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Spatial variation of soil physical and chemical components of Lamitan City, Basilan province, Bangsamoro autonomous region in Muslim Mindanao (BARMM), Philippines

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Abstract
The study conducted to analyze the physical and chemical components of the soil of Lamitan City, Basilan, aimed to characterize the proportion of soil's physical and chemical parts and spatially map each soil's physical and chemical components, soil samples collected from fourteen (14) villages in the study area. The soil organic matter (SOM) and soil organic carbon (SOC) range from 3.07-6.71 % and 1.78-3.90 %, respectively. Both soil organic matter (SOM) and soil organic carbon (SOC) are categorized as moderate to high. The amount of nitrogen, phosphorous, and potassium in the entire Lamitan City range from 0.14 - 0.34 %, 0.30 – 38.85 ppm, and 38.35-341.13 ppm, respectively. The nitrogen level is categorized as excessive, while phosphorus is categorized as low and medium. However, soil potassium is highly varied, categorized as very low, low, and medium, while in the rest of the areas is high. The pH of the study area ranged from 4.97– 7.68. The lowest pH was analyzed from the soil sample (S14) at village Panadakan, while the highest was taken from the soil sample (S2 and S3) at villages Baroy and Limook. Based on Table 7, soil samples (S6, S7, S11 to S14) were considered acidic, soil sample (S1, S4, S8, S9, S10) was neutral at pH between 6.5 – 7.5, while soil samples (S2, S3, and S5) were considered alkaline. It means the soil pHs' of Lamitan City were varied, categorized from acidic to alkaline.

Keywords: Basilan, Lamitan City, BARMM, Organic matter, Organic Carbon

Introduction

Soil fertility is a complex soil quality closest to plant nutrient operation. It combines numerous natural, chemical, and physical soil parcels that affect nutrient vacuity. It is a significant aspect of soil productivity where the chemical fertility and physical condition of soils are decisive as they are the product eventuality. Good natural or advanced soil fertility is necessary for successful cropping and the base for any high-product system (Moral & Rebollo, 2017) [16]. It supports factory products due to the relations among physical, chemical, and natural processes. Among these, soil texture, pH, and organic matter explosively affect soil functions likewise water and nutrient vacuity (Abbott and Murphy, 2003; Khalil *et al*., 2015; Cardone *et al*., 2020) [1, 11, 5].

The decline of the soil has been considered the major constraint for feeding an ever-growing population (Gupta, 2019). Soil declination results from the high use of ferocious husbandry exertion, land use change, and mismanagement of soil (Lucas-Borjaetal., 2019) [13] has led to severe soil declination through soil organic carbon (SOC) loss, degraded soil structure, frequent erosion, and decline in soil ecosystem services (Adelman and Barton, 2002; Tsiafoulietal., 2015; Rockströmetal., 2017) [2]. Similarly, soil pH is another soil parameter that affects the availability of nutrients (Nájeraetal., 2015; Li *et al*., 2015). The ideal soil pH is close to neutral; utmost plant nutrients are optimally available to shops within this 6.5 to 7.5 pH range, plus, this pH range is generally truly compatible with plant root growth. Among the different nutrients, nitrogen (N), phosphorus (P), and potassium (K) are macronutrients needed by crops. It is vital in physiological and biochemical processes in crops (El- Fattah & Helaly, 2015) and essential nutrients in plant cells' metabolic and biochemical processes (Yusuf *et al*., 2021) [31].

Lack of information on the current status of soil physical and chemical components could lead to reducing the land production potential due to improper application of fertilizers. However, not knowing that an area(s) are fertilized, others need to be treated before or at a time of cultivation to optimize production and reduce the environmental hazard caused by chemical fertilizers. Proper diagnosis of soil-limiting nutrients will increase fertilizer use efficiency. Therefore, the study aimed to characterize the proportion of physical and chemical and spatially map each component because it is vital to know and identify the soil's nutrient content so that only the limiting nutrients in the right proportion based on crops' needs are applied otherwise plant growth and yield might be affected.

Methodology

Study Area

The study was conducted in 14 villages of Lamitan City. The city center of Lamitan is situated at approximately 6° 39' 37.07" North, 122° 08' 18.33 East, on the island of Basilan. Elevation at these coordinates is estimated at 9.0 meters above mean sea level. The city has a land area of 354.45 square kilometers constituting 10.26 % of Basilan's total area. The city is mostly planted with coconut and rubber trees with a few fruit trees like lanzones, marang, and rambutan. Some vegetables are cultivated in some vacant areas.

Collection of Soil Samples

The soil samples were collected from fourteen (14) different villages in the entire city using a purposive sampling technique. The samples were put into transparent cellophane, sealed, and labeled from where it was collected. The locations of samples were geo-tagged for the purpose of spatial mapping.

Methods of Analysis

The method used for soil physical analysis such as percent sand, silt, and clay was the hydrometer method, however, percent organic carbon and organic matter were analyzed using walk black and computation methods, respectively. On the other hand, the percent nitrogen, available phosphorous, exchangeable potassium, and soil pH were analyzed using computation, bray No. 1, ammonium acetate, and potentiometric methods, respectively. The soil samples were brought to the Bureau of Soils and Water Management (DA-BSWM), the Department of Agriculture soil laboratory, regional office IX, Zamboanga City. The samples were subjected to physical and chemical components analysis such as total nitrogen, available phosphorus, potassium, pH and organic matter, organic carbon, and particle size distribution, respectively.

3. Results and Discussion

Table 1: Soil Physical and Chemical Components of Lamitan City, Basilan

Sample	N (%)	P (ppm)	K (ppm)	pH	OM (%)	OC (%)	Sand (%)	Silt (%)	Clay (%)	Textural class	Village
1	0.23	3.23	184.62	6.98	4.58	2.66	31.4	28.6	40	Clay	Sengal
2	0.18	4.54	122.60	7.68	3.67	2.13	41.4	46.6	12	Loam	Baroy
3	0.18	4.54	122.60	7.68	3.67	2.13	51.4	32.6	16	Loam	Limook
4	0.34	9.80	139.88	7.00	6.71	3.90	43.4	40.6	16	Loam	Balobo
5	0.22	25.37	130.35	7.59	4.43	2.58	37.4	46.6	16	Loam	Bohe ibu
6	0.20	2.27	133.26	5.67	3.90	2.27	47.4	36.6	16	Loam	Parang basak
7	0.22	2.83	76.02	5.82	4.39	2.55	55.4	32.6	12	Sandy loam	Bohe bessey
8	0.18	7.02	248.18	6.65	3.69	2.14	43.4	38.6	18	loam	Maganda
9	0.15	32.85	317.43	6.62	3.08	1.79	33.4	38.6	28	clay loam	Sayugan
10	0.20	6.82	341.13	6.99	3.92	2.28	35.4	28.6	26	loam	Colonia
11	0.16	1.90	150.64	6.42	3.12	1.81	35.4	28.6	26	loam	Campo- Uno
12	0.17	0.32	43.44	5.18	3.30	1.92	33.4	36.6	30	clay loam	Sabung
13	0.15	0.42	38.36	5.00	3.09	1.79	41.4	28.6	30	clay loam	Baas
14	0.14	0.30	38.35	4.97	3.07	1.78	39.4	34.6	26	loam	panadakan
Mean	0.20	7.30	149.06	6.45	3.90	2.27	40.69	35.60	22.29		
SD	0.05	9.40	92.36	0.93	0.93	0.54	6.83	5.99	7.99		

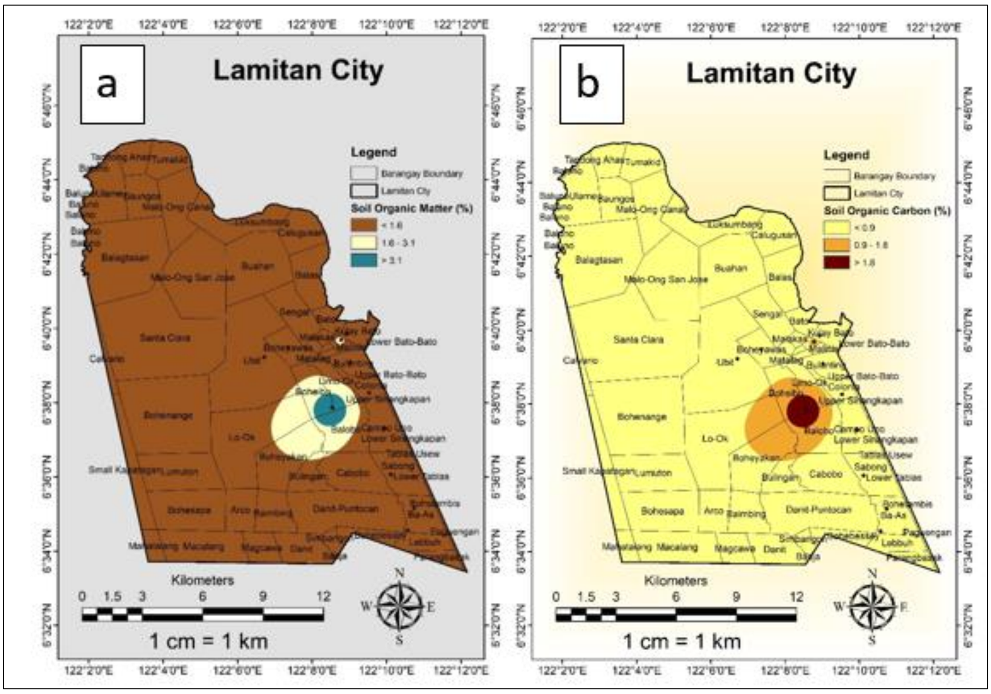
Organic Matter (OM)

The values of organic matter (table 1) indicated that sample (S4), taken from Balobo was the highest value of 6.71 percent, followed by sample (S1), taken at the Sengal village with a value of 4.58 percent, while the least amount of organic matter, the samples were taken from villages of Panadakan and Sayugan of 3.07 and 3.08 percent, respectively. Based on Table 2, soil organic matter (SOM) in the study area is greater than (> 3.1), which means the amount of organic matter (SOM) is high under the loam textural class. Soil organic matter is the organic element of soil. It has direct benefits for agrarian products. It significantly improves the soil's capacity to store and supply essential nutrients (similar to nitrogen, phosphorus, potassium, calcium, and magnesium) and to retain poisonous rudiments. It allows the soil to manage changes in soil acidity and helps soil minerals to putrefy briskly. Soil organic matter improves soil structure. It eventually helps to control soil corrosion and improves water infiltration and water holding capacity, giving factory roots and soil organisms better living conditions. It's a primary source of carbon that provides energy and nutrients to soil organisms (The Agricultural European Innovation Partnership (EIP-AGRI), 2016).

Table 2: Ranges of Soil Organic Matter (SOM) For Every Soil Separates per Class

Class	Soil Organic Matter (%)			
	Sand	**Sandy Loam**	**Loam**	**Clay Loam/Clay**
Low	<0.9	<1.2	<1.6	<2.1
Moderate	0.9–1.7	1.2–2.4	1.6–3.1	2.1–3.4
High	>1.7	>2.4	>3.1	>3.4

From Vitinotes (2006) as cited by Riches et al., 2013



Note: Map boundaries are not authoritative

Fig 1: Spatial Distribution of, a) Organic Matter, b) Organic Carbon in the City of Lamitan

Organic Carbon (OC)

Table 1 shows that the highest organic carbon is located in the village of Balobo with a value of 3.90 %, while the lowest value of 1.78 %, a soil sample taken from the Panadakan. Based on Table 3, soil organic carbon (SOC) in the study area is in a range greater than (> 1.8), which means the amount of organic carbon (SOC) is high under the loam textural class.
Soil organic carbon (SOC) improves soil aeration, water retention capacity, and drainage and enhances microbial growth. As the amount of carbon in the soil is higher the risk of loss of nutrients through leaching and erosion is reduced. Similarly, the amount of carbon in the soil is increased and the carbon dioxide in the atmosphere provides better climatic conditions for plant growth. An increase in soil organic carbon results in a more stable carbon cycle and improved agricultural productivity. The spatial distribution (figure 1b) shows higher organic carbon in the center of the southeast quadrant of the study area, while the rest of the areas have lower organic carbon of the study.

Nitrogen (N)

The highest percentage of nitrogen (Table 1) in the study area is situated in Balobo village at 0.34 %, followed by 0.23 % from Sengal village. The lowest value is recorded from the sample taken from the upper Bato-Bato of 0.10 %. The percentage of nitrogen (Table 4) in the entire city is excessive, amount falling within the range of >0.003.

Nitrogen is vital because it is a primary component of chlorophyll, the compound by which plants use sunlight energy to produce sugars from water and carbon dioxide. It is also a primary component of amino acids, the building blocks of proteins. Without proteins, plants wither and die. Without enough nitrogen, plant growth is affected negatively. With too much nitrogen, plants produce excess biomass, or organic matter, such as stalks and leaves, but not enough root structure. In extreme cases, plants with very high levels of nitrogen absorbed from soils can poison farm animals that eat them (https://hy-pro.nl).

Table 3: Ranges of Soil Organic Carbon (SOC) For Every Soil Separates per Class

Class	**Soil Organic Carbon (%)**			
	Sand	Sandy Loam	Loam	Clay Loam/Clay
Low	<0.5	<0.7	<0.9	<1.2
Moderate	0.5–1.0	0.7–1.4	0.9–1.8	1.2–2.4
High	>1.0	>1.4	>1.8	>2.4

Note: SOC was computed using this equation, Organic matter (%) = total organic carbon (%) x 1.72 (https://www.agric.wa.gov.au)

The spatial distribution of nitrogen (Figure 2a) showed that most of the southeast, the tip of northern parts, and a small portion of the center of Lamitan City have nitrogen levels of >0.001%, while most of the areas range from 0.001-0.002 %. However, in lesser areas with nitrogen concentration within a range of 0.002-0.003 % and >0.003 % at the southeast quadrant of Lamitan City.

Table 4: Fertility level of nitrogen (Percent and ppm) in the soil

Fertility Level	Percent	ppm
Low	<0.001	<10
Medium	0.001-0.002	10-20
High	0.002-0.003	20-30
Excessive	>0.003	>30

Table 5: Fertility level of Phosphorous (ppm) in the soil

Fertility Level	Bray P1 method PO_4 Concentration ppm
Low	<20
Medium	20-40
High	40-100
Excessive	>100

Phosphorous (P)

The amount of phosphorous (Table 1) indicated that the soil sample (S9) has the highest value of 32.85 ppm, followed by the soil sample (S5) of 25.37 ppm taken from Sayugan and Bohe Ibu villages, respectively. The lowest value of 0.30 ppm is analyzed from a soil sample (S14) taken from Panadakan village. The level of phosphorous (Table 5) in the study area is categorized as low and medium.

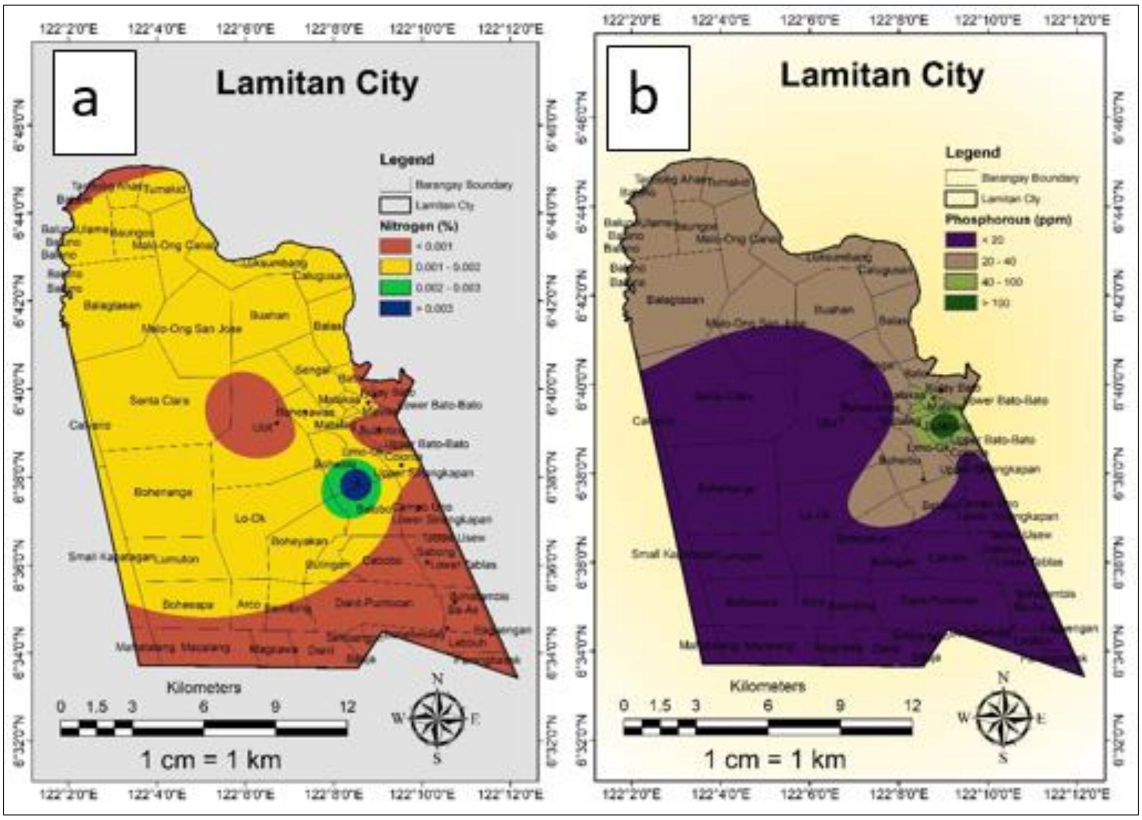
Phosphorus is an essential nutrient for plant structure compounds and catalysis in the conversion of numerous biochemical reactions in plants. Its role in capturing and converting the sun's energy into beneficial plant compounds is well known. Thus, it is essential for the general health and vigor of all plants. Some specific growth factors that have been associated with phosphorus such as stimulated root development, increased stalk, and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased nitrogen-fixing capacity of legumes, improvements in crop quality, increased resistance to plant diseases, and supports development throughout the entire life cycle.

The spatial distribution of phosphorous (Figure 2b) showed that areas in the northern part have soil phosphorous concentrations of range 20-40 ppm, while the southern part has a concentration of >20 ppm.

Potassium (K)

The amount of potassium (Table 1) in the study area ranged from 38.35- 341.13 ppm. The lowest amount is analyzed from the soil sample (S14) taken from Panadakan, while the highest is taken from Maganda at soil sample (S8). The concentration of potassium is less varied since the SD value is less than the mean. Based on Table 6, the soil potassium in the area is categorized into very low, low, and medium, but based on the mean value, it belongs falls into the low category.

Potassium (K) is an essential nutrient for factory growth. It's classified as a macronutrient because shops take up large amounts of K during their life cycle. It also helps regulate the opening and ending of the stomata, which regulates the exchange of water vapor, oxygen, and carbon dioxide. However, it stunts factory growth and reduces yield, if potassium is deficient or not supplied in acceptable quantities. Other functions of potassium are similar as increases root growth and perfecting failure resistance, maintaining turgor; reducing water loss and hanging, abetting in photosynthesis and food conformation, reducing respiration, precluding energy losses, enhancing translocation of sugars and bounce, producing grain rich in bounce, *)* increases plants' protein content, builds cellulose and reduces lodging, and helps retard crop diseases (https://extension.umn.edu).



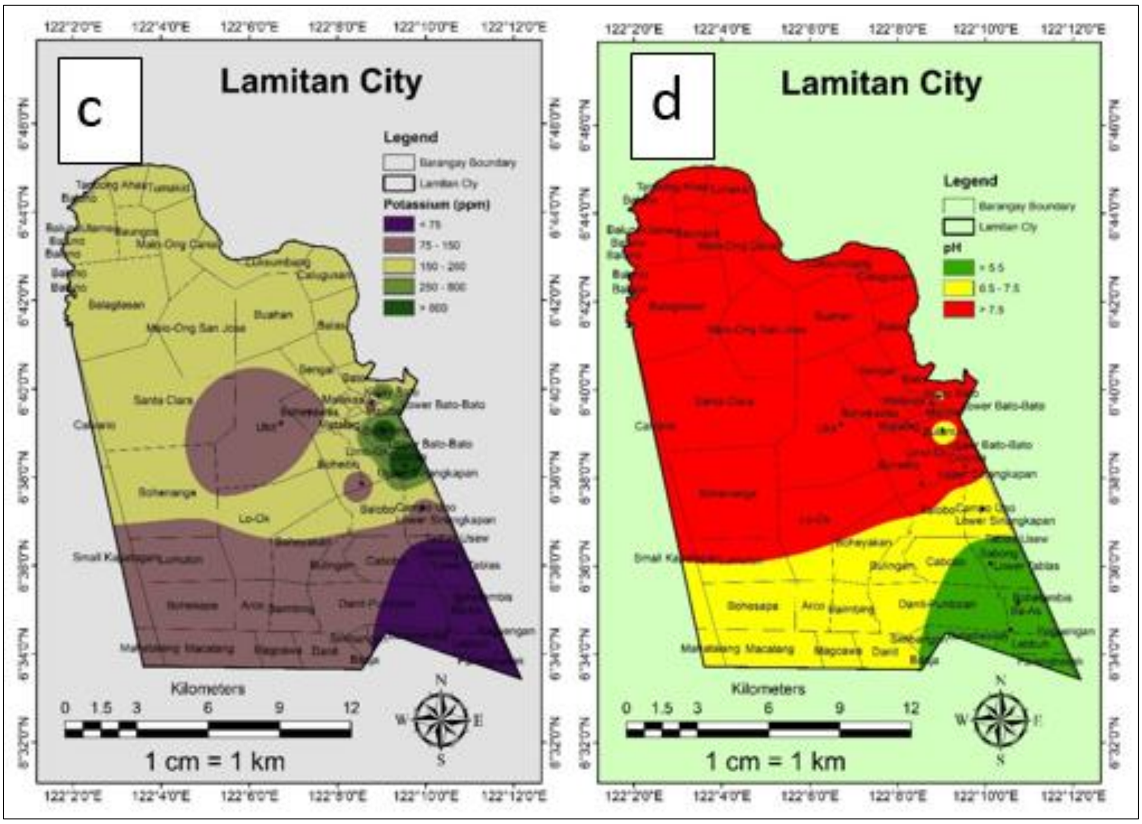


Fig 2: Spatial Distribution of, a) Nitrogen, b) Phosphorous, c) Potassium, d) pH in the Lamitan City. *(Note: Map boundaries are not authoritative)*

The spatial distribution of potassium (Figure 2c) in the study area showed that most of the northern part has a medium concentration, while the southern portion of the central parts is low. However, a very low amount of potassium goes entirely to the southeastern part of the city.

Table 6: Fertility level of Potassium (ppm) in the soil

Fertility Level	ppm
Very Low	< 75
Low	75 -150
Medium	150 - 250
High	250 -800
Very High	> 800

pH

The pH (Table 1) of the study area ranged from 4.97 – 7.68. The lowest pH was analyzed from the soil sample (S14) at village Panadakan, while the highest was taken from the soil sample (S2 and S3) at villages Baroy and Limook. Based on Table 7, soil samples (S6, S7, S11 to S14) were considered acidic, soil sample (S1, S4, S8, S9, S10) was neutral at pH between 6.5 – 7.5, while soil samples (S2, S3, and S5) were considered alkaline. It means the soil pHs' of Lamitan City were varied, categorized from acidic to alkaline.

Soil pH affects the number of nutrients and chemicals that are answerable in soil water, and therefore the amount of nutrients available to shops. There are nutrients that are more available in acidic environments while others are under alkaline conditions. Still, the utmost mineral nutrients are readily available to shops when soil pH is near neutral. The development of strongly acidic soils (lower than5.5 pH) can affect poor plant growth as a result of one or further of the following factors aluminum poison, manganese poison, calcium insufficiency, magnesium insufficiency, low situations of essential plant nutrients analogous to phosphorus and molybdenum (https://www.qld.gov.au).

Alkaline soils may have problems with deficiencies of nutrients such as zinc, copper, boron, and manganese. Soils with an extremely alkaline pH (greater than 9) are likely to have high levels of sodium.

The spatial distribution of soil pH (Figure 2d) in the study area showed that the soil on the northern part of the city is alkaline, while the southern part soil is considered neutral, but the soil on the southeastern part is strongly acidic.

Table 7: pH level of the soil

Classification	pH Value
Strongly Acidic	>5.5
Neutral	6.5-7.5
Alkaline	>7.5

Conclusion

The soil organic matter within the range from 3.07 – 6.71 %, where sample (S4) registered the highest value of 6.71%, while soil sample (S14) was the least amount of organic matter at 3.07 %. The soil organic matter (SOM) in the study area is more than (> 3.1), which means the amount of organic matter (SOM) is high under the loam textural class. Likewise, the soil organic carbon (SOC) is in a range greater than (> 1.8), which means the amount of organic carbon (SOC) is high under the loam textural class. Furthermore, the nitrogen ranges from 0.10 – 0.34%, where the value is greater than the (>0.003), which categorizes as excessive. The amount of phosphorous indicated that the soil sample (S9) has the highest value of 32.85 ppm, followed by the soil sample (S5) of 25.37 ppm. The lowest value of 0.30 ppm was analyzed from a soil sample (S14). The level of phosphorous in the study area is categorized as low and medium. For potassium, it ranges from 38.35- 341.13 ppm. The soil potassium in the area is categorized into very low to medium, but based on the mean value, it falls into the low category. The pH of the study area ranged from 4.97 – 7.68. The soil samples (S6, S7, S11 to S14) were acidic, soil samples (S1, S4, S8, S9, and S10) were neutral at pH between 6.5 – 7.5, while soil samples (S2, S3, and S5) were considered alkaline. It means the soil pHs' of Lamitan City were varied, categorized from acidic to alkaline.

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