impacts on soils, crops, and biodiversity in the UK: A review. Sci Total Environ 610: 316-332. DOI: 10.1016/j.scitotenv.2017.08.020.

Hoskins BR. 1997. Soil Testing Handbook for Professionals in Agriculture, Horticulture, Nutrient and Residuals Management. 3rd ed. Maine Forestry and Agriculture Experiment Station, University of Maine, Orono, Maine, USA.

Hunt N, Gilkes R. 1992. Farm Monitoring Handbook. The University of Western Australia: Nedlands, Australia

Lal R, Shukla MK. 2004. Principles of Soil Physics. CRC Press, Boca Raton. DOI: 10.4324/9780203021231.

McKenzie NJ, Jacquier DJ, Isbell RF, Brown KL. 2004. Australian Soils and Landscapes An Illustrated Compendium. CSIRO Publishing, Collingwood, Victoria. DOI: 10.1111/j.1365-2389.2004.0694d.x.

Olivares B, Calero J, Rey JC, Lobo D, Landa BB, Gómez JA. 2022. Correlation of banana productivity levels and soil morphological properties using regularized optimal scaling regression. Catena 208: 105718. DOI: 10.1016/j.catena.2021.105718.

Olivares B, Hernández R. 2020. Application of multivariate techniques in the agricultural land's aptitude in Carabobo, Venezuela. Trop Subtrop Agroecosyst 23 (2): 1-12.

Olivares B, Rey JC, Lobo D, Navas-Cortés JA, Gómez JA, Landa BB. 2021. Fusarium wilt of bananas: A review of agro-environmental factors in the venezuelan production system affecting its development. Agronomy 11 (5): 986. DOI: 10.3390/agronomy11050986.

Olivares B. 2022. Determination of the Potential Influence of Soil in the Differentiation of Productivity and in the Classification of Susceptible Areas to Banana Wilt in Venezuela. UCO Press, Spain. https://helvia.uco.es/handle/10396/22355.

Pancelli MA, Prado R de M, Flores RA, de Almeida HJ, Moda LR, de Souza Junior JP. 2015. Growth, yield, and nutrition of sugarcane ratoon as affected by potassium in a mechanized harvesting system. Aust J Crop Sci 9 (10): 915-924.

Paredes F, Orlando BO, Rey J, Lobo D, Galvis-Causil S. 2021. The relationship between the normalized difference vegetation index, rainfall, and potential evapotranspiration in a banana plantation in Venezuela. Sains Tanah J Soil Sci Agroclimatol 18 (1): 58-64. DOI: 10.20961/stjssa.v18i1.50379.

PCARRD. 1991. Standard Method of Analysis of Soils, Plant Tissue, Water, and Fertilizer. PCCARD, Los Banos, Laguna. [Philippines]

Philippine Statistics Authority (PSA). 2019. Crops Statistics of the Philippines 2014-2018. Philippines.

Rajendran A, Shanmuganathan M. 2019. Physico-chemical analysis of soils for the better yield of sugarcane and rice using Heber soil quality index. East Afr Agric For J 83 (3): 206-220. DOI: 10.1080/00128325.2019.1602898.

Rice RW, Gilbert RA, McCray JM. 2010. Nutritional Requirements for Florida Sugarcane. DOI: 10.32473/edis-sc028-2010.

Rondon T, Hernandez RM, Guzman M. 2021. Soil organic carbon, physical fractions of the macro-organic matter, and soil stability relationship in lacustrine soils under banana crop. PLoS One 16 (7): e0254121. DOI: 10.1371/journal.pone.0254121.

Shivanna AM, Nagendrappa G. 2014. Chemical analysis of soil samples to evaluate the soil fertility status of selected command areas of three tanks in Tiptur Taluk of Karnataka, India. IOSR J Appl Chem 7 (11): 01-05. DOI: 10.9790/5736-071110105.

Suleiman R, Jimoh IA, Aliyu J. 2017. Assessment of soil physical and chemical properties under vegetable cultivation in Abuja Metropolitan Area, Nigeria. Zaria Geogr 24 (1): 89-99. DOI: 10.35691/JBM.0202.0141.

Verma RR, Manjunath BL, Singh NP, Kumar A, Asolkar T, Chavan V, Srivastava T, Singh P. 2018. Soil mapping and delineation of management zones in the Western Ghats of coastal India. Land Degrad Dev 29 (12): 4313-4322. DOI: 10.1002/ldr.3183.

Wagh GS, Chavhan DM, Sayyed MRG. 2013. Physicochemical analysis of soils from eastern part of Pune City. Univers J Environ Res Technol 3 (1): 93-99.

Wakgari T, Kibret K, Bedadi B, Temesgen M, Erkossa T. 2020. Effects of long-term sugarcane production on soils physicochemical properties at Finchaa Sugar Estate. J Soil Sci Environ Manag 11 (1): 30-40. DOI: 10.5897/JSSEM2018.0710.

Walkley A, Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci 37 (1): 29-38. DOI: 10.1097/00010694-193401000-00003.