ANALYSIS OF SPATIAL VARIABILITIES IN SELECTED SOIL PROPERTIES UNDER AN OIL PALM CULTIVATION IN NEBODA, SRI LANKA

T.D.S. Ariyarathna* and M.M.M. Najim
Department of Zoology and Environmental Management,
University of Kelaniya, Sri Lanka

The impacts of oil palm (*Elaeis guineensis*) plantations on soil properties have not comprehensively studied in Sri Lanka. Information is lacking on the spatial differences of soil properties within oil palm cultivations. Therefore, the oil palm cultivation in Culloden estate, Dodangoda, in Kalutara District was selected as a suitable study area to assess the variability of selected soil physical and chemical properties. The main objectives of this study were to evaluate the impacts of oil palm cultivation on selected physical and chemical properties of soil and to determine the spatial differences between soil properties in the oil palm site and a reference site. The selected plantation was divided into 3 sites (S1, S2 and S3). Three representative sampling points from each zone were selected. A composite sample was prepared mixing the soil from each sampling point in a particular zone. The reference sampling (R) was taken from an abandoned grassland. Monthly sampling was done for six months. The Generalized Linear Model (GLM) followed by Tukey's pairwise comparison at 95% confidence level, was used to determine the spatial variation of studied soil parameters by using IBM SPSS statistics 26 software. When the soil texture was considered, oil palm cultivation had silty clay, and the reference land had silty clay loam. Soil pH, Soil electrical conductivity, soil bulk density, soil porosity, soil organic matter content, soil nitrogen, and phosphorus contents indicated a significant difference compared to the reference site ($p<0.05$, GLM followed by the Tukey's pair-wise comparison as a post-hoc analysis at 95% level of confidence). The highest mean soil nitrogen content and mean phosphorus content in the oil palm plantation at the topsoil were $0.17\pm0.004\%$ and 13.21 ± 0.64 ppm respectively. Anthropogenic activities have a significant impact on the soil compaction in oil palm cultivations. If the cultivation practices are implemented sustainably, soil under oil palm can be managed to minimize negative impacts and promote long-term sustainability.

Keywords: oil palm, soil physical properties, chemical properties, soil depth, Generalized Linear Model

**Corresponding Author: ariyarat-em18005@stu.kln.ac.lk*

ANALYSIS OF SPATIAL VARIABILITIES IN SELECTED SOIL PROPERTIES UNDER AN OIL PALM CULTIVATION IN NEBODA, SRI LANKA

T.D.S. Ariyarathna* and M.M.M. Najim
Department of Zoology and Environmental Management,
University of Kelaniya, Sri Lanka

INTRODUCTION

Growing oil palm may cause nutrients to be removed from the soil through harvest either for food, fibre or wood and crop residues. Nutrient removal may result in a reduction in soil fertility if inorganic fertilizers or manure are inadequate. A decline in soil fertility shows a rapid decline in the quality of the soil (Hartemink, 2005). Analyzing soil parameters in oil palm cultivated land is mostly important for understanding the soil's health and fertility, which directly affects crop yield and quality. Soil properties are usually continuous variables and at various points, they differ according to some changes in direction and distance from nearby samples (Burgess & Webster, 1980). Various soil parameters should be measured and analyzed to make informed decisions regarding crop management.

Because of the contradictions in different research, a study on the spatial variability of soil properties in Sri Lankan oil palm cultivation is required. Therefore, oil palm cultivation in Culloden estate, Dodangoda, Kalutara is selected as a suitable study area to assess the spatial variability of some soil physical and chemical properties in oil palm cultivation with time. When considering most research, information is still lacking on the spatial differentiation of soil nutrient status within one field on undulated topography under actual plantation operation. By considering all these factors, this study seeks to analyze the spatial variability of soil properties in an oil palm cultivated plot in the Culloden state.

The objectives of this study are to evaluate the impact of oil palm cultivation on the selected physical and chemical properties of soil and to determine the spatial variation between the oil palm cultivation and the reference site. The main hypotheses are that oil palm cultivation has adverse impacts on the physical and chemical properties of the soil and that there are significant spatial differences in soil properties between the oil palm site and the reference grassland site.

METHODOLOGY

The study area in Figure 01 (GPS coordinates of 6.59° North, 80.09° West) is located in “Neboda” (within Dodangoda DS division) in the Kalutara district. The selected oil palm cultivation is in the “Thudulaga East” GN Division and “Wellatha” GN Division in the Neboda area and it belongs to the Culloden estate of Agalawatta plantations. The selected land for the study is a flat terrain that is approximately 21 hectares in size and was cultivated in 2001. The selected reference grassland site is about 400 m distance from the oil palm cultivated land. It is a small grassland, which can be considered abandoned land. Nine sampling points within the oil palm land were selected systematically. The total area was divided into 3 sites Site 1(S1), Site 2(S2), and Site 3(S3), which are similar in size. Then, three representative sampling points from each zone were selected. The reference sampling hereafter mentioned as R, was taken from small undisturbed land containing natural grass cover.

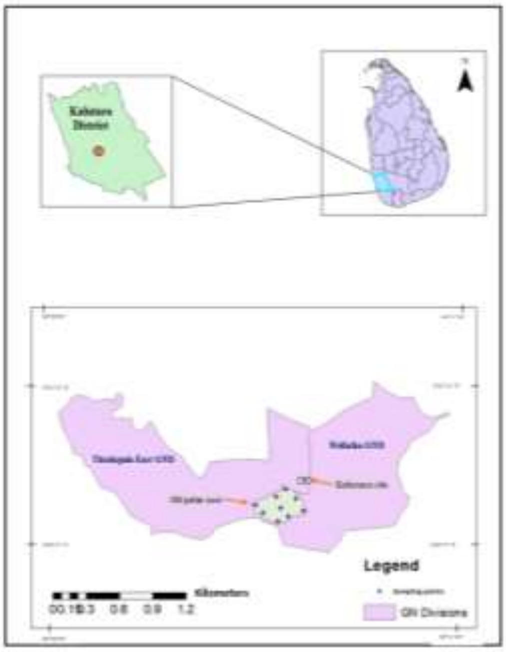

Figure 01: The map of the study area

All the laboratory analyses mentioned are performed under strict laboratory conditions as in Table 01, using 3 replicates. The Generalized Linear Model (GLM) followed by Tukey's pairwise comparison at 95% confidence level, was used to determine the spatial variation of studied soil parameters by using IBM SPSS statistics 26 software.

Table 01: Methods of analysis of soil parameters

Parameter	**Analyzing/determination method**
Soil pH	Soil pH meter
Soil electrical conductivity	Calibrated multiparameter
Soil texture	Pipette method
Soil bulk density	Core sample method
Soil particle density	Pycnometer method
Cation exchange capacity (CEC)	Ammonium acetate method
Organic matter content (%)	Loss-on-ignition method
Total nitrogen content (%)	Kjeldahl Method
Available phosphorus content	Modified Truog method
Soil porosity (%)	[1 – (Bulk density/Particle density)] ×100

RESULTS AND DISCUSSION

Soil texture: -
According to Table 02, oil palm cultivation has silty clay soil, and the reference land has silty clay loam soil. Silty clay soil generally has medium particles, between the size of sand and clay particles. Silty clay loam consists of moderate amounts of fine sand, a small amount of clay, and a large quantity of silt particles.

Table 02: Soil texture according to United States Department of Agriculture (USDA) classification in the soils from oil palm and the reference site

Site	Sand%	Silt%	Clay%	Soil texture (USDA)
Oil palm	14.9	41.3	43.8	Silty clay
Reference	17.3	46.6	36.1	Silty clay loam

Variabilities of soil properties at 30 cm depth: -

According to the results of the General Linear Model, significant differences were observed among the studied sites for all the considered soil parameters at the 30 cm depth ($p<0.05$), as shown in Table 03. The highest mean pH level was observed from the reference site (R) as 5.58 ± 0.02, while the lowest pH value was reported from S2 as 5.46 ± 0.02. According to the results of post–hoc analysis, there was no statistically significant difference in pH among all three sites of the oil palm cultivation. In the case of soil conductivity also, the reference site (R) reported the significantly highest soil conductivity value as 65.50 ± 1.03 μs/cm compared to the oil palm cultivation sites. Meanwhile, soil samples collected from S1 reported the lowest soil conductivity value as 47.92 ± 0.97 μs/cm. There was a significant difference in soil conductivity among all the sites (Table 03). The highest mean bulk density value was observed from S1 as 0.89 ± 0.05 g/cm^3, while the lowest value was observed from R as 0.49 ± 0.002 g/cm^3. The highest mean soil particle density value was observed from S3 as 1.31 ± 0.01 g/cm^3, while soil samples of S1 reported the lowest values (1.26 ± 0.09 g/cm^3). However, the post-hoc analysis revealed no significant difference in particle density between S1, S2 and the reference site, which were significantly different from S3 ($p<0.05$). The highest mean soil porosity value was observed from R as 61.4 ± 2.10%, while soil samples of S1 reported the lowest values (29.3 ± 1.03%). There was no significant difference in soil porosity between S2 and S3. Nevertheless, they were significantly different from S1 and R. In the case of soil organic matter content (%), the R site reported the highest mean value (7.3 ± 0.21%), while the lowest value was observed from S3 as 5.7 ± 0.27%. There was no significant difference in organic matter between S2 and R ($p>0.05$). But they were significantly different from S1 and S3 ($P<0.05$). When the soil cation exchange capacity is considered, the highest mean value was observed from S3 as 15.23 ± 0.04 meq/100 g, while the lowest value was observed from S2 as 14.23 ± 0.29 meq/100 g, as shown in Table 03. In the case of soil nitrogen content (%), the reference site reported the highest mean value as 0.28 ± 0.02%, while the S1 site reported the lowest value as 0.14 ± 0.01%. In terms of soil phosphorus content, the highest mean value was observed from S3 (13.21 ± 0.64 ppm), while the lowest value was observed from S1 (11.42 ± 0.11 ppm), as shown in Table 03.

Table 03: Spatial variation in soil parameters at 30 cm depth

Site / Parameter	S1	S2	S3	R
pH	$5.47±0.032^{a}$	$5.46±0.022^{a}$	$5.48±0.054^{a}$	$5.58± 0.024^{b}$
EC (μs/cm)	$47.92±0.97^{a}$	$54.07±0.88^{b}$	$52.18±1.72^{c}$	$65.50± 1.03^{d}$
Bulk density (g/cm^3)	$0.89±0.05^{d}$	$0.69±0.01^{b}$	$0.78±0.01^{c}$	$0.49± 0.002^{a}$
Particle density (g/cm^3)	$1.26±0.09^{a}$	$1.26±0.03^{a}$	$1.31±0.01^{b}$	$1.27± 0.011^{a}$
Porosity %	$29.3±1.03^{a}$	$45.1±0.881^{b}$	$44.2±1.01^{b}$	$61.4±2.10^{d}$
OM (%)	$6.9±0.661^{b}$	$7.2±0.230^{c}$	$5.7±0.271^{a}$	$7.3±0.202^{c}$
CEC (meq/100g)	$15.23±0.04^{c}$	$14.23±0.29^{a}$	$14.76±0.21^{b}$	$14.56±0.3^{ab}$
N (%)	$0.13±0.09^{a}$	$0.14±0.004^{a}$	$0.17±0.05^{b}$	$0.28± 0.004^{c}$
P (ppm)	$11.42±0.11^{a}$	$12.32±0.29^{b}$	$13.21±0.64^{d}$	$12.39±0.07^{c}$

Note: Values are mean ± SEM. Different superscript letters in each row depict statistically significant differences as suggested by the General Linear Model followed by the Tukey's pair-wise comparison as a post-hoc analysis at 95% level of confidence.

In this study, oil palm cultivation has “silty clay” soil, and the reference site contains “silty clay loam” soil according to the soil triangle of the United States Department of Agriculture (USDA) classification Silty clay soil is a type of soil with a relatively high proportion of fine particles, consisting of silt and clay, with minimal sand content. According to most studies, the most suitable soil texture for oil palm plantation is sandy clay and silty clay (Rozieta *et al*., 2015). Higher clay content in the oil palm soil might affect its properties such as water retention and drainage.

At the study sites, soil pH is significantly higher in reference sites than in the oil palm sites. Generally, the oil palm soil is acidic. Soil electrical conductivity in all the study sites is significantly different from each other, according to the results of this study. The most probable reasons are spatial variability and soil compaction. The reference site has a higher soil conductivity due to leaching and accumulation and differences in the vegetation. In this study, the bulk density of all the S1, S2, and S3 sites showed significantly higher values than the reference site. It can be concluded that cultivating oil palms influences soil compaction. In this study, S1 has the lowest porosity at both depths because it has the highest bulk density value, as discussed above. Due to soil compaction, the porosity decreases and reduces the amount of water that soil can hold. S1, S2, and the reference sites have a soil particle density in a similar range because they both contain significant proportions of silt and clay particles.

In this study at 30 cm depth, S2 and R have no significant difference in soil organic matter. The most probable reasons are natural soil characteristics, organic matter inputs, and management practices. The literature shows that generally, CEC in oil palm soil is 2-10 cmol/kg (Ogeh & Osiomwan, 2012). So, this oil palm cultivation has a good CEC. S1 and S2 have no significant difference, but they are significantly different from S3 and R. The most probable reasons are land management practices, crop uptake and nitrogen cycling, and differences in organic matter and microbial activity. In this oil palm plantation, soil organic matter, levels are low compared to reference sites and it leads to lower nitrogen content compared to abandoned grasslands. Generally, phosphorus shows a high spatial variation within a plantation. Available phosphorus at the top layer can be classified as moderate to high spatial variance. Depending on the fertilization regime and practices implemented in the plantation, soil phosphorus levels may be higher than in reference sites, where no fertilizers are applied.

CONCLUSION AND RECOMMENDATIONS

Most of the properties are significantly different from the reference site. Oil palm shows a high spatial variation within the same cultivation and compared to the reference site. So, it can be concluded that there is a significant difference between soil properties in the oil palm site and the reference site**.** In this oil palm cultivation, the soil compaction is significantly higher, compared to the reference site. So, it can be concluded that anthropogenic activities have a significant impact on the variability of soil properties in oil palm cultivations. Therefore, it can be concluded that, if the cultivation practices are implemented sustainably, it can be managed in ways that minimize negative impacts on soil health and promote long-term sustainability, especially in Sri Lankan conditions.

It is better to compare the soil properties not only with a reference site but also with another plantation crop such as rubber or tea. If this research can be expanded to study the biological properties in soil, such as microbial diversity, and the rate of soil organic matter decomposition by microbes and earthworm activities, more comprehensive results can be obtained.

REFERENCES

Burgess, T.M., & Webster, R. (1980). Optimal interpolation and isorhythmic mapping of soil properties: II block kriging. *Journal of Soil Science*, *31*(2), pp.333-341.

Hartemink, A. E. (2003). *Soil fertility decline in the tropics: with case studies on plantations*. Cabi. https://doi.org/10.1016/S0038-0717(97)00217-4

Ogeh, J. S., & Osiomwan, G. E. (2012). Evaluation of the Effect of Oil Palm on some Physical and Chemical Properties of Rhodic paleudults. *Nigerian Journal of Basic and Applied Sciences*, *20*(1), 78-82.

Rozieta, R., Sahibin, A. R., & Razi, I. W. M. (2015, September). Physico-chemical properties of soil at oil palm plantation area, Labu, Negeri Sembilan. In *AIP Conference Proceedings* (Vol. 1678, No. 1, pp. 5-9). https://doi.org/10.1063/1.4931216