Research Article

Impact of Land Use Patterns on Soil Microbial Biomass in Reddish Brown Earth: A Case Study from *Anuradhapura*

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Abstract

This study investigated changes in soil microbial biomass (SMB), specifically microbial biomass carbon (MBC), across surface and sub-surface layers of Reddish Brown Earth (RBE) soil under four land uses (LUs); forest, conventional agriculture, organic agriculture, and home garden. Composite soil samples from surface (0-15 cm) and sub-surface (15-30 cm) soils were analyzed for MBC, microbial activity, soil pH, organic matter (OM), and moisture content. Three random soil samples were collected from each LU. Statistical analysis included ANOVA followed by Tukey's HSD test. Surface soil MBC (0.68-0.74 mg g^{-1}) did not significantly differ ($p>0.05$) among forest, home garden, and organic land. In sub-surface soil, the forest exhibited significantly higher MBC (0.79 mg g^{-1} ± 0.061). Conventional agriculture recorded the lowest MBC in both surface (0.571 mg g^{-1} ±0.04) and sub-surface (0.356 mg g^{-1} ±0.06) soils. MBC decreased significantly with soil depth, except for an insignificant increase in forest soil correlating with moisture content. Microbial activity was significantly higher in organic land for both soil layers, and OM was notably higher in forest soils. Soil pH did not differ significantly ($p>0.05$) among LUs. MBC showed a positive correlation with OM and a negative correlation with soil pH at both depths. In conclusion, LUs and soil depth significantly influenced MBC, distinguishing them as LU signatures. Further research is needed to explore temporal variations in SMB under various LUs in RBE soils

***Keywords**: Land use patterns, Microbial activity, Microbial biomass carbon, Surface and sub-surface soils*

1. Introduction

Microbial biomass carbon is a sensitive health quality indicator to identify changes in soil quality as well as an envisaging tool for future soil quality and ecosystem functioning. The biomass measurement has also been used as an early indication of changes in the organic matter content of soils due to variations in soil management (Brookes, 1995). Soil microbial biomass, which represents about 1-4% of total soil organic C, is a more sensitive indicator of changing soil conditions than direct analysis of the organic C content. The amount and composition of microbial biomass are sensitive to changes in the chemical and physical environments of the soil. The microbial biomass is the most labile pool of organic matter and serves as an important reservoir of plant nutrients, such as N and P. Further, it forms the base of the detritus food web and serves as a sink and source for most plant-available nutrients (Anderson and Domsch, 1980) thus has the potential to influence plant growth and long term agricultural sustainability (Paranawithana *et al.,* 2020). Certain management practices significantly affect microbial biomass C in agricultural soils (Hu *et al.,* 1997). Some studies have documented that microbial biomass decreases with increasing Chemical fertilizer (CF) application. Further, these inputs cause soil degradation, reduction of biodiversity (Lupwayi *et al.,* 2001) and ultimately decrease of environmental sustainability (Horrigan *et al.,* 2002). However, organic farming systems avoid applications of CF and pesticides and promote mainly, the soil quality by increasing the microbial biomass. In this way, they may reduce the negative effects on microbial biomass, which has been attributed to conventional farming (Reganold *et al.,* 1987). Globally, several studies have been conducted to evaluate the effect of different land use practices on soil microbial biomass (Ghosh *et al.,* 2020) without much evidence from Sri Lanka. This study aims to comprehensively assess and understand the responses of specific soil microbial properties within both surface and subsurface layers. The investigation, conducted across various land use patterns in RBE soil located in Anuradhapura, where it plays a crucial role in agriculture, aims to provide insights into the impacts of diverse land use on specific microbial properties. By SMB, under different land use patterns, the objective is to understand how these key components of the soil microbiome are influenced. This understanding is imperative for informing region-specific and sustainable land management practices, thereby addressing potential environmental implications associated with diverse land use in the Anuradhapura region.

2. Material and Methods

2.1 Experimental sites

Four different land uses were selected under Reddish Brown Earth (RBE) soil, classified according to USDA Taxonomy as Rhodustalf (Mapa *et al.*, 2020), in Anuradhapura. These land uses include forest land (8.370804°N, 80.4218810°E), conventional agricultural land (8.4014580°N, 80.4187580°E), organic agricultural land (8.373387°N, 80.4149790°E), and home garden (8.369946°N, 80.416892°E), with an average annual temperature of 27°C and an average annual rainfall of 1,368 mm.

2.2 Soil analysis

Bulk soil samples were obtained from, surface soil (0-15cm) and sub-surface soil (15-30cm) in selected homogeneous units as triplicates in each location using soil augur. The soils collected from the experimental fields were analyzed for pH with 1: 2.5 soil suspension using a pH meter, soil moisture (dry basis) by gravimetric method (Reynolds, 1970), organic matter content (Baker, 1976) and microbial activity by using CO_2 evolution method (Wong and Wong, 1986). The microbial biomass carbon was determined using chloroform fumigation-extraction method (Jenkinson, and Powlson, 1976). This technique involves exposing soil samples to chloroform vapor to selectively inhibit microbial activity, followed by a subsequent extraction process to measure the amount of carbon incorporated into microbial biomass. By comparing fumigated and non-fumigated samples, this method provides an estimate of the carbon content associated with microbial organisms in the soil, offering insights into soil microbial dynamics.

2.3 Data analysis

The differences of soil parameters among land uses were performed through ANOVA using R software. Pearson's multiple correlation analysis was carried out to determine the relationship between soil parameters and microbial biomass in different LUs. Microsoft Excel was used for graphical representation of data.

3. Results and Discussion

3.1 Microbial Biomass C

MBC is a better indicator of active microbes present in the soil (Ghosh *et al.,* 2020). According to Liang *et al.* (2012), LUs and their management can influence the changes in microbial biomass in soil mainly in surface soils. In the present study, the variation of MBC with different land uses is represented in Figure 1.

The significantly highest MBC was recorded in forest soil (LU1) (0.791 mg g^{-1} ± 0.02) over other LUs whilst the lowest was recorded in conventional agricultural land (LU3) (0.356 mg g^{-1} ± 0.013) for sub-surface, and the surface significantly the lowest MBC was recorded in conventional agricultural land (0.571 mg g^{-1} ± 0.007) over other LUs. Moreover, no observable differences in MBC were recorded among the LU1 (0.739 mg g^{-1} ± 0.022), LU2 (0.723 mg g^{-1} ±0.021), and LU4 (0.682 mg g^{-1} ± 0.063). Overall, the MBC of surface and subsurface soils were significantly the lowest in LU3 over other LUs, because the LU3 is applied chemical fertilizers extensively.

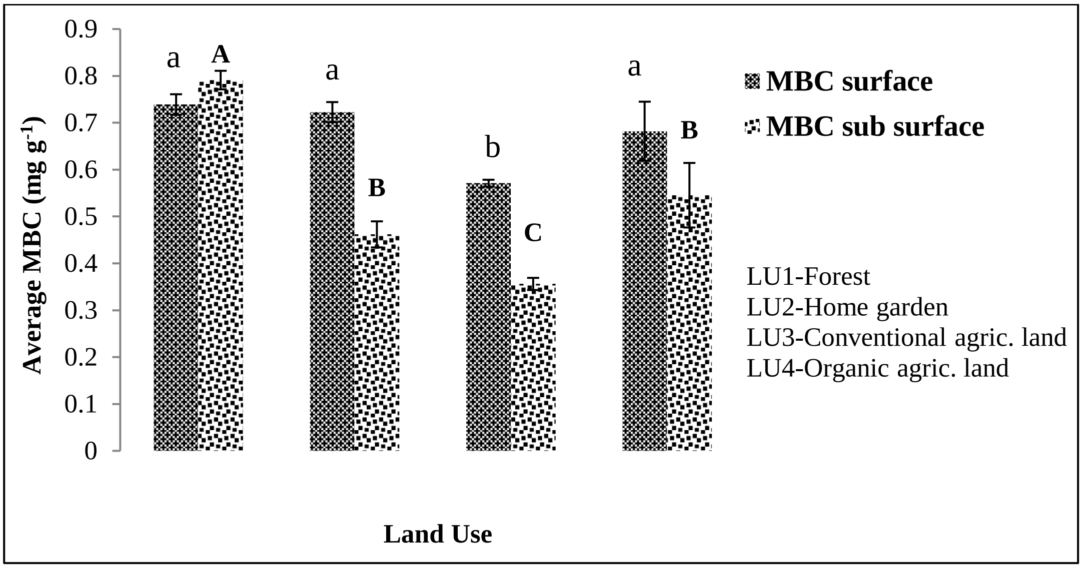

Figure 1: Microbial Biomass Carbon (MBC) in surface and subsurface soil layers of different LUs. Bars with different uppercase or lowercase letters are significantly different at 5% probability level according to Tukey's mean comparison test.

Soil C contents were higher in surface and subsurface soils of LU4 compared to other LUs perhaps due to organic fertilizer applications such as vermicompost and farm yard manure (Azarmi *et al.,* 2008) which improve substrate utilization capacity of microbes. Moreover, increased microbial enzymatic activities mediate nutrient cycling and SOM decomposition (Klose and Tabatabai, 2002), as was observed in Figure 1.

The accumulation of heavy metals (Cu, Pb, and Zn) due to the continuous application of chemical fertilizers could be the reason for the lowest MBC recorded in LU3 (Dahlin *et al.,* 1997). The heavy metals can form complexes with soil organic matter and reduce microbial C decomposition (Po Hsu Kao *et al*., 2006). The management practices like CF application (Budhdhika *et al.,* 2013), tillage (Deng and Tabatabai, 1997; Balota *et al.,* 2004), and grazing (Kooch *et al.,* 2020) can significantly affect microbial enzymic activities in LU3. The addition of crop residue to the soil is interrupted during fallow periods, while in crop rotation, it may lower OM and, in particular, may enhance the toxic effects of agrochemicals, such as pesticides, potentially causing detrimental effects on MBC. The forest soil has higher MBC may be due to the accumulation of plant litter. This forest is a conserved forest with minimum human disturbance, with composing of several canopy strata and the highest tree root activities. The location in the dry zone of Sri Lanka makes the soil a more favourable habitat for mixed communities of decomposing microbes in the optimal temperature of around 25 ^{o}C and availability of abundant moisture.

3.2 Variation of soil moisture with the soil depth in forest land

The key parameters affecting the size of microbial biomass in soil are temperature and moisture (Wardle and Parkinson, 1990). In this study, the decrease in MBC in forest surface soil in comparison to subsurface is possibly proportional to soil moisture variation. The variation of soil moisture in the surface and sub-surfaces of selected LUs are illustrated in Figure 2.

3.3 Evolved CO_2, Organic Matter Content and pH

The MBC is affected by several physiochemical factors such as climate, vegetation, soil acidity, and alkalinity (Zhao *et al.,* 2020). The variations of average evolved CO_2, average OM, and average pH of selected LUs are illustrated in Figure 3.

The significantly highest microbial activity which is estimated by CO_2 evolution was recorded in LU4 for both surface (0.670 ± 0.026) and sub-surface soils (0.574 ± 0.102). The significantly lowest (0.163 ± 0.012) microbial activity was estimated in

LU3 for sub-surface soils while it was lowest (0.225 ± 0.011) in LU2 for surface soils. Rhizopheric activity thereby microbial population; plant root secretions improve the soil microbe activity (Zhao *et al.*, 2020), declines with soil depth, following a downturn CO_2 evolution rate. The microbial population is higher in surface soils due to the availability of favorable environmental factors and root rhizosphere in LU3, and LU4 cultivated with annual shallow-rooted vegetable crops controversially in LU1 and LU2 soils report higher CO_2 evolution in subsurface soils than surface soils possibly due to moisture availability in subsurface soils more than in surface soils and cultivated with deep-rooted perennial crops having subsurface rhizosphere as illustrated in Figure 2.

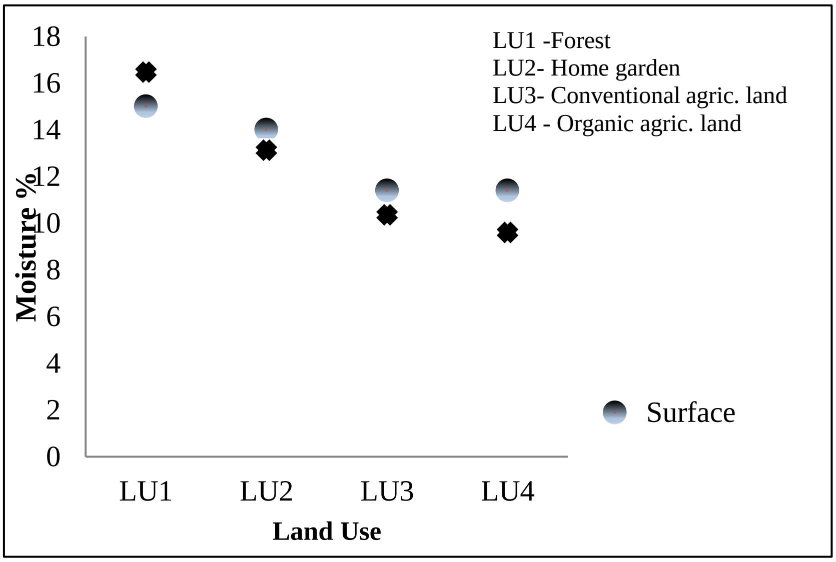

Figure 2: Variation of soil moisture with the soil depth

According to Figure 3(b), LU4 is rich in added farmyard compost and vermicompost. Soil organic matter content representing labile organic carbon and MBC representing microbial activity and are intimately connected and directly correlated with soil respiratory activity, a measure of soil microbial activity (Dhull *et al.*, 2004). In LU1 plant litter collection at the root base of forest soils increase OM loading and these act as a substrate for existing microbes. There is a natural equilibrium between the synthesis of organic matter by vegetation and its breakdown by microorganisms in undisturbed soils (Jayman and Sivasubramanium,1981). The CO_2 evolution from LU2 is observed at the lowest may be due to not having been treated with organic fertilizers or nutrients externally.

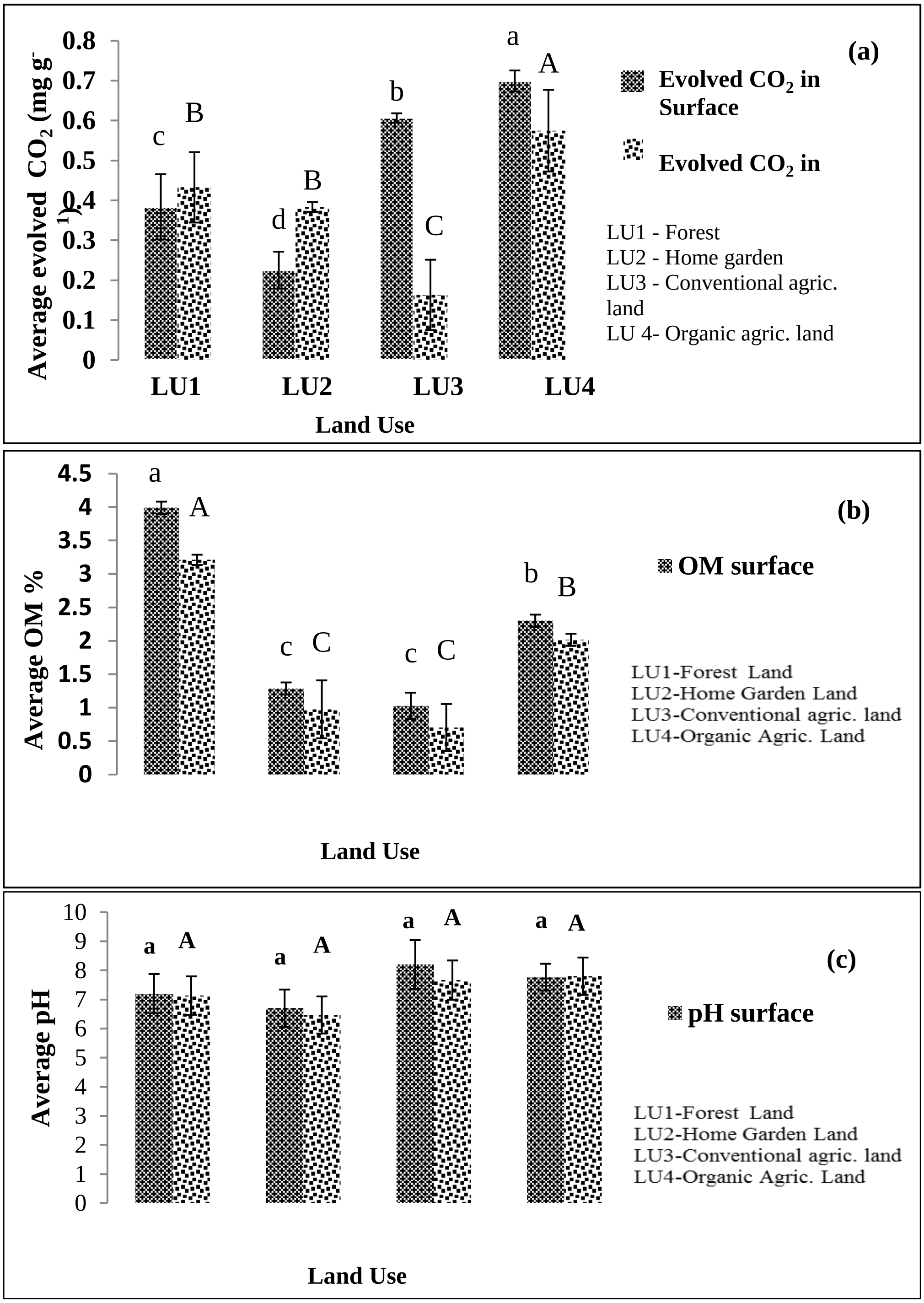

Figure 3: (a) Average evolved CO_2, (b) Average OM, and (c) Average pH in Surface and Subsurface Layers of Different LUs. Different letters of each bar are statistically significant at 5% probability level according to Tukey's mean comparison test.

Soil organic matter acts as substrate and support for microbial activity. The study of organic matter content in four LUs provides insight into MBC in respective soils. Organic matter content was varied (3.991%± 0.702) among the LUs in this study. The Significantly highest Organic matter content was recorded in LU1 (3.991 % ± 0.091), followed by LU4 (2.301% ± 0.0908), LU2 (1.28% ±0.091) for surface soils while it was lowest in LU3 (1.02% ±0.198). The significantly highest Organic matter content in sub-surface soils was recorded in LU1 (3.211% ±0.077), followed by LU4 (2.015% ±0.091), LU2 (0.975% ± 0.433), and the lowest was recorded in LU3 (0.702% ± 0.352).

The overall, Organic matter content in both surface and subsurface was lowest in LU3.

One of the major parameters that determine microbial biomass, diversity, and composition is soil pH. No significant differences in the pH among LUs have been recorded. From the results, it is suggested that the soil pH is not significantly impacted by LU (Dhull *et al.*, 2004). Overall, the pH values of different LUs ranged between (8.2-6.5) which exists within the optimum pH range for RBE soils for cultivation (Panabokke, 1996).

3.4 Correlation analyses

Figure 4 illustrates the correlations between MBC and organic matter content in surface soils among the LUs.

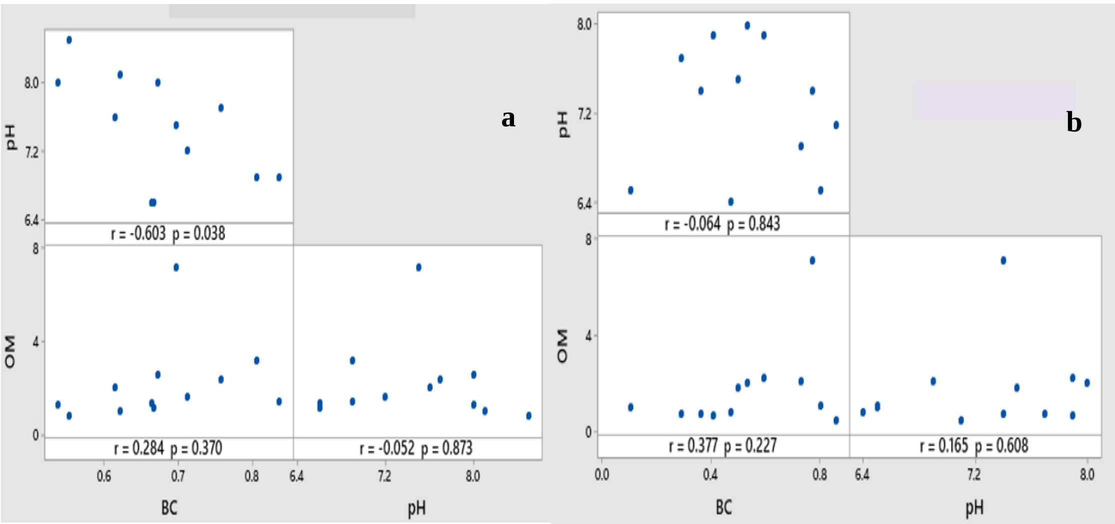

Figure 4: Correlation analysis between MBC and organic matter content in surface (a) and sub-surface (b) soils among the LUs

The MBC in surface soils was negatively correlated with pH (r = -0.603) and positively correlated with OM (r = 0.284). These results can be confirmed by the findings of Wanghon *et al.*, (2009) from a similar analysis carried out. The organic matters in soils undergoes reactions with negatively charged anions and positively charged oxide sites ultimately favoring an increase in negatively charged sites and leading to a reduction in soil pH (Oades,1989; Chagantti, 2014).

Similar correlation patterns were observed among parameters in subsurface soils as in surface soils (Figure 4b) except if, OM was positively correlated with pH (r = 0.165) attributing to lower OM in soil with depth and subsequent pH reduction.

4. Conclusions

The aim of this study was to assess variations in SMB under four different LU practices within the soil of Anuradhapura in the RBE region, with a specific focus on MBC content. The results demonstrated a noteworthy increase in MBC in surface soils of forest, home garden, and organic agricultural land, with forest soil displaying significantly higher MBC in sub-surface layers. Moreover, microbial activity exhibited a significant elevation in organic land for both surface and sub-surface soils. Forest soils consistently showed the highest organic matter content in both surface and sub-surface layers, while pH levels did not exhibit significant variations across the different LUs. Correlation analysis highlighted a positive relationship between MBC and organic matter (OM). The study identified soil depth and moisture content as limiting factors influencing changes in MBC. In summary, land use practices and soil depth exert a substantial influence on MBC, reflecting SMB variations in two soil layers across the RBE study sites.

This underscores the necessity for further studies to assess the temporal variations of SMB under different LUs in RBE soils.

5. References

Anderson, J. P. E and, Domsch, K. H. (1980). Quantities of plant nutrients in the microbial biomass of selected soils, *Soil Science,* 130(4), 211-216.

Azarmi R., Giglou M.T. and Taleshmikail R.D. (2008). Influence of vermicompost on soil chemical and physical properties in tomato (*Lycopersicum esculentum*) field, *African Journal of Biotechnology,* 7 (14), 2397-2401.

Baker, K.F. (1976). *The determination of organic carbon in soil using a probe colorimeter: laboratory practice,* United Trade Press, London, 25, 82-83.

Balota, E.L., Kanashiro, M., Colozzi-Filho, A., Andrade, D.A. and Dick, R.P. (2004). Soil enzyme activities under long-term tillage and crop rotations systems in subtropical agro-ecosystems, *Brazilian Journal of Microbiology,* 35, 300-306.

Brookes, P.C. (1995). The use of microbial parameters in monitoring soil pollution by heavy metals, *Biological Fertility of Soils,* 19, 269–279.

Buddhika, U. V. A., Athauda, A. R. W. P. K., Seneviratne, G., Kulasooriya S. A. and, Abayasekara C. L. (2013). Emergence of diverse microbes on application of biofilmed biofertilizers to maize growing soil, *Ceylon Journal of Science (Biological Science)*, 42 (2), 87-94.

Chaganti, V.S.N. (2014). *evaluating the potential of biochars and composts as organic amendments to remediate a saline-sodic soil leached with reclaimed water*. University of California, Riverside, 24-45.

Dahlin, S., Witter, E., Martensson, A., Turner, A. and Baath, E. (1997). where's the limit? Changes in the microbiological properties of agricultural soils at low levels of metal contamination, *Soil Biology and Biochemistry*, 29(9), 1405-1415.

Deng, S.P. and Tabatabai, M.A. (1997). Effect of tillage and residue management on enzyme activities in soils. *Biology and Fertility of Soils,* 22, 202–207.

Dhull, S., Goyal, S., Kapoor, K. and Mundra, M. (2004). Microbial biomass carbon and microbial activities of soils receiving chemical fertilizers and organic amendments, *Archives of Agronomy and Soil Science*, *50*(6), 641-647.

Ghosh, A., Singh, A.B., Kumar, R.V., Manna, M.C., Bhattacharyya, R., Rahman, M.M., Sharma, P., Rajput, P.S. and Misra, S. (2020). Soil enzymes and microbial elemental stoichiometry as bio-indicators of soil quality in diverse cropping systems and nutrient management practices of Indian vertisols, *Applied Soil Ecology*, *145*, 103-304.

Horrigan, L., Lawrence, R.S., and Walker, P. (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture, *Environmental Health Perspective,* 110, 445–456.

Hu, S., Coleman, D.C., Carrol, C.R., Hendrix, P.F. and Beare, M.H. (1997). Labile soil carbon pools in subtropical forest and agricultural ecosystems as influenced by management practices and vegetation types, agriculture, *Ecosystems and Environment,* 65, 69-78.

Jayman, T. C. Z. and Sivasubramaniam, S. (1981). The mineral status and physical composition of some cultivated and uncultivated tea soils of Sri Lanka, *Reprinted from the Journal of the National Agricultural Society of Ceylon*, 11, 27-39.

Jenkinson, D.S. and Powlson, D.S. (1976). The effects of biocidal treatments on metabolism in soil: A method for measuring soil biomass. *Soil Biology and Biochemistry* 8, 167-177.

Kooch, Y., Moghimian, N., Wirth, S. and Noghre, N. (2020). Effects of grazing management on leaf litter decomposition and soil microbial activities in Northern Iranian rangeland, *Geoderma*, 361, 100-114.

Lupwayi, N. Z., Monreal, M. A., Clayton, G. W., Grant, C. A., Johnston, A. M. and Rice, W.A. (2001). Soil microbial biomass and diversity respond to tillage and sulphur fertilizers, *Canadian Journal of Soil Science*, 81, 577–589.

Mapa, R.B., ed. (2020). *The Soils of Sri Lanka*, New York, NY, USA, springer, 119-124.

Oades, J.M., Gillman, G.P., Uehara, G., Hue, N.V., Van Noordwijk, M., Robertson, G.P. and Wada, K. (1989). Interactions of soil organic matter and variable-charge clays, *Dynamics of soil organic matter in tropical ecosystems*, *3*, 69-96.

Panabokke, C. R. (1996). *Soils and Agro-Ecological Environments of Sri Lanka*. Colombo: Natural Resources, Energy and Science Authority of Sri Lanka. 22-29.

Paranavithana T.M., Premathilaka U.L.R.W., Gunathilake S.K., Karunaratne S.B. and, Ratnayake R.R. (2020). Evaluation of microbial biomass carbon in paddy soils of Anuradhapura District, Sri Lanka, *Proceedings of the Postgraduate Institute of Science Research Congress*, Sri Lanka: 26th - 28th November 2020.

Reganold, J.P., Elliott, L.F. and Unger, Y.L. (1987). Long-term effects of organic and conventional farming on soil erosion, *Nature*, 330, 370-372.

Reynolds, S.G. (1970). The gravimetric method of soil moisture determination part IA study of equipment, and methodological problems, Journal *of Hydrology*, 11(3), 258-273.

Wanhong, D., Yao, H., Li, Wu. and Jia, Yu. (2009). Relationships between soil organic matter content (SOM) and ph in topsoil of zonal soils in China, *Acta Pedologica Sinica*, 46(5), 851-860.

Wardle, D.A. and Parkinson, D. (1990). 'Interactions between microclimatic variables and the soil microbial biomass', *Biology and Fertility of Soils*, 9(3), 273–280.

Wong, M.H. and Wong, J.W.C. (1986). Effects of fly ash on soil microbial activity, *Environmental Pollution Series A, Ecological and Biological*, *40*(2), 127-144.

Zhao, X., Sun, Y., Huang, J., Wang, H. and Tang, D. (2020). Effects of soil heavy metal pollution on microbial activities and community diversity in different land use types in mining areas, *Environmental Science and Pollution Research*, 27, 215-226.