International Journal of Multidisciplinary Research and Growth Evaluation.

Quantification of Soil Physical and Chemical Components of Akbar Municipality, Basilan Province, Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), Philippines

Alejandro A Jalil [1*], Algaib P Taib [2], Mudir L Ismael [3], Mujib L Jainal [4]
[1] Basilan State College, College of Agriculture and Fisheries, Sta. Clara Campus, Lamitan City, Basilan, Philippines
[2] Basilan State College, Tipo-Tipo Extension Campus, Tipo-Tipo, Basilan, Philippines

* Corresponding Author: **Alejandro A Jalil**

Article Info

ISSN (online): 2582-7138
Volume: 04
Issue: 03
May-June 2023
Received: 07-04-2023;
Accepted: 23-04-2023
Page No: 354-360

Abstract
The study conducted to quantify the physical and chemical components of the soil of the Akbar municipality, Basilan, aimed to characterize the proportion of soil's physical and chemical and spatially map each soil's physical and chemical components, soil samples collected from six (6) villages in the study area. The soil organic matter (SOM) and soil organic carbon (SOC) range from 2.01 - 6.68 % and 1.17-3.88%, 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 Akbar Municipality range from 0.1 - 0.33 %, 1.34 - 36.96 ppm, and 145.07 - 725.28 ppm, respectively. The nitrogen level is categorized as excessive, while phosphorous is categorized as low and medium. However, the concentration of potassium is highly varied only one (1) sampling point is categorized as low and medium levels, while in the rest of the areas, the concentration is high. The pH of the study area ranged from 5.73 – 7.56. The lowest pH is taken from the soil sample (S1), while the highest is taken from the soil sample (S3). The soil samples (S1, S2, and S4) were considered acidic, soil samples (S5) and S6) were neutral, and soil sample (S3) was considered alkaline. It means the soil pHs' varied, categorized from acidic to alkaline.

Keywords: Soil Physical, Chemical Components, Basilan

1. 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 range of pH is generally truly compatible to 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.

2. Methodology

Study Area

The study was conducted in 13 barangays of Akbar municipality. The municipal center of Akbar is situated at approximately 6° 40' North, 122° 11' East, on the island of Basilan. Elevation at these coordinates is estimated at 12.9 meters or 42.2 feet above mean sea level. The municipality has a land area of 182.01 square kilometers or 70.27 square miles, constituting 5.27% of Basilan's total area. The municipality 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 six (6) different villages in the entire municipality 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 purpose of spatial mapping.

Methods of Analysis

The method used for soil physical analysis such as percent sand, silt, and clay were the hydrometer method, however, percent organic carbon and organic matter were analyzed using walky 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 Akbar Municipality, Basilan

Sampling	N (%)	P (ppm)	K (ppm)	pH	OM (%)	OC (%)	Sand (%)	Silt (%)	Clay (%)	Village
S1	0.33	1.34	156.91	5.73	6.68	3.88	45.4	30.6	24	Mangusu
S2	0.2	2.02	308.57	6.05	3.93	2.28	47.4	30.6	22	Mangalut
S3	0.13	36.96	725.28	7.56	2.53	1.57	31.4	44.6	24	Semmut
S4	0.17	2.25	277.22	6.02	3.32	1.93	25.4	42.6	32	U. Bato-Bato
S5	0.1	4.68	145.07	6.98	2.01	1.17	43.4	34.6	22	Caddayan
S6	0.24	33.59	277.21	6.56	4.74	2.75	43.4	30.6	26	U. Sinangkapan

Organic Matter (OM)

The values of organic matter (table 3) indicated that sample (S1), taken from Mangusu was the highest value of 6.68 percent, followed by sample (S6), taken at the village of Upper Sinangkapan with a value of 4.74 percent, while the least amount of organic carbon, the samples were taken from villages of Caddayan and Semmut of 2.01 and 2.53 percent, respectively. Based on table 2, soil organic matter (SOM) in the study area is within the range of 1.6 -3.1 and greater than (> 3), which means the amount of organic matter (SOM) is moderate to 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).

The spatial distribution of organic matter (Figure 1a) showed that at the center of the municipality at village Katipunan where the soil has a higher amount of organic matter extended towards most parts of Serongon and Caddayan villages, and a portion of Semmut in the northwest part of the municipality. However, the soil at both ends of the study area at villages upper Sinangkapan, Langong, and Languyan, and at both lower and Upper bato-bato have a lower amount of organic matter. It implies that areas in those villages have a lesser water-holding capacity and require frequent irrigation versus areas with higher organic matter.

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

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

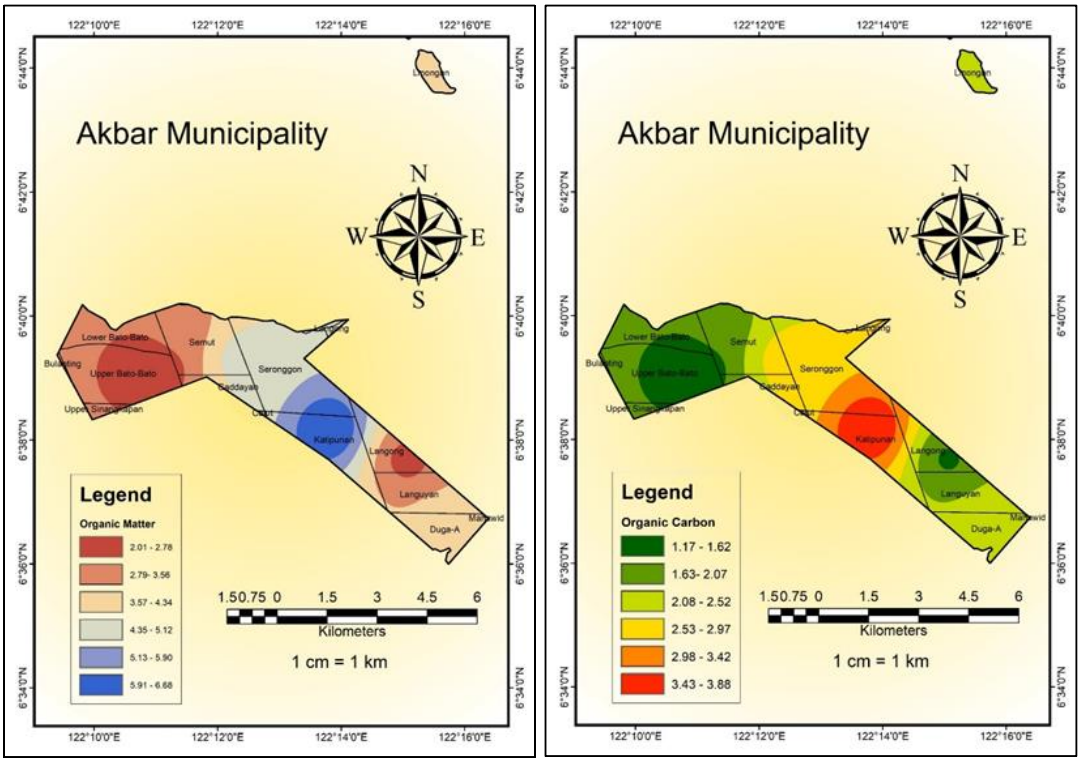


Fig 1: Spatial Distribution of, a) Organic Matter, b) Organic Carbon in the Municipality of Akbar. (Note: Map Municipal boundaries is not official)

Organic Carbon (OC)

Table 1 shows that the highest organic carbon is located in the village of Mangusu with a value of 3.88 %, while the lowest value of 1.17 %, a soil sample taken from the Caddayan. Based on table 5, soil organic carbon (SOC) in the study area is within the range of 0.9 -1.8 and greater than (> 1.8), which means the amount of organic carbon (SOC) is moderate to high under the loam textural class.

Soil organic carbon (SOC) improves soil aeration, water retention capacity, 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, as the amount of carbon in the soil is increased and the carbon dioxide in the atmosphere is reduced which 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 municipality on the boundaries of the seronggon and langong villages. While lower organic carbon is located in the northeast and southwest portions of the study area, specifically within the upper bato-bato and langong.

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

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)

Nitrogen

The highest percentage of nitrogen (Table 1) in the study area is situated in Mangusu village at 0.33 %, followed by 0.24 % from Mangalut 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 Akbar Municipality 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 4: Fertility level of nitrogen (Percent and ppm) in the soil of Abkar Municipality

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

The spatial distribution of nitrogen (Figure 2a) showed that most of the southeast part of Akbar municipality has nitrogen levels of 0.18 – 0.21%; likewise, in the northwest portion, the nitrogen levels are mostly 0.10-0.13 and 0,13-0.16%. However, the nitrogenous part is the center of the municipality at the Katipunan and Seronggon villages.

Phosphorous

The amount of phosphorous (Table 1) indicated that the soil sample (S3) has the highest value of 36.96 ppm, followed by the soil sample (S6) of 33.59 ppm taken from Semmut and upper Sinangkapan villages, respectively. The lowest value of 1.34 ppm is analyzed from a soil sample (S1) taken from Mangusu 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 on the northeast and southwest parts of the study area have lowest phosphorous concentration compared with the rest of the areas.

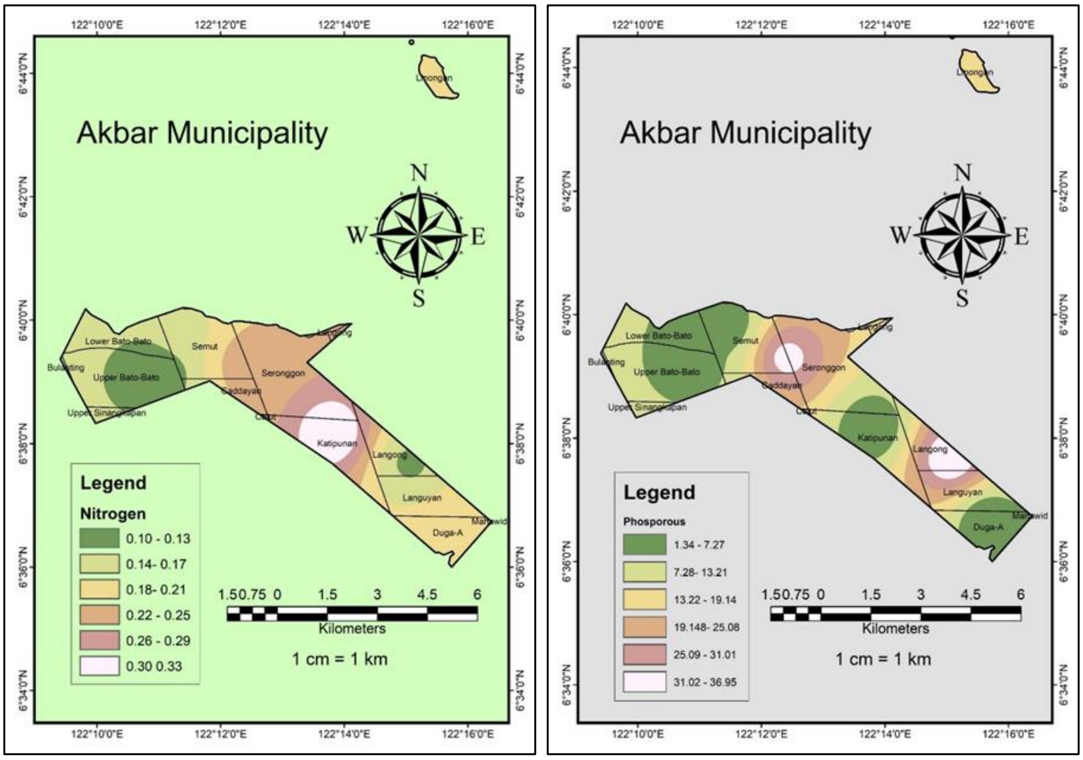
Table 4: Fertility level of Phosphorous (ppm) in the soil of Abkar Municipality

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

Potassium

The amount of potassium (Table 1) in the study area ranged from 145.07- 725.28 ppm. The lowest amount is analyzed from the soil sample (S5) taken from Caddayan, while the highest is taken from Semmut at soil sample (S3). The concentration of potassium is highly varied. Based on table 5, only one (1) area each has a low and medium level of potassium, while the rest of the areas are high concentrations of potassium.

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 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,



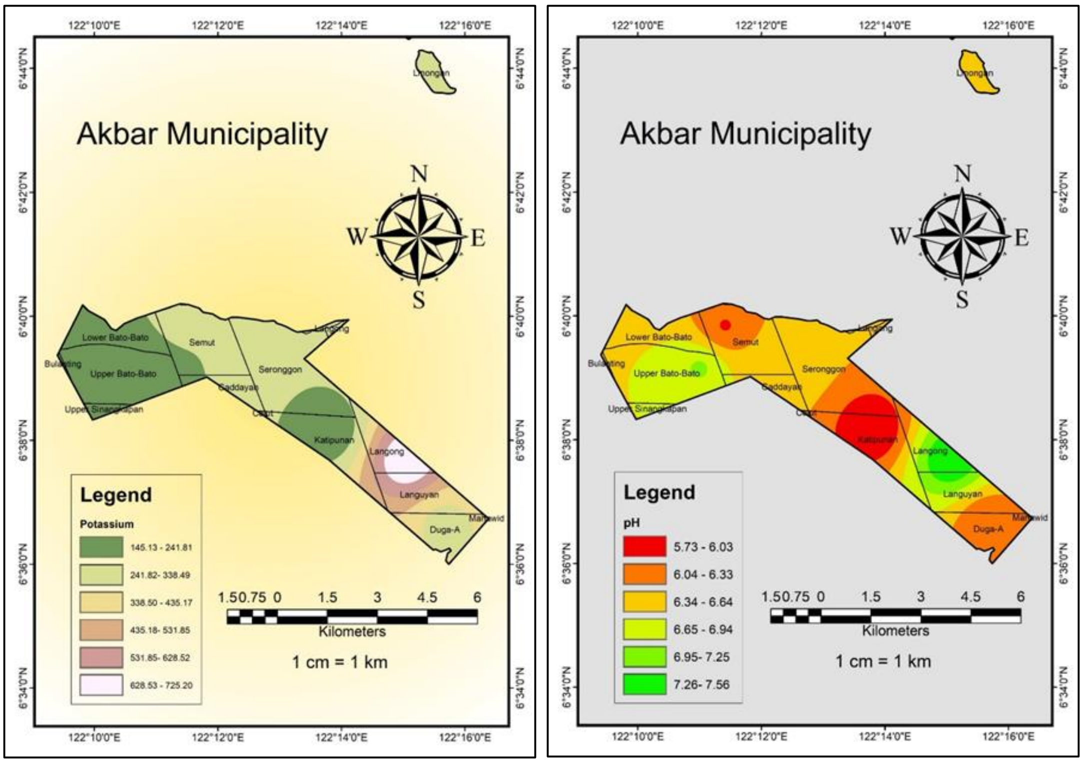


Fig 2: Spatial Distribution of, a) Nitrogen, b) Phosphorous, c) Potassium, d) pH in the Municipality of Akbar. *(Note: Map Municipal boundaries is not official)* increases plants' protein content, builds cellulose and reduces lodging, and helps retard crop diseases (https://extension.umn.edu).

The spatial distribution of potassium (Figure 2c) in the study area showed that a low to medium amount started from the center to the entire western parts. Conversely, a higher amount of potassium goes entirely to the eastern part of Akbar municipality.

Table 5: Fertility level of Potassium (ppm) in the soil of Akbar Municipality

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

Soil pH

The pH (Table 1) of the study area ranged from 5.73 – 7.56. The lowest pH was taken from the soil sample (S1) at village Mangusu while the highest was taken from the soil sample (S3) at village Semmut. Based on Table 6, soil samples (S1, S2, and S4) were considered acidic, soil samples (S5 and S6) were neutral, and soil sample (S3) was considered alkaline. It means, the soil pHs' of Akbar municipality were varied, categorized from acidic to alkaline.

Soil pH affects the amount of nutrients and chemicals that are answerable in soil water, and therefore the amount of nutrients available to shops. There are nutrients are more available under acidic environment while others under alkaline conditions. Still, 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 in 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 as 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 most of the areas have soil pH ranging from 5.73 to 6.64 while only a few areas in the upper bato-bato and Pangong villages have higher soil pH.

Table 6: pH level of the soil of Abkar Municipality

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

4. Conclusion and Recommendation

The soil organic matter (SOM) in the study area is within the range of 1.6 -3.1 and greater than (> 3), which means the amount of organic matter (SOM) is moderate to high under the loam textural class. The organic carbon is located in the village of Mangusu with a value of 3.88 % while the lowest value of 1.17 %, a soil sample taken from Caddayan. The soil organic carbon (SOC) in the study area is within the range of 0.9 -1.8 % and greater than (> 1.8), which means the amount of organic carbon (SOC) is moderate to high under the loam textural classes. The highest percentage of nitrogen in the study area was situated in Mangusu village with a value of 0.33 %, followed by 0.24 % from Mangalut village. However, the lowest value was recorded from the sample taken from the upper bato-bato of 0.10 %. The percentage of nitrogen in the entire Akbar Municipality is excessive where an amount falls within the range of >0.003. The amount of phosphorous indicated that the soil sample (S3) has the highest value of 36.96 ppm, followed by the soil sample (S6) of 33.59 ppm taken from Semmut and upper Sinangkapan villages, respectively. Conversely, the lowest value of 1.34 ppm is analyzed from a soil sample (S1) taken from Mangusu village. The level of phosphorous in the study area is categorized as low and medium. The amount of potassium in the study area ranged from 145.07- 725.28 ppm. The lowest amount was analyzed from the soil sample (S5) taken from Caddayan, while the highest is taken from Semmut at soil sample (S3). The concentration of potassium is highly varied. Only one (1) area each has a low and medium level of potassium while the rest of the areas are high concentrations of potassium. The pH of the study area ranged from 5.73 – 7.56. The lowest pH was taken from the soil sample (S1) at village Mangusu, while the highest is taken from the soil sample (S3) at village Semmut.

5. References

1. Abbott LK, Murphy MV. Soil Biological Fertility: A Key to Sustainable Land Use in Agriculture; Kluwer Academic Publishers: Dordrecht, the Netherlands, 2003, 264.
2. Adelman DE, Barton JH. Environmental regulation for agriculture: Towards a framework to promote sustainable intensive agriculture. Stan. Envtl. LJ, 2002 21:3.
3. Ayoubi S, F Khormali, KL Sahrawat, AC. Rodrigues de Lima, Assessing impacts of land use change on soil quality indicators in a loessial soil in Golestan province, Iran, Journal of Agricultural Science and Technology. 2011; 13:727–742.
4. Bremner JM. Nitrogen-total. Methods of soil analysis: Part 3 Chemical methods. 1996; 5:1085-1121.
5. Cardone L, Castronuovo D, Perniola M, Scrano L, Cicco N, Candido V. The Influence of Soil Physical and Chemical Properties on Sa ff ron (Crocus sativus L.) Growth, Yield and Quality, 2020, 1-22.
6. Cihacek LJ, Lizotte DA. Evaluation of an aluminum digestion block for routine total soil phosphorus determination by alkaline hypobromite oxidation. Communications in soil science and plant analysis. 1990; 21(19-20):2361-2370.
7. Dexter AR. Soil physical quality: Part I. Theory, effects of soil texture, density, and organic matter, and effects on root growth. Geoderma. 2004; 120(3-4):201-214.
8. Eckert D, Sims JT. Recommended soil pH and lime requirement tests. Recommended soil testing procedures for the northeastern United States. Northeast Regional Bulletin, 493, 11-16.The agricultural European Innovation Partnership (EIP-AGRI). (2016). Soil organic matter matters Investing in soil quality for long-term benefits. Soil Organic Matter Matters Investing in Soil Quality for Long-Term Benefits, 1995, 8. https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_brochure_soil_organic_matter_matters_2016_en_web.pdf.
9. https://extension.umn.edu/phosphorus-and-potassium/potassium-crop-production
10. https://www.qld.gov.au/environment/land/management/soil/soil-properties/ph-levels
11. Khalil HPSA, Hossain MS, Rosamah E, Azli NA, Saddon N, Davoudpoura Y, Islam MN, Dungani R. The role of soil properties and it's interaction towards quality plant fiber: A review. Renew. Sustain. Energy Rev. 2015; 43:1006-1015.
12. Ladha JK, H Pathak, A Tirol-Padre, D Dawe. Productivity trends in intensive rice-wheat cropping systems in Asia, in Improving the Productivity and Sustainability of RiceWheat Systems, Issues and Impacts, pp. 45–76, ASA Special Publications, ASA, CSSA, SSSA, Madison, WI, USA, 2003.
13. Lucas-Borja ME, Zema DA, Plaza-Álvarez PA, Zupanc V, Baartman J, Sagra J, *et al*. Effects of different land uses (abandoned farmland, intensive agriculture and forest on soil hydrological properties in Southern Spain. Water. 2019; 11(3):503.
14. Magdoff F. Building Soils for Better Crops. In Soil Science, 1993, 156(5). https://doi.org/10.1097/00010694-199311000-00014
15. McCauley A, Jones C, Jacobsen J. Soil pH and organic matter. Nutrient management module. 2009; 8(2):1-12.
16. Moral FJ, Rebollo FJ. Characterization of soil fertility using the Rasch model. 2017; 17(2):486-498.
17. Nájera F, Tapia Y, Baginsky C, Figueroa V, Ca- beza R, Salazar O. Evaluation of soil fer- tility and fertilisation practices for irrigated maize (Zea mays L.) under Mediterranean conditions in central Chile. J Soil Sci. Plant Nutr. Pedrera-Parrilla. 2015; 15(1):84-97.
18. Nanganoa LT, JN Okolle, V Missi, JR Tueche, LD Levai, JN Njukeng. Impact of different land-use systems on soil physicochemical properties and macrofauna abundance in the humid tropics of Cameroon, Applied and Environmental Soil Science, 2019, 9. Article ID 5701278.
19. The agricultural European Innovation Partnership (EIP-AGRI). Soil organic matter matters Investing in soil quality for long-term benefits. Soil Organic Matter Matters Investing in Soil Quality for Long-Term Benefits, 2016, 8. https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_brochure_soil_organic_matter_matters_2016_en_web.pdf.
20. Rockström J, Williams J, Daily G, Noble A, Matthews N, Gordon L, *et al*. Sustainable intensification of agriculture for human prosperity and global sustainability. Ambio. 2017; 46(1):4-17.
21. Saraf AK, Choudhury PR. Integrated remote sensing and GIS for groundwater exploration and identification of artificial recharge sites. International journal of Remote sensing. 1998; 19(10):1825-1841.
22. Seth A, D Sarkar, RE Masto, *et al*. Critical limits of Mehlich 3 extractable phosphorous, potassium, sulfur, boron and zinc in soils for nutrition, of rice (Oryza sativa L.), Journal of Soil Science and Plant Nutrition. 2018; 18(2):512-523.
23. Spain AV, Isbell RF, Probert ME. Organic matter contents of Australian soils, in Soils: An Australian Viewpoint, (CSIRO, Melbourne/Academic Press, London), 1983, 551-563.
24. Stewart ZP, GM Pierzynski, BJ Middendorf, PVV Prasad. Approaches to improve soil fertility in subSaharan Africa, Journal of Experimental Botany. 2020; 71(2):632-641.
25. Sui D, Morrill R. Computers and geography: From automated geography to digital earth. In Geography and technology. Springer, Dordrecht, 2004, 81-108.
26. Tening AS, JAI Omueti, G Tarawali, MA Mohamed-

Saleem. Potassium status of some selected soils under different land-use systems in the sub-humid zone of Nigeria, Communication in Soil Science and Plant Analysis. 1995; 26:5-6.
27. Tesfahunegn GB, TA Gebru. Variation in soil properties under different cropping and other land-use systems in Dura catchment, Northern Ethiopia, PLoS One, 2020, 15(2). Article ID e0222476.
28. The agricultural European Innovation Partnership (EIP-AGRI). Soil organic matter matters Investing in soil quality for long-term benefits. Soil Organic Matter Matters Investing in Soil Quality for Long-Term Benefits, 2016, 8. https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_brochure_soil_organic_matter_matters_2016_en_web.pdf.
29. Tsiafouli MA, Thébault E, Sgardelis SP, De Ruiter PC, Van Der Putten WH, Birkhofer K, *et al*. Intensive agriculture reduces soil biodiversity across Europe. Global Change Biol. 2015; 21(2):973-985.
30. Vitinotes. Measuring organic carbon in soil (Cooperative Research Centre for Viticulture: Adelaide, SA, Australia), 2006.
31. Yusuf R, Syakur A, Awalni F, Kalaba Y. Combinations of seaweed extract and NPK on vegetative growth of chili growing under glasshouse condition. IOP Conference Series: Earth and Environmental Science, 2021, 694(1). https://doi.org/10.1088/1755-1315/694/1/012034.
32. Zia MS, F Hussain, M Aslam, ME Akhtar, A Hamid. Basis for formulation of fertilizer recommendations for crop production, International Journal of Agriculture and Biology. 2003; 5(3):392-396.
33. Zhao S, Peng C, Jiang H, Tian D, Lei X, Zhou X. Land use change in Asia and the ecological consequences. Ecological Research. 2006; 21(6):890-896.