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Investigation on the variations of soil properties of different agricultural soils in central Myanmar

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Abstract

Soil properties are varied under human disturbance and understanding how the soil properties change is vital to know the potential of soils and their sensitivity to different soil managements. The aim of this study was to analyze the variation in soil physicochemical characters as influenced by different soil managements (orchards, crop rotation, and intensive use of fertilizer), in central dry zone in Myanmar. Eight soil properties such as soil texture, pH, electrical conductivity (EC), organic matter (OM), total nitrogen, available phosphate (Olsen P), extractable potassium (extractable K), cultivable bacterial counts were analyzed for top soil samples collected from twenty-one agricultural sites which planted for seven different crops. The results showed that studied soil properties except from soil texture were significantly different among studied soils ($P<0.05$), Olsen P were significantly higher in orchard soils (most intact), than other soil. (OM), (EC), and extractable K were significantly higher in onion soils (intensive use of fertilizer), Clay percent is significantly and positively correlated with most of the soil properties except from Olsen P. These results imply that soil properties are varied based on soil type and land use; therefore, agricultural management is important to maintain and enhance soil physicochemical properties and sustain ecosystem.

Keywords: Soil Properties, Soil Management, Soil Type, land Use, Central Dry Zone.

INTRODUCTION

Soil physical and chemical properties greatly influence on crop production[1]. Land use and agricultural management have great impact on soil properties which affect soil quality that led to augmentation or limitation of crop yield and sustainable agriculture[2]. The degradation of soil physicochemical properties usually evolves from interactions among physical process such as erosion, chemical process such as nutrient depletion, acidification and biological processes such as organic matter depletion. In the woodland and grassland areas of Africa, South America, and Asia, shifting of small-scale farmers practicing or semi shifting cultivation are accountable for loss of soil structure and fertility[3].

Myanmar is an agricultural country, agriculture accounted for 38%, of GDP, 70% of the workforce and generates 25 to 30 percent of total export earnings in 2018 (https://www.fao.org/myanmar/fao-in-myanmar/), However, Myanmar's agriculture has not performed well during the last 50 years because of low productivity, instability of yield and unequal distribution of land[3].

The central dry zone is a relatively low-lying area in the middle of Myanmar and 12 percent of the country's land area. Approximately 23 percent of the total population of Myanmar live this area; 80 percent of them are classified as rural population and 60 percent of households survive on agriculture[3]. Central dry zone is the center of rain-fed, upland cropping in Myanmar and the climate is arid to semi-arid with mean annual rainfall ranging from around 500 to 1,000 mm per annum[4]. In central dry zone, peas and beans such as green gram, groundnut, pigeon pea, cowpea is commonly grown in sequence with sesame and the coarse grains, pearl millet, sorghum, sunflower, green beans and maize[3,5,6]. In addition, palm sugar (jaggery), cotton and tobacco are important crops in some areas although a few communities grow onions and chilies on a commercial basis (https://www.lift-fund.org/download/file/fid/836), Moreover, some perennial trees such as wood apple (Thanaka in Myanmar name), and jambolan (Thapyay in Myanmar name), are also planted as orchard. Wood apple prefers hot and dry weather that is compatible with central dry zone[5]. Jambolan, a species from Syzygies genus which prefer to grow under tropical and subtropical climate. These species can grow in various soil types and geological formations and some of them tolerate saline soil and are found on deep, rich, well-drained soils[7]. Syzygies genus is from Myrtaceae family which possesses 1200–1800 species. All Syzygies species are rich medicinal applications; some species of Syzygies have antibacterial, antioxidant activities[8]. and some has potential as effective anti-diabetic agent.

Although bean, pulses, oilseed crops, wood apple and jambolana are usually grown in central dry zone, approximately 6-7 years ago, most of the farmers grow onion because of market prices and short cultivation time (Lynn et al, 2020), For onion cultivation, intensive fertilizers, pesticides and irrigation system need to apply. Consequently, soil physicochemical properties are changed, and the lands are seriously eroded and degraded and it may be needed to reclaim and restore the land in these areas (https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2021/04/myanmar-baef-report-adaptation.pdf).

And also, there may be different between the soil properties in mono-cropping and intercropping of soils. However, the information of that around Myaing Township in central dry zone of Myanmar is still rare. Studying soil physicochemical properties in different soils will help to understand which agricultural system can enhance soil properties and sustainable agriculture in long term effect. The main objective of this study was to look into how land use and soil type configures soil physicochemical properties and bacterial abundance in agricultural soils with typical farming practices around Myaing Township in central dry zone of Myanmar.

MATERIALS AND METHODS

Soil sample collection

Twenty-one soil samples which planted with seven major crops in central dry zone were collected from Myaing Township, Magway Region in low land plain. Wood_A (soil from wood apple orchard), JB (soil from jambolana orchard), SS (soil from mono-crop of sesame), GB_SS (soil from crop rotation of green beans and sesame), CP-SF (soil from crop rotation of chickpeas and sunflower), ON-CH (soil from crop rotation of onion and chickpeas), and ON (soil from monocrop of onion), were collected from three sites for each crop. Full site details, cultivation history and soil texture were given in Table 1.

Table 1: Information of soil sampling sites and soil texture and soil type of 21 different soils for 7 major crops in central dry zone of Myanmar

Soils	Sampling sites		Cultivation	Clay (%)	Silt (%)	Sand (%)	Soil Type
Wood_A -1	Latitude	21º 49' 49" N	Wood Apple orchard	15.31	17.86	64.09	Sandy loam
	Longitude	94º 50' 40" E					
Wood_A-2	Latitude	21º 50' 19" N	Wood Apple orchard	0.00	12.59	85.79	Sandy
	Longitude	94º 51' 11" E					
Wood_A -3	Latitude	21º 50' 49" N	Wood Apple orchard	2.53	22.78	74.63	Loamy sand
	Longitude	94º 51' 12" E					
JBL-1	Latitude	21 º 51' 2" N	Jambolan orchard	13.99	13.99	70.24	Sandy loam
	Longitude	94º 51' 11" E					
JBL-2	Latitude	21º 51' 2" N	Jambolan orchard	26.11	41.78	31.12	Loam
	Longitude	94º 51' 10" E					
JBL-3	Latitude	21º 50' 59" N	Jambolan orchard	10.26	17.95	74.61	Sandy loam
	Longitude	94º 50' 56" E					
SS-1	Latitude	21º 49' 53" N	Sesame (two times per year)	5.05	15.15	79.39	Loamy sand
	Longitude	94º 50' 40" E					
SS-2	Latitude	21º 49' 47" N	Sesame (two times per year)	12.79	17.90	66.38	Sandy loam
	Longitude	94º 50' 41" E					
SS-3	Latitude	21º 49' 55" N	Sesame (two times per year)	2.51	12.56	82.09	Loamy sand
	Longitude	94º 50' 54" E					
GB-SS-1	Latitude	21º 49' 46" N	Rotation of green beans and sesame	7.63	12.72	78.16	Loamy sand
	Longitude	94º 50' 46" E					
GB-SS-2	Latitude	21º 49' 57" N	Rotation of green beans and sesame	2.53	15.15	81.20	Loamy sand
	Longitude	94º 50' 53" E					
GB-SS-3	Latitude	21º 49' 57" N	Rotation of green beans and sesame	15.35	12.79	69.30	Sandy loam
	Longitude	94º 51' 8" E					
CP-SF-1	Latitude	21º 50' 54" N	Rotation of chickpea and sunflower	38.46	22.55	40.52	Clay loam
	Longitude	94º 51 31" E					
CP-SF-2	Latitude	21º 50' 50" N	Rotation of chickpea and sunflower	59.46	27.03	14.82	Clay
	Longitude	94º 51' 34" E					
CP-SF-3	Latitude	21º 50' 52" N	Rotation of chickpea and sunflower	57.07	27.17	18.80	Clay
	Longitude	94º 51' 43" E					
ON-CH -1	Latitude	21º 51' 7" N	Rotation of onion and chilli	48.78	35.23	18.91	Clay
	Longitude	94º 50' 48" E					
ON-CH -2	Latitude	21º 51' 7" N	Rotation of onion and chilli	47.87	37.23	15.80	Clay
	Longitude	94º 50' 44" E					
ON-CH -3	Latitude	21º 51' 9" N		45.70	37.63	17.81	Clay

	Longitude	94º 50' 44" E	Rotation of onion and chilli				
ON-1	Latitude	21º 51' 9" N	Onion	53.76	24.19	21.52	Clay
	Longitude	94º 50' 49" E					
ON-2	Latitude	21º 51"13" N	Onion	56.15	32.09	9.05	Clay
	Longitude	94º 50 45" E					
ON-3	Latitude	21º 51' 1" N	Onion	10.18	10.18	81.65	Loamy sand
	Longitude	94º 51' 11" E					

Samples were collected on July, 2020 when crops were not planted in soils except for Wood_A and JB which were the soils from perennial tree orchards. From each site, three replicate of soil samples were collected, and for each replicate, three soil cores (top 0–10 cm), were collected randomly using a soil sampler, and then, mixed to obtain one homogenized replicate[5]. The samples were screened through a 2-mm sieve and any visible debris were eliminated. A portion of each soil sample was stored at 4°C to analyze bacterial composition. The remaining soil sample was air dried to measure other soil properties.

Measurement of soil properties

The soil pH was measured using a pH meter (Mettler Toledo, Switzerland), after shaking a soil: water (1:2 w/v) suspension and electrical conductivity (EC) of soil was measured after shaking the soil with distilled water (1:5 w/v) [9]. Soil moisture content was determined after oven-drying at 105 °C to a constant weight. Soil texture (clay, silt, sand %) was determined with hydrometer[10]. Organic matter in soil was determined with hydrogen peroxide combustion method[11,12]. A conversion factor of 1.724 was used to convert organic matter to organic carbon in soil by assuming organic matter contains 58 percent organic C[13]. Total nitrogen (TN) content was determined by Kjeldahl digestion (UDK149 Automatic Kjeldahl Nitrogen Analyzer, Korea), [14]. Olsen-P was extracted from soil using 0.5 M $NaHCO_3$ and analyzed [15] at 830 nm with a UV-Vis spectrophotometer (UVD2950, USA). For Extractable potassium, soil was extracted with ammonium acetate and measured with flame photometer (JEMWAY PFP-7, UK) [16].

Estimation of bacterial abundance in soil

Nutrient medium was used to estimate the total bacterial count in collected soils. Glucose nitrogen free mineral medium was used to estimate the count for nitrogen fixing bacteria[17]. For phosphate solubilizing bacteria, Pikovskaya’s medium was applied[18]. For potassium decomposing bacterial count, K decomposing media was used[19]. After 24-48 h of incubation at 35°C, discrete colony showing clear zones were counted as phosphate solubilizing bacteria and potassium decomposing bacteria. Serial dilution method was used for all the estimation of bacterial abundance. One gram of soil was added to 9 ml normal saline and shake for 30 min. After that, stand in still for 30 min to be stable and took 1 ml for serial dilution until [10-6]. Then, 100 ul from each dilution was spread on respective media and results were analyzed after appearing colonies.

Statistical analysis

One way analysis of variance (ANOVA), and comparisons of soil properties and bacterial abundance were performed using Duncan’s test (P<0.05), with agricolae R package[20]. Correlation of soil properties and bacterial abundance were calculated with corrplot in R and all the figures were displayed with ggplot2 in R program[21].

RESULTS

Variation in soil physicochemical properties

The significance of variations in the soil properties ($p < 0.05$), among the seven different crops across the low land plain are presented in (Fig. 1, 2 and 3), Most soil are sandy, sandy loam and loamy sand apart from CP-SF, ON-CH, and ON soils which soil textures are clay (Table 1), JBL, CP-SF, ON-CH, and ON, soils showed the highest pH and soil moisture content whereas pH in SS soil was significantly lower than other soils and the lowest soil moisture was found in Wood_A, SS, GB-SS soils. The highest EC, was appeared in ON-CH and ON soils while Wood_A, SS, and GB-SS soils showed the lowest value (Fig. 1). Organic matter OM, in CP-SF soil was significantly higher than other soils while OM content of GB-SS soil was the lowest. The highest total nitrogen (TN) content is found in JBL soil whereas GB-SS, soil showed the lowest TN, although TN contents in all soils were not significantly different except from JBL and GB-SS soil. The amount of OM, TOC and CN ratio in Wood_A, JBL, SS and GB-SS soils were not much different (Fig. 2). Similarly, JBL, soil possess the highest available P while the lowest value was found in CPSF soil. For extractable K, CP-SF was the highest and SS soil showed the lowest ranging from 0.017 to 0.62 percent in soil (Fig. 2).

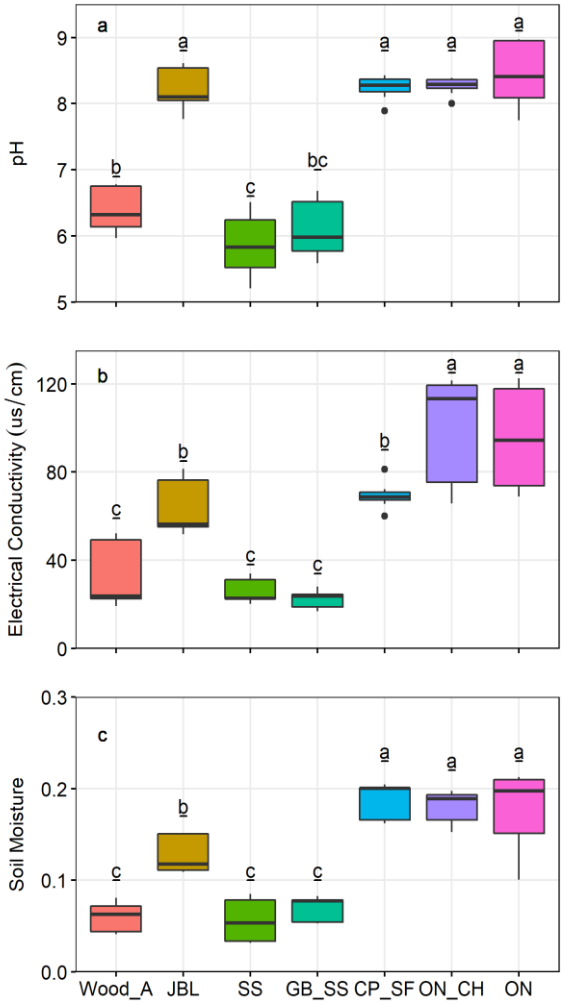

Fig. 1: pH, EC and soil moisture of 21 different soils for 7 crops. Different small letters indicate significant difference ($p < 0.05$). Error bars represent standard error (n=9). Wood_A – soil from wood apple orchard, JBL- soil from jambolan orchard, SS – soil from sesame farmland, GB_SS – soil from the rotation of green beans and sesame, CP-SF – soil from the rotation of chickpeas and sunflower, ON_CH – soil from the rotation of onion and chilli, ON – soil from the onion cropping.

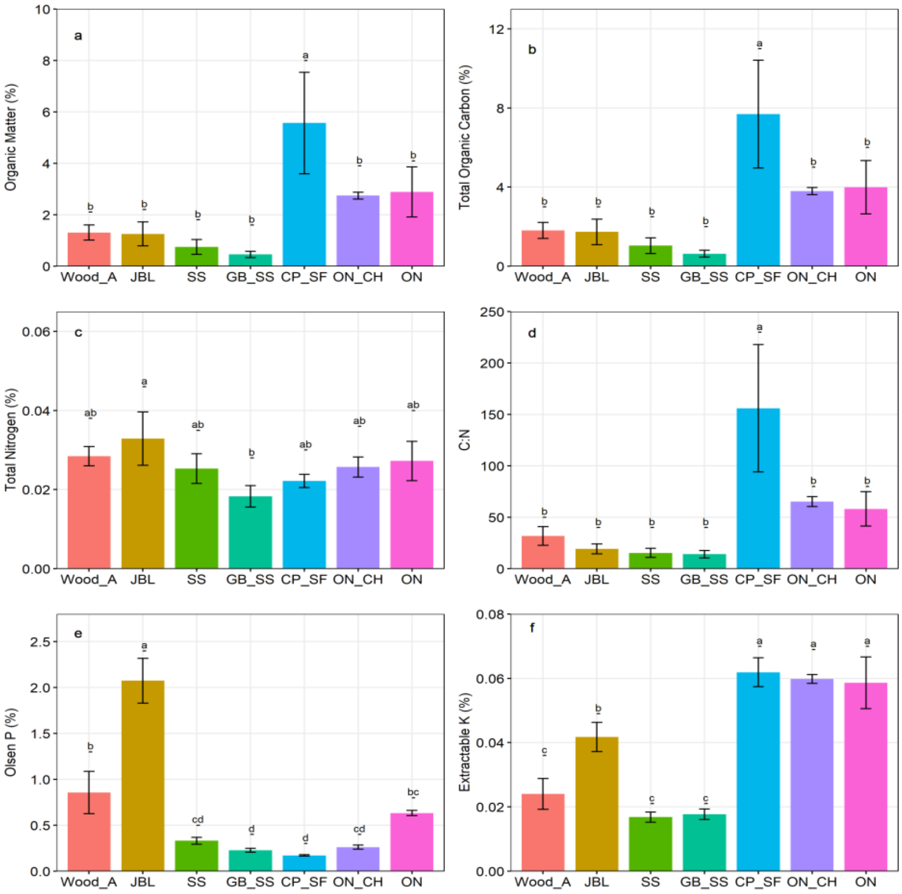

Fig. 2: Nutrient contents of 21 different soils for 7 crops. Different small letters indicate significant difference ($p < 0.05$). Error bars represent standard error (n=9). Wood_A – soil from wood apple orchard, JBL- soil from jambolan orchard, SS – soil from sesame farmland, GB-SS – soil from the rotation of green beans and sesame, CP-SF – soil from the rotation of chickpeas and sunflower, ON-CH – soil from the rotation of onion and chilli, ON – soil from the onion cropping.

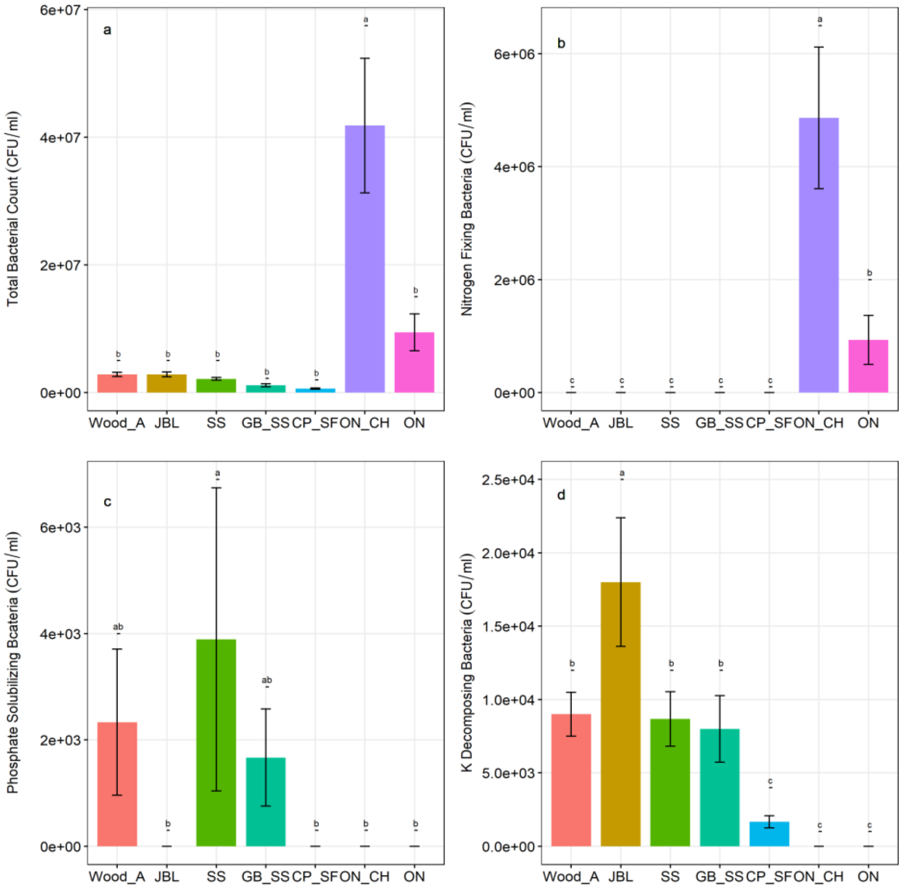

Fig. 3: Cultivable bacterial abundance of 21 different soils for 7 crops. Different small letters indicate significant difference ($p < 0.05$). Error bars represent standard error (n=9). Wood_A – soil from wood apple orchard, JBL- soil from jambolan orchard, SS – soil from sesame farmland, GB_SS – soil from the rotation of green beans and sesame, CP-SF – soil from the rotation of chickpeas and sunflower, ON_CH – soil from the rotation of onion and chilli, ON – soil from the onion cropping

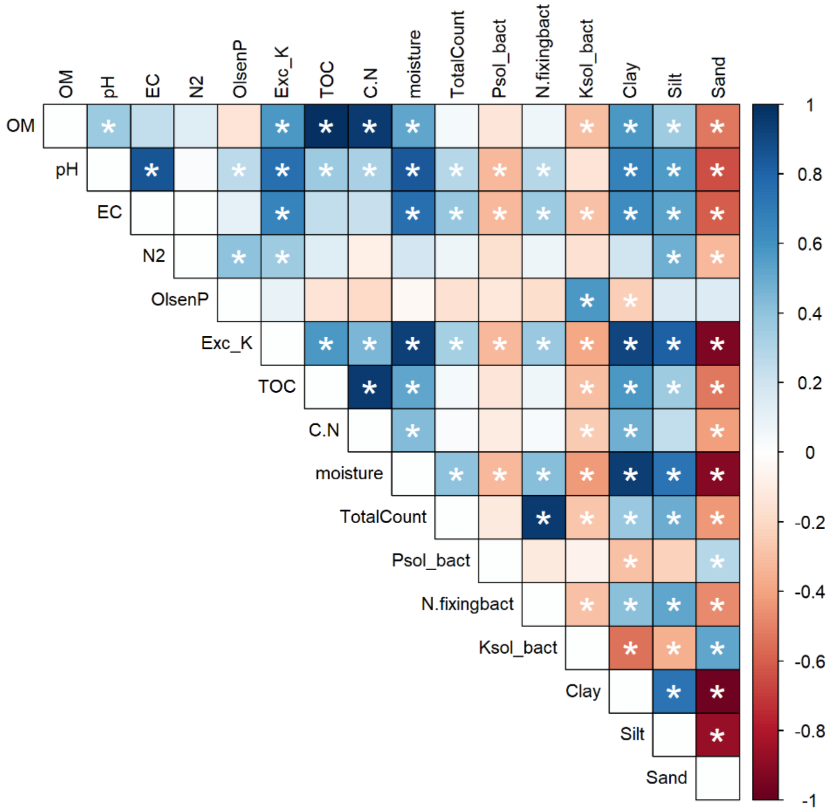

Fig. 4: Relationship between soil physiochemical properties of 21 different soils for 7 crops, C:N – the ratio of carbon to nitrogen

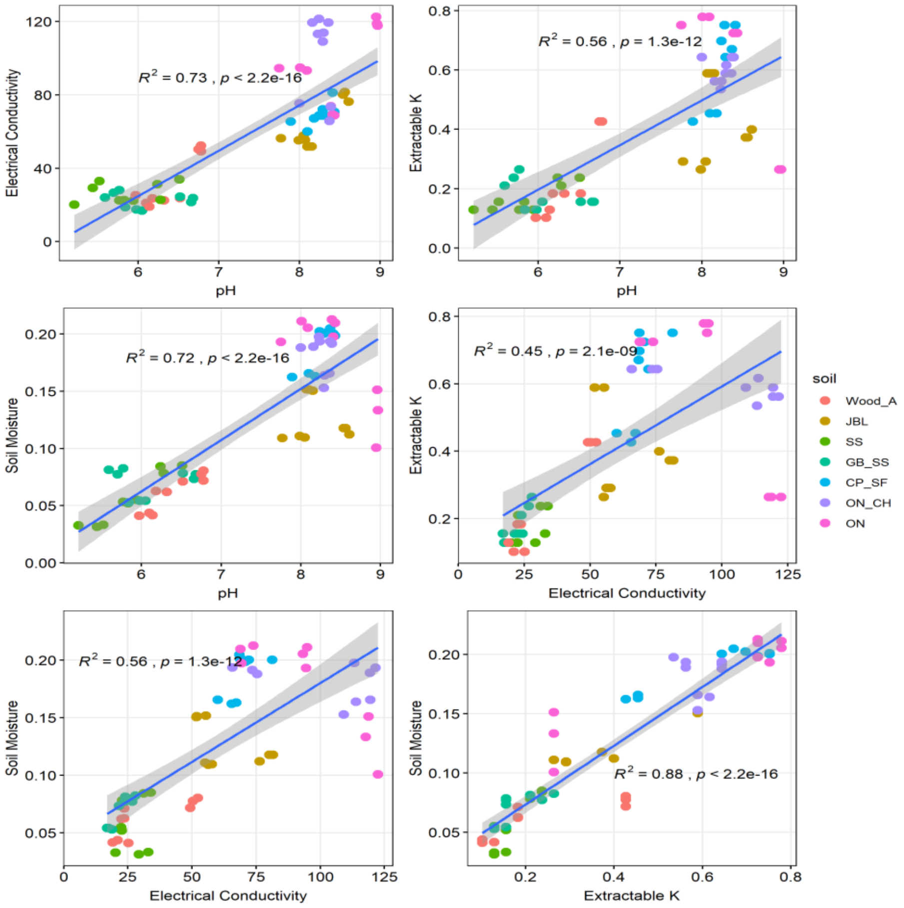

Fig. 5: Relation between soil physicochemical soil parameters by linear regression method (only R2> 0.45 and P>0.05 are presented)

Bacterial abundance

The highest cultivable total bacterial count was found ON-CH soil whereas the lowest in CP-SF soil. Nitrogen fixing bacteria were found only in CH and CH-ON soils. Phosphate solubilizing and Potassium decomposing bacteria were found only in Wood_A, SS and GB-SS soils (Fig.3).

Correlation between soil physicochemical properties

Soil moisture was significantly and positively correlated with pH, EC and extractable K ($P<0.001$), and ($R2>0.56$), Extractable K was apparently dominated by pH and EC, ($P<0.001$), and ($R2>0.45$), pH and EC were found significantly and positively related with each other ($P<0.001$), and ($R2=0.73$), (Fig. 4 and Fig. 5), Clay percent and Silt percent were positively correlated with soil properties whereas sand% showed negative influence on soil properties (Fig. 4), Although most of soil properties were positively correlated with clay percent, Olsen P and the abundance of P-solubilizing bacteria and K- solubilizing bacteria were negatively correlated with it. Surprisingly, Olsen P and abundance of these two bacteria were positively correlated with sand percent (Fig. 4).

DISCUSSION

Soil is the basis of sustainable agriculture, and soil fertility is becoming the major issue at global level because of climate change and mismanagement of land use which can decrease soil properties by hanging in the soil biota. Nearly two billion hectares of soils are considered to be degraded, which are less productive due to deterioration of essential soil processes[2]. Therefore, observation of soil properties in different agricultural soils will help to maintain the soil quality of agricultural lands.

Twenty-one soils which grow seven different crops under conventional agriculture was studied. The soil properties differed significantly among different soils (Fig. 1, Fig. 2 and Fig. 3), Since central dry zone has average annual rainfall levels (960 mm), which are lower than in other areas of the country[22]. Most tested soil are sandy, sandy loam and loamy sand apart from CP-SF, ON-CH and ON soils. The highest pH and EC in ON-CH and ON soils described that higher usage of chemical fertilizers and pesticides rooting for higher pH and EC, (Fig. 1), Irrigation can increase EC of soil because of evapotranspiration [23]. Irrigation in ON-CH and ON soils might be the answer to the highest EC values in those soils.

Studies show that ideal EC levels in soil should be in the range of 110-570 milli Siemens per meter (mS/m), [24]. Higher EC values indicate an excess of nutrients whereas lower EC values indicate low available nutrients[25]. Therefore, Low EC are often found in low organic matter containing soils such as sandy soil whereas high EC values are usually found in soils with high clay content because clay soils have a much better ability to store and hold onto cations. It was explained that texture, salinity and moisture are most significantly influence on EC levels (http://traceandsave.com/what-can-electrical-conductivity-tell-us-about-our-soil), That finding is in agreement with our results in which clay soils showed higher EC levels than sandy soils (Fig. 1).

Surprisingly JBL showed the highest pH along with ON soil although JBL soil was added only a few amounts of chemical fertilizer. It was found that most soils in Magway region had pH ranging from (6-8.5) [26] and that is compatible with our results except from SS soil which pH was less than 6. Similar to pH, the soil moisture content of JBL, CP-SF, ON-CH and ON were significantly higher than other soils since pH and soil moisture content were positively correlated.

The lowest value of EC was found in Wood_A SS and GB-SS soils because these soils were with less agricultural management practices. And also, another reason for this result is that these soils are sandy soils which have poor capacity to store and hold onto cations and lose nutrients easier than silt and clay soils[27]. These results described that both land use and soil type played significant role in variations of pH, EC and soil moisture content.

CP-SF soils possessed the highest content of OM, TOC and soil moisture which indicated that clay soil type, crop rotation, water content of soil had positive effect on the physicochemical properties of soil. It was observed that crop rotation could increase the input of organic C in the soil, which led to enhancing soil fertility[5,28]. Moreover, it was well documented that soil organic matter can increase water holding capacity of soil by increasing the micropores and macropores in the soil either by gluing soil particles together[29]. Not only OM soil moisture significantly and positively correlated with pH, EC and extractable K. Moreover, pH and EC were significantly and positively related to each other. Similar to our results, a significant positive correlation between soil pH and EC was described in agricultural lands in western Iran[30].

The lowest amount of OM in GB-SS, soil was the answer for the lowest amount of TN in that soil since increased OM had a positive effect on soil TN[5]. Surprisingly, the highest amount of TN and available P were found in JBL soil although these soils were with less chemicals input and the soil types were loamy and sandy loam. CP-SF, ON and ON-CH soils showed higher extractable K amount than other soils because these soils contained higher clay contents than other soils since clay content was the major player for variation of soil properties except for nitrogen (Fig. 4).

Olsen P was positively correlated with pH value although other research reported that low pH can help to occupy higher available P[5]. Soils with less anthropogenic activity showed the highest Olsen P content and more information was needed to explain about it well. Nitrogen and Olsen P were positively correlated because phosphorus availability can enhance nitrogen fixation in which nitrogen fixation process requires large amounts of adenosine triphosphate (ATP), [31].

The abundance of total bacteria and nitrogen fixing bacteria were positively correlated with pH, EC, extractable K, soil moisture, clay percent and silt percent (Fig. 4), since soil chemical properties are good indicators of the richness of soil fauna and flora[32]. Other study reported that soil properties had positive effect on abundance of total bacteria and nitrogen fixing bacteria[31]. Different bacterial abundance from different soils was as a result of variation in the soil edaphic factors succeeded by differences land-use[32]. In contrast to total bacterial count, the abundance of P solubilizing bacteria and K decomposing bacteria were negatively correlated with most of the soil properties. More research works with advanced technology are needed to confirm these results since only plate count method was used to estimate bacterial abundance. Our results showed that both soil type and land use had significant effects on variations of soil physicochemical properties and abundance of total bacteria and plant growth promoting bacteria although more research with a wide range of soil samples and more advanced technology are needed to broaden the knowledge on soil properties in this central Myanmar area.

CONCLUSION

This study assessed soil properties and abundance of total bacteria, N-fixing bacteria, P-solubilizing bacteria and K-decomposing bacteria in twenty-one different soils under seven different crops in semi-arid environment of Myanmar. All soil samples showed different soil properties including pH, EC, OM, TOC, TN, Olsen-P and extractable-K and also different bacterial abundances. Soils with higher input of chemical fertilizers possessed higher amount of pH, EC, OM, TOC and extractable K. Moreover, soils with higher clay percent showed higher values of soil properties and richer in soil nutrients which described clay percent is the main player in variation of soil nutrients in this region. Although understanding soil biology and soil health are important for sustainable agriculture and higher yields which lead to the profit of farmers, there is very little knowledge in field data relevant to the needs of their particular regions. This study will fill in these requirements by analyzing soil physicochemical properties and estimating the plant growth promoting bacterial abundance in soils under major crops in this central Myanmar region.

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Conflict of Interest

None declared.

Financial Support

None declared.

REFERENCES

1. Arévalo-Gardini E, Canto M, Alegre J, Loli O, Julca A, Baligar V, et al. Changes in Soil Physical and Chemical Properties in Long Term Improved Natural and Traditional Agroforestry Management Systems of Cacao Genotypes in Peruvian Amazon. 2015;10(7):e0132147.
2. Gurjar G, Swami S, Telkar S, Meena N, Kant K, Kumar R. Soil biological properties and their importance in agricultural production. Biomolecule reports. 2017;4.
3. Herridge DF, Win MM, Nwe KMM, Kyu KL, Win SS, Shwe T, et al. The cropping systems of the Central Dry Zone of Myanmar: Productivity constraints and possible solutions. Agricultural Systems. 2019;69:31-40.
4. Pavelic P, Senaratna SS, Johnston R, McCartney M, Sotoukee T, Balasubramanya S, Suhardiman D, Lacombe G, et al: Integrated Assessment of Groundwater Use for Improving Livelihoods in the Dry Zone of Myanmar. IWMI Research Report. 2015;164:52.
5. Lynn TM, Zhran M, Wang LF, Ge T, Yu SS, Kyaw EP, et al. Effect of land use on soil properties, microbial abundance and diversity of four different crop lands in central Myanmar. 3 Biotech. 2021;11(4):154.
6. Boori M, Choudhary K, Paringer R, Evers M: Food vulnerability analysis in the central dry zone of Myanmar. Computer Optics. 2017;41:552-58.
7. Nigam V, Nigam R. Distribution and medicinal properties of Syzygium species. Current Research in Pharmaceutical Sciences. 2012;3:73-80.
8. Wathsara HP, Weeratunge HD, Mubarak MN, Godakumbura PI, Ranasinghe P: In Vitro Antioxidant and Antidiabetic Potentials of Syzygium caryophyllatum L. Alston. Evidence-Based Complementary and Alternative Medicine. 2020;e9529042.
9. Lynn TM, Ge T, Yuan H, Wei X, Wu X, Xiao K, Kumaresan D, et al. Soil Carbon-Fixation Rates and Associated Bacterial Diversity and Abundance in Three Natural Ecosystems. Microbial Ecology. 2017;73(3):645-57.
10. Gee GW, Bauder JW. Particle size analysis. Methods of soil analysis, part. 1986;81(1):383-11.
11. Robinson WO: The Determination of Organic Matter in Soils by Means of Hydrogen Peroxide. Journal of Agricultural Research. 1927;34:339-56.
12. Schumacher B. Methods for the determination of total organic carbon (TOC) in soils and sediments: ecological risk assessment support center. Method NCEA-C-1282: United States Environmental Protection Agency. 2002:1-23.
13. Nelson DW, Sommers LE: Total Carbon, Organic Carbon, and Organic Matter. In: Methods of Soil Analysis. 1996;961-10.
14. Bremner JM: Determination of nitrogen in soil by the Kjeldahl method. Journal of Agricultural Science. 1960;55(1):11-33.
15. Olsen SR, Somers LE: Phosphorus. In: Methods of soil analysis. Edited by Page AL, Miller RH, Keene DR. Madison: Soil Science Society of America. 1982;403–48.
16. Jankowski SJ, Freiser H: Flame Photometric Methods of Determining the Potassium Tetraphenylborate. Analytical Chemistry. 1961;33(6):773-75.
17. Latt ZK, Yu SS, Kyaw EP, Lynn TM, Nwe MT, Mon WW, Aye KN, et al. Using Cellulolytic Nitrogen Fixing Bacterium, Azomonas agilis for Effective Degradation of Agricultural Residues. Open Microbiol J. 2018;12:154-62.
18. Pikovskaya RI: Mobilization of phosphorus in soil in connection with the vital activity of some microbial species. Mikrobiologiya. 1948;17:362-70.
19. Lynn TM, Win HS, Kyaw EP, Latt ZK, Yu SS. Characterization of Phosphate Solubilizing and Potassium Decomposing Strains and Study on their Effects on Tomato Cultivation. International Journal of Innovation and Applied Studies. 2013;3(4):959-66.
20. De Mendiburu F. Agricolae: statistical procedures for agricultural research. R package version. 2014;1(1):1-4.
21. Wickham H. ggplot2: elegant graphics for data analysis. springer; 2016.
22. LIFT LaFSF: Myanmar Dry Zone Development Programme Scoping Report. FAO Investment Centre 2014;1-62.
23. Corwin D, Lesch S: Application of Soil Electrical Conductivity to Precision Agriculture: Theory, Principles, and Guidelines. Symposium on Use of Soil Electrical Conductivity in Precision. 2003;95:455-71.
24. Bratoev K, Beloev H, Mitkov A, Mitev G: On the possibility of conducting fast and reliable soil tests. international scientific journal "mechanization in agriculture & conserving of the resources". 2020;(2):71-76.
25. Othaman NC, Isa MM, Ismail RC, Ahmad MI, Hui CK. Factors that affect soil electrical conductivity (EC) based system for smart farming application. InAIP Conference Proceedings. 2020;8(1):020055.
26. JICA JICA: Data Collection Survey on the Project for Development of Water Saving Agricultural Technology in the Central Dry Zone in the Republic of the Union of Myanmar. Final Report. 2013;3-291.
27. Minhal F, Ma'as A, Hanudin E, Sudira P: Improvement of the chemical properties and buffering capacity of coastal sandy soil as affected by clay and organic by-product application. Soil and Water Research. 2020;15(2):93-100.
28. Li T, Liu T, Zheng C, Kang C, Yang Z, Yao X, Song F, et al. Changes in soil bacterial community structure as a result of incorporation of Brassica plants compared with continuous planting eggplant and chemical disinfection in greenhouses. 2017;12(3):e0173923.
29. Bhadha JH, Capasso JM, Khatiwada R, Swanson S, LaBorde C. Raising soil organic matter content to improve water holding capacity. Uf/Ifas. 2017;24:1-5.
30. Bhadha JH, Capasso JM, Khatiwada R, Swanson S, LaBorde C. Raising soil organic matter content to improve water holding capacity. Uf/Ifas. 2017;24:1-5.
31. Ranjbar F, Jalali M: The combination of geostatistics and geochemical simulation for the site-specific management of soil salinity and sodicity. Computers and Electronics in Agriculture. 2016;121:301-12.
32. Huhe B S, Cheng Y, Nomura N, Nakajima T, Nakamura T, Uchiyama H, et al. Effect of Abandonment on Diversity and Abundance of Free-Living Nitrogen-Fixing Bacteria and Total Bacteria in the Cropland Soils of Hulun Buir, Inner Mongolia. 2014;9(9):e106714.
33. Mhete M, Eze PN, Rahube TO, Akinyemi FO: Soil properties influence bacterial abundance and diversity under different land-use regimes in semi-arid environments. Scientific African. 2020;7:e00246.