Profile of Soil Properties in Several Land Uses

Nuzul H. Darlan[1,*] Iput Pradiko[1] Muhammad A. Yusuf[1] Rizki D. P. Pane[1] Eko N. Ginting[1]

[1] *Department of Soil Science and Agronomy Research, Indonesian Oil Palm Research Institute (IOPRI)*
[*]*Corresponding author. Email: nuzulhijri@gmail.com*

ABSTRACT
Oil palm is the most efficient vegetable oil producer whose products can be used in various food, pharmaceutical, oleochemical, and biodiesel industries. Expanding the new planting area, starting from land clearing, and planting oil palm, to young and mature oil palm plants, will affect the abiotic environment around it, such as the characteristics of the soil and the organisms in it. The purpose of this study was to examine the impact of changes in land use from secondary forest to oil palm plantations on the soil's chemical, physical, and biological properties. This research was conducted in the Dawas experimental plantation, Musi Banyuasin district, South Sumatra province. Parameters observed were soil physical properties, soil chemistry, plant vegetative and leaf nutrients, soil cover biomass, and soil mesofauna. From the research, it can be concluded that the chemical and physical properties of the soil are not significantly different in several land uses and land slopes. Slope and plant age did not significantly affect nutrient uptake and soil mesofauna.

Keywords: *soil properties, oil palm, slopes, secondary forest.*

1. INTRODUCTION

The palm oil crop is the most efficient vegetable oil-producing crop whose products can be used in various food, pharmaceutical, oleochemical, and biodiesel industries. Oil palm plants also contribute to Indonesia's export foreign exchange and domestic needs. This has prompted several efforts to increase palm oil production by intensification and extensification. Intensification efforts are carried out with various genetic studies of plant materials and technical cultures, while extensification efforts are carried out with various new planting area expansion programs.

The process of expanding the new planting area will affect the surrounding biotic and abiotic environment, such as the chemical-physical properties of the soil and soil organisms caused by changes in land use. Variations in soil's physical and chemical properties are most likely due to soil management practices and changes in soil vegetation [1-2]. Based on the theory presented by [3], oil palm plantations generally tend to reduce soil fertility and N-availability. In many cases, it also found that the soil fertility under plantation crops is lower than that under the forest. However, the rate of decline under plantations is often much lower than under forest planting due to higher input levels and lower nutrient loss [4]. Furthermore, [5] also noted that oil palm impacts the loss of diversity compared to forests.

This condition can be mitigated by optimizing soil management practices in oil palm plantations [6]; however, the effect of this practice on soil ecosystem processes and soil properties is largely unknown. The abundance and diversity of soil microorganisms and soil-dwelling fauna such as earthworms, beetles, and earwigs increase with good tillage practices such as applying plant residues [7]. It supports this well-run nutrient mineralization process, including soil carbon stabilization and nutrient cycles [8].

The Dawas experimental plantation in Musi Banyuasin Regency, South Sumatra province, has a reasonably diverse area. It started to build in 2005 and will continue to grow so that there are immature plants (TBM), mature plants (TM), and newly opened land. It also has a stretch of land adjacent to the secondary forest in the complex. There is also a protected forest covering

A. D. Saputro et al. (Eds.): ICOSEAT 2022, ABSR 26, pp. 213–221, 2023.
https://doi.org/10.2991/978-94-6463-086-2_28

an area of ± 8 ha to support the High Conservation Values Forest (HCVF) program, which synergizes with the development of oil palm plantations.

These conditions make Dawas plantation very suitable for integrated research on the influence of oil palm plantation development on the environment, regarding the physical and chemical properties of the soil, or its influence on the physiology of oil palm plants. The area to be observed is on one stretch of land (assuming a uniform macro climate), so errors or standard deviations that may occur at the time of observation will be minimized. The purpose of this study is to examine the impact of changing the land use of secondary forests into oil palm plantations on the soil's chemical, physical, and biological properties.

2. METHODS

This research was conducted in the Dawas experimental plantation, Musi Banyuasin Regency, South Sumatra province. The Dawas plantation is in the development stage so that there are still secondary forests, Immature Palms, and Mature Palms in the plantation area on one relatively homogeneous broad land. The climatic conditions in Dawas are relatively wet and have a strict dry season such as a dry month of 1-2 months/year. The topographical slopes of Dawas plantation varies from flat, wavy, in to hilly.

The research design used in this study was a randomized group design (RGD) with two types of treatment. The treatments applied in this study are immature palms (IP) and mature palms (MP). Each treatment was carried out on a plot of 1 ha (130 plants), repeated twice, and grouped into three classes of a land slope, namely: (i) L1: slope class 0–8 %; (ii) L2: slope class 8–15 %; and (iii) L3: slope class >15%.

The parameters observed in this study are soil physics properties, soil chemical properties, floor biomass, leaf chemical elements, plant vegetative, and soil mesofauna. The physical properties of soil are texture, porosity, aggregate stability, bulk density, and soil permeability rate. Soil samples taken using soil samples are disturbed by composite means at a depth of 0-20 cm and 20-40 cm; as well as soils are not disturbed by using ring samples taken at a depth of 0-20 cm, 20-40 cm, and 40-60 cm are taken inside and outside the disk. Analysis of soil physics properties is carried out in the soil physics laboratory, IOPRI.

Soil chemical analysis was carried out on composite soil samples The experimental analysis included macronutrient content, namely: N-dd, P-dd, K-dd, Ca-dd, and Mg-dd, as well as N-total, P- total, K- total, Ca- total, and Mg- total, as well as micro-content (Cu, Fe, B, Al, Zn) in the soil on every treatment. The analysis was carried out in the IOPRI laboratory.

The plant observations were carried out at the beginning of the study every six months. Observations include midribs number, rachis length, petiole area, leaves area, and leaf area index. The leaf nutrient contents were N, P, K, Ca, and Mg. The analysis was carried out in the IOPRI laboratory.

The observations of ground cover biomass (ground floors) were carried out on a small plot measuring 1m x 1m that had been marked for the next to be taken at the exact location the following year to increase ground cover biomass.

Furthermore, soil mesofauna description was carried out from three sampling points with soil samples taken representing: (i) in the weeding circle (a distance of 100 cm from the base of the tree); (ii) the outermost circle weeding (a distance of 2 m from the base of the tree); (iii) between plants (a distance of 4.5 m from the base of the tree); and (iv) interrow. Soil samples for the observation of mesofauna are taken at a depth of 0-15 cm. The land is further extracted with the Berlese-Tullgren tool.

3. RESULT AND DISCUSSION

3.1. Soil physical characteristics

Components of soil's physical properties include color, texture, structure, porosity, density, consistency, aggregate stability, and temperature. These properties affect infiltration, erosion, nutrient cycle, and biological activity [9]. Soil texture is the condition of the soil based on the comparison of the composition of dust and clay sand on the soil. Soil texture affects the movement of water, solutes, and air in the soil, heat movement, soil volume weight, specific surface area, ease of soil compaction (compressibility), and others [10]. The texture is closely related to the chemical and physical properties of the soil and indirectly affects plant growth and nutrient absorption by plants.

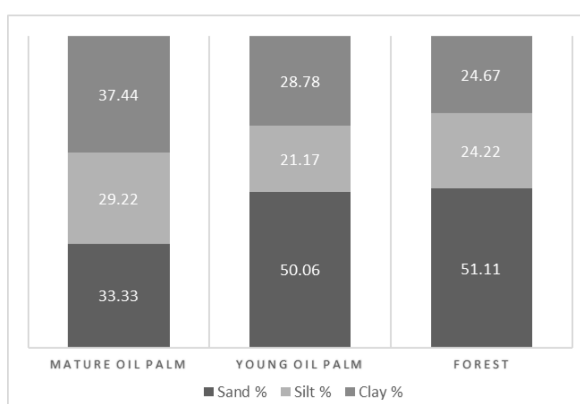

Figure 1 Soil texture

In Figure 1, it can be seen the composition of sand, dust, and clay on MP, IP, and secondary forests (SF). Determining the soil texture type based on the soil fraction's composition can use the texture triangles as a reference. From the percentage of sand, clay, and dust fractions on the soil, it can be determined the type of soil texture on the MP is clayey loam, IP is sandy clay, and SF is sandy loam.

The soil on the IP land has a fraction composition that is almost the same as the SF land, which is dominated by the sand fraction, while clay fractions dominate the soil on the MP land. The texture of the soil is usually unchanged by management practices. Soil texture is formed from the parent material and weathering and pedogenic processes such as recrystallization, eluviation, and illuviation. However, textures can be altered by erosion, deposition, cutting, and some other human interventions [9].

Soils that contain a lot of loam are considered best for plants because they contain more water and nutrients than sandy soils and have better drainage, aeration, and tillage than clay soils [11]. Soils with a high clay will cause waterlogging and soil salinity and reduce biological activity. Meanwhile, sandy soils will cause high infiltration, low water retention capacity, and poor nutrient retention [12]. The most suitable soil texture for oil palm plantations is sandy loam and muddy loam because these types of soil texture can store enough water and plant nutrients [13].

Other parameters of soil physical properties are permeability, bulk density (BD), porosity, and aggregate stability. Based on Figure 2, it can be seen that the value of permeability, porosity, and aggregate stability is higher found in the MP than in the IP, and the last is SF. Meanwhile, the bulk density parameter does not differ between the three crop fields. Excessive tillage, excessive irrigation, and single plantings could damage the soil structure. On the other hand, fertilization, especially organic fertilization, would improve the structure of the soil [9]. The addition of organic matter can cause a reduction in the aggregate value of the soil and bulk density, as well as an increase in the value of porosity and soil permeability [14].

3.2. Soil Chemistry Analysis

The soil's chemical properties based on land use are presented in Fig. 3. Based on Fig. 3, it can be seen that overall the oil palm cropland produces the highest nutrient levels, especially elements C, N, C / N, P, Ca, Mg, Base cation, KTK, Base saturation, and Al-exchanged compared to other lands. The fertilizer on the MP was commonly applied with a higher dose than on the IP [15] so that the number of nutrients in the soil would be higher in the MP area. Furthermore, SF are generally not applied fertilizer. In addition, the availability of nutrients in the soil is influenced by many factors that are often interrelated. These include parent rock material, particle size, hummus, moisture content, pH, aeration, temperature, root surface area, rhizo-flora, and mycorrhizal development [15].

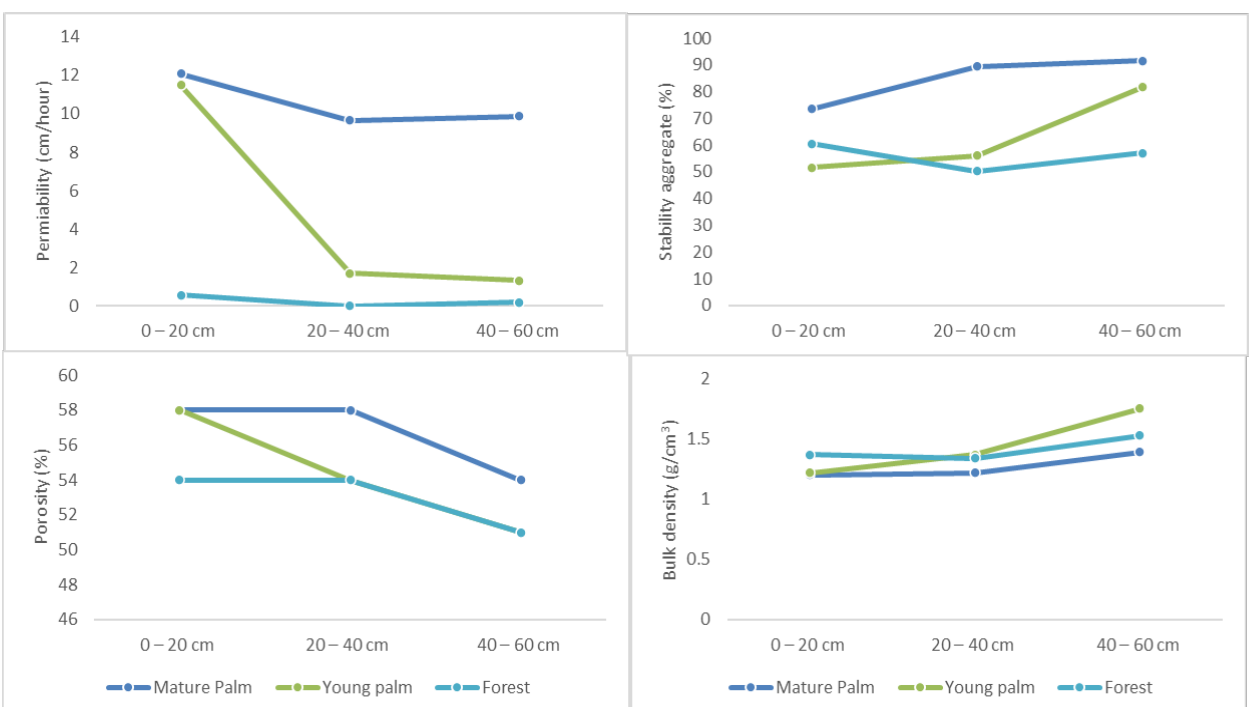

Figure 2 Physical Soil Characteristics

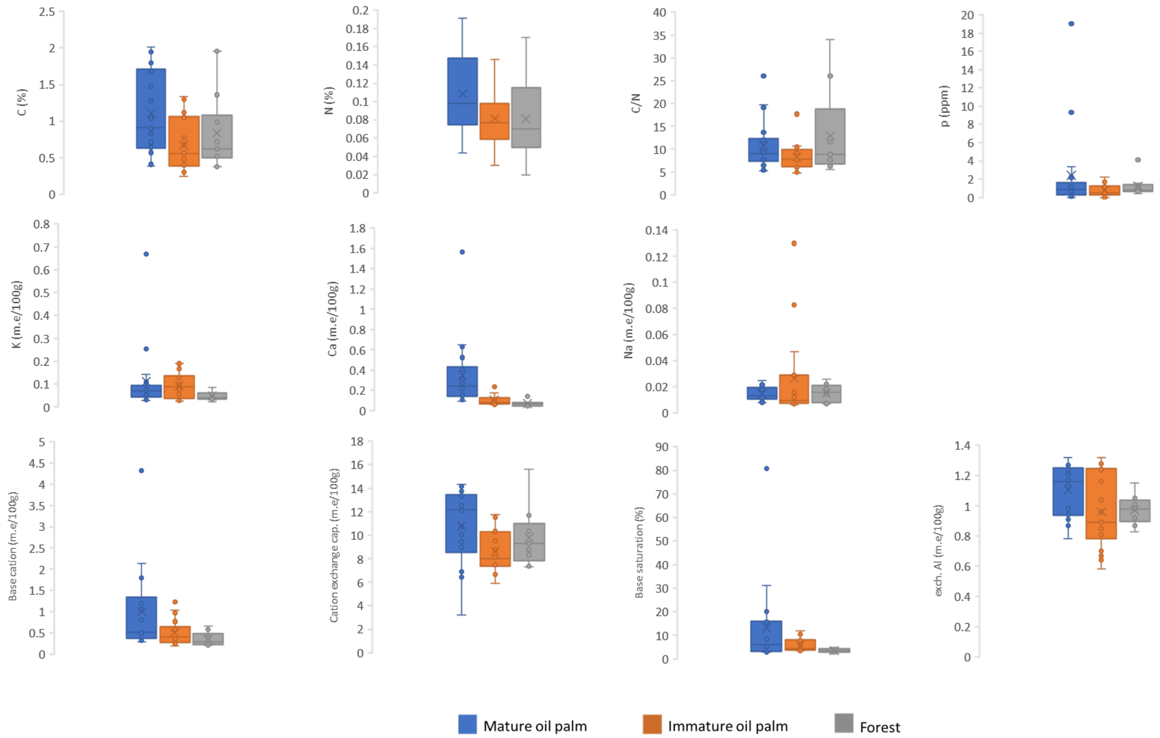

Figure 3 Chemical characteristics of the soil based on land use

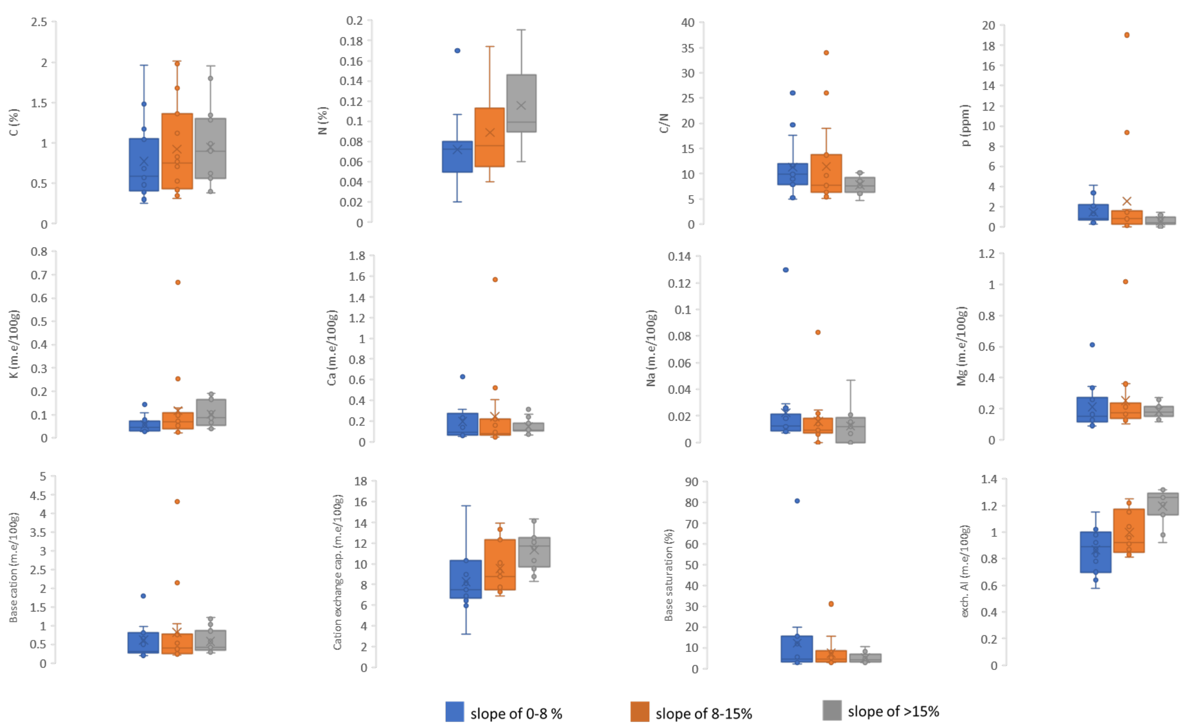

Figure 4 The chemical character of the soil based on the slopes level.

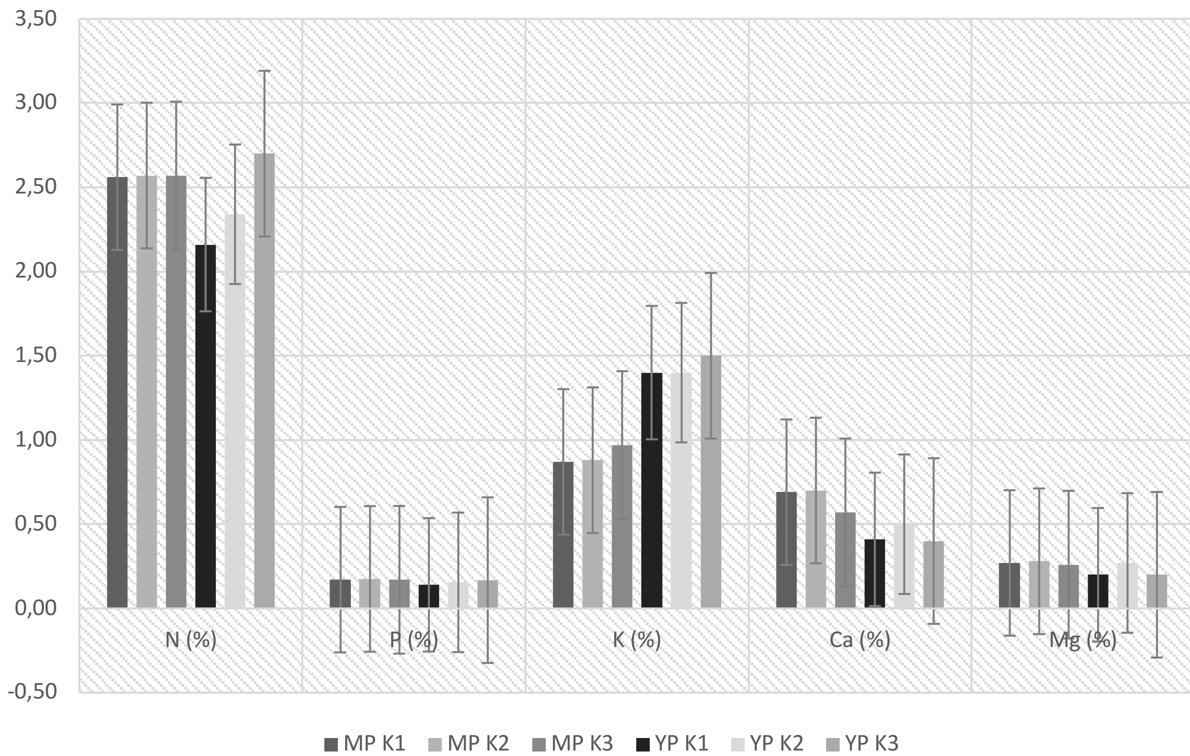

Figure 5 Leaf Chemistry Analysis

The soil's chemical properties based on the land's slope are presented in Figure 4. Overall, land with a slope of >15% contains nutrients C, N, K, Ca, Na, Mg, base cation, cation exchange capacity, exch. Al and base saturation are higher than fields with a slope of 0-8 % and 8-15%. The chemical properties of soils at different slope are significantly influenced by the level of soil development and the leaching process [16]. Soils can significantly accumulate these dissolved ions such as Ca, Mg, K, and Na from the apex and settle at the bottom position of the slope due to the leaching process [16]. Furthermore, erosion due to tillage on inclined or slope land is a significant factor in land degradation on slopes [17]. Even so, in the results of this study, there was no significant difference between soil nutrients in various slopes.

3.3. Leaves Chemistry Analysis

Leaf chemical analysis in this study includes N, P, K, and Ca and Mg content analysis in the MP and IP on some slopes. Based on Figure 5, no consistent nutrient pattern was found in the plant's age and the field's slope. The nutrient concentration of oil palm leaves is influenced by many factors such as soil type, water availability, fertilization, vegetative growth, and seasonal factors, including rainfall [18-19]. The current state of leaf nutrient concentration will determine the health status of the oil palm and lead to the appropriate level of fertilization to be applied [18].

3.4. Floor Biomass

Table 1. Soil Biomass

Cropland	Information	Floor biomass (g)	Root weight at 0-20 cm (g)
Yielding Plants	slopes 0-8%	169,8	221,3
	slope 8-15%	659,3	150
	slopes >15%	1185,3	76,4
Immature Plants	slopes 0-8%	1013,3	264,7
	slope 8-15%	878,7	117,9
	slopes >15%)	675,7	284,5

Floor biomass is the total dry mass of aboveground organic matter in various plant compartments, including trunks, branches, leaves, stumps, and bark [20]. The floor biomass of MP and IP land varies from slopes, but if averaged, the floor biomass on the IP is higher when compared to MP (Table 1). Floor biomass is generally more affected by maintenance carried out on plantations [21]. The distribution of palm biomass over the soil surface is generally showed that the stem produces most of the biomass (about 73%) compared to the leaves (rachis + petioles + fruit/leaflet) which made a total of about 27%. The proportion of floor biomass of oil palm (stem vs. leaf) in both IP and MP of the palm compartment (stem vs. leaf) varies slightly based on age and diameter [21].

Furthermore, based on Table 1, soil biomass is different on each slope. The slope impacts aboveground and subterranean carbon due to its influence on groundwater regimes and plant density [22]. The highest biomass and carbon stocks will be obtained at a more slight slope due to the higher density of the palms compared to the steeper slope [23]. The more density of the tree, the higher the biomass [24].

3.5. Vegetative Plants

The measurement of leaf area in the MP and IP on some slopes shows that the area of leaves in some slope in MP was not much different in 2015 and 2014. However, in the mature and immature palms, the highest increase in leaf area was observed on slopes >15%. This finding is inconsistent with the opinion of [25], who states that the steeper and longer slopes will increase the magnitude of erosion so that the speed of run-off and carrying capacity increase the high leaching of nutrients in the soil [26]. Nutrients are essential factors that affect plant growth. Even so, plant growth is also influenced by sunshine (solar radiation), carbon dioxide, and water [27].

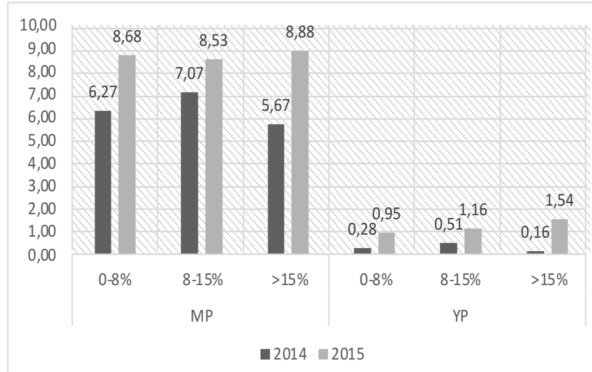

Figure 6 Leaf Area on 2014 and 2015

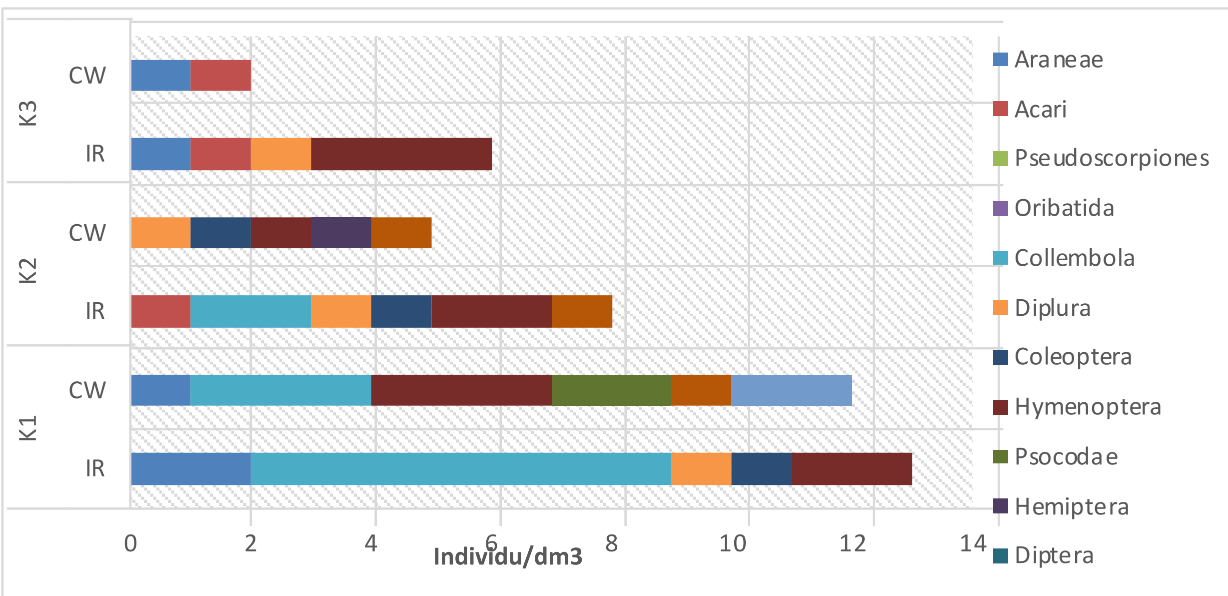

Figure 7 Mesofauna soil that found on the research area

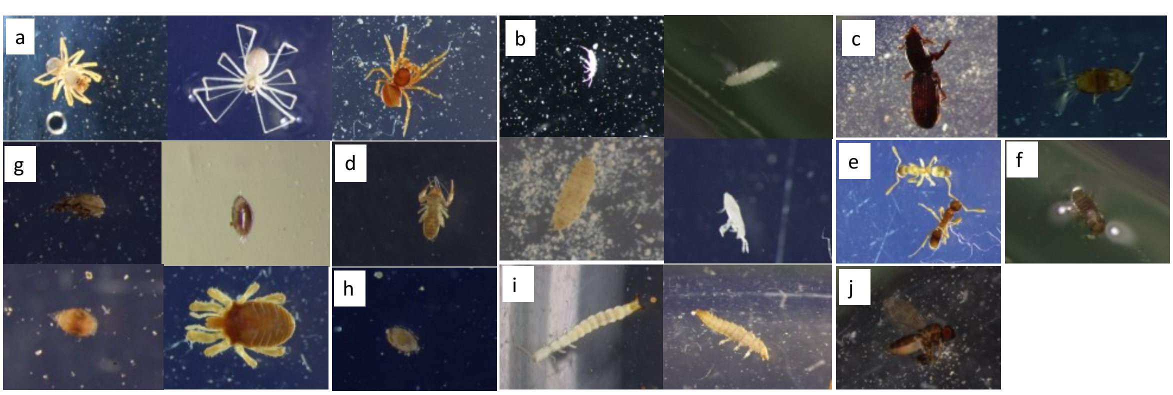

Figure 8 The documentation of soils messofauna. (a) Araneae (b) Collembola (c) Coleoptera (d) Pseudoscorpiones (e) Hymenoptera (f) Psocodae (g) Acari (h) Oribatida (i) Diplura (j) Diptera

3.6. Mesofauna Soil

Soil mesofauna is an essential part of the ecosystem and a link between micro and macro fauna that form an essential part of decomposing soil communities that transfer nutrients through microbial activity [28]. The presence of mesofauna in the soil is strongly influenced by environmental factors, such as soil temperature, pH, and other soil properties. Furthermore, in this study, the land slope is considered the main environmental factor affecting soil organic matter content and nutrient availability [29]. Changes in soil fauna communities also occur after fertilization caused by the quantity and quality of food, as well as modifications in the physical and chemical properties of the soil [30]. Mesofauna populations are closely related to the leaf litter biomass produced by each vegetation so the biomass availability will determine the density of mesofauna [31]. Leaf litter biomass correlates with populations, which means the higher biomass will increase mesofauna populations that vary between vegetation [32].

The observation has found there are eleven types of mesofauna in oil palm plantations in Dawas, namely, from the orders Araneae, Acari, Collembola, Coleoptera, Pseudoscorpiones, Hymenoptera, Psocodae, Oribatida, Diplura, Diptera and Hemiptera. The most dominant mesofauna that found in oil palm plantations are Hymenoptera and Collembola, respectively 34 and 29 amounts of individuals/dm3. Based on the theory, Collembola is one type of mesofauna that is easily adaptable [32]. Some of the mesofauna orders of land found in agricultural land are Collembola, Acarina, Hymenoptera, Diptera, Coleoptera, Orthoptera, Araneae, Spirobolida, Polyxenida, Scolopendromorpha, Hemiptera, Odonata, and Oligochaeta [33]. The population and diversity of mesofauna are the largest in soils with high porosity and organic matter [34]. The reduction of soil fauna populations often occurs due to disturbances in the soil, such as fires, droughts, tillage, and pesticide applications [35].

4. CONCLUSIONS

The chemical and physical characteristics of the soil do not show a noticeable difference between the land where the oil palm crop grows and the immature palm and the forest land. The 0->15% land slope also has no real influence on the physical and chemical properties of the soil. Furthermore, the density of mesofauna on oil palm land is different in the weeding circle and the interrow in each area.

AUTHORS' CONTRIBUTIONS

NHD was setting up research in the field, recapitulated data, sampling, processed data, and finalized the manuscript. IPO and MAY conducted data collection, observation and sampling on the field, RDP was analyse the biological data and drafted the manuscript, ENG made corrections to the data analysis and the manuscript. (NHD: Nuzul Hijri Darlan, IPO: Iput Pradiko, MAY: Muhammad Arif Yusuf, RDP: Rizki D. P. Pane, ENG: Eko Noviandi Ginting).

ACKNOWLEDGMENTS

The authors would like to thank the technicians from the Department of Soil Science and Agronomy who have worked hard in the field during the research. The authors also thank IOPRI management for funding this research.

REFERENCES

[1] A. Aweto, and G. Enaruvbe, "Catenary Variation of Soil Properties under Oil Palm Plantation in South Western Nigeria", Ethiopian Journal of Environmental Studies and Management 3(1) (2010) 1–7. https://doi.org/10.4314/ejesm.v3i1.54389

[2] X. Sui, R. Zhang, B. Frey, L. Yang, M.H. Li, and H. Ni, "Land use change effects on diversity of soil bacterial, Acidobacterial and fungal communities in wetlands of the Sanjiang Plain, northeastern China", Scientific Reports 9(1) (2019) 1–14. https://doi.org/10.1038/s41598-019-55063-4

[3] K. Allen, M.D. Corre, A. Tjoa, and E. Veldkamp, "Nutrient leaching losses in lowland forests converted to oil palm and rubber plantations in Sumatra, Indonesia", Plos ONE 10(7) (2015) 1–21. https://doi.org/10.5061/dryad.q20p

[4] A. E. Hartemink, Soil fertility decline in the tropics: with case studies on plantations. Cabi, 2003.

[5] V. Vijay, S.L. Pimm, C.N. Jenkins, and S.J. Smith, "The Impacts of Oil Palm on Recent Deforestation and Biodiversity Loss Varsha", Plos One 11(7) (2016) 1–19. https://doi.org/10.1371/journal.pone.0159668

[6] T. Guillaume, M. Damris, and Y. Kuzyakov, "Losses of soil carbon by converting tropical forest to plantations: Erosion and decomposition estimated by δ13C", Global Change Biology 21(9) (2015) 3548–3560. https://doi.org/10.1111/gcb.12907

[7] M.P. Carron, Q. Auriac, D. Snoeck, C. Villenave, E. Blanchart, F. Ribeyre, R. Marichal, M. Darminto, and J.P. Caliman, "Spatial heterogeneity of soil quality around mature oil palms receiving mineral fertilization", European Journal of Soil Biology 66(2015) (2015) 24–31. https://doi.org/10.1016/j.ejsobi.2014.11.005

[8] S. Hättenschwiler, A.V. Tiunov, and S. Scheu, "Biodiversity and litter decomposition in terrestrial ecosystems", Annual Review of Ecology, Evolution, and Systematics 36(2005) (2015)191–218. https://doi.org/10.1146/annurev.ecolsys.36.112904.151932

[9] K.T. Osman, Physical Properties of Soil. In Soils Springer, Netherlands, 2015, pp. 49-65. https://doi.org/10.1007/978-94-007-5663-2_5

[10] D. Hillel, Soil Temperature and Heat Flow. In Introduction to Soil Physics, Academic Press, 1982, pp. 155-175. https://doi.org/10.1016/b978-0-08-091869-3.50013-5

[11] M.O. Eyong, and K.I. Ofem, "Soil Mechanical Composition and Texture as Indices for On-site and Field Precise Choice of Land Use Type to Adopt", Asian Soil Research Journal 4(3) (2020) 28–43. https://doi.org/10.9734/asrj/2020/v4i330094

[12] H.S. Dhindsa, R.D. Sharma, and R. Kumar, "Role of fly ash in improving soil physical properties and yield of wheat (*Triticum aestivum*)", Agricultural Science Digest - A Research Journal 36(2) (2016) 97–101. https://doi.org/10.18805/asd.v36i2.10626

[13] R. Rozieta, A.R. Sahibin, and I. Wan Mohd Razi, "Physico-chemical properties of soil at oil palm plantation area, Labu, Negeri Sembilan", AIP Conference Proceeding 1678 (2015) 1–5. https://doi.org/10.1063/1.4931216

[14] D. Darusman, S. Syahruddin, S. Syakur, and M. Manfarizah, "Biochar and Tillage Systems Influenced on Soil Physical Properties" Aceh International Journal of Science and Technology 6(2) (2017) 68–74. https://doi.org/10.13170/aijst.6.2.6897

[15] Jackson, R. S. Site Selection and Climate. In Soil Influences (Fourth Edi), Elsevier Inc., 2014, pp. 307-346. https://doi.org/10.1016/b978-0-12-381468-5.00005-1

[16] C.C. Tsui, Z.S. Chen, and C.F. Hsieh, "Relationships between soil properties and slope position in a lowland rain forest of southern Taiwan", Geoderma 123(1–2) (2004) 131–142. https://doi.org/10.1016/j.geoderma.2004.01.01

[17] Basic, F., Kisic, I., Mesic, M., Nestroy, O., & Butorac, A. (2004). Tillage and crop management effects on soil erosion in central Croatia. Soil and Tillage Research, 78(2), 197–206. https://doi.org/10.1016/j.still.2004.02.007

[18] C.-T. Lee, Z.A. Rahman, M.H. Musa, S. Norizan, and C.-C. Tan, "Leaf Nutrient Concentrations in Oil Palm as Affected by Genotypes, Irrigation and Terrain", Journal of Oil Palm & The Environment, 2(2016) (2011) 38–47. https://doi.org/10.5366/jope.2011.05

[19] J. Sardans, A. Rivas-Ubach, and J. Peñuelas, "Factors affecting nutrient concentration and stoichiometry of forest trees in Catalonia (NE Spain)" Forest Ecology and Management 262(11) (2011) 2024–2034. https://doi.org/10.1016/j.foreco.2011.08.019

[20] M. Neumann, A. Moreno, V. Mues, S. Härkönen, M. Mura, O. Bouriaud, M. Lang, W.M.J. Achten, A. Thivolle-Cazat, K. Bronisz, J. Merganicˇ, M. Decuyper, I. Alberdi, R. Astrup, F. Mohren, Hasenauer and H. Hasenauer, "Comparison of carbon estimation methods for European forests", Forest Ecology and Management vol. 361 (2016) 397-420.

[21] P. Migolet, K. Goïta, A. Ngomanda, A.P.M. Biyogo, "Estimation of aboveground oil palm biomass in a mature plantation in the Congo Basin", Forests 11(5) (2020) 1–23. https://doi.org/10.3390/F11050544

[22] R.A. Houghton, "Aboveground forest biomass and the global carbon balance" Global Change Biology 11(6) (2005) 945–958. https://doi.org/10.1111/j.1365-2486.2005.00955.x

[23] B. Bohara, M.S. Miya, S. Timilsina, D. Gautam, and S. Regmi, "Biomass and Carbon Stock Variation along slopes in Tropical Forest of Nepal: A case of Depard Community Forest, Makwanpur, Nepal" Journal of Multidisciplinary Applied Natural Science 1(2) (2021) 89–99. https://doi.org/10.47352/jmans.v1i2.85

[24] B. Mwakisunga, and A.E. Majule, "The influence of altitude and management on carbon stock quantities in rungwe forest, southern highland of Tanzania", Open Journal of Ecology 02(04) (2012) 214–221. https://doi.org/10.4236/oje.2012.24025

[25] Martono, Pengaruh Intensitas Hujan dan Kemiringan Lereng Terhadap Laju Kehilangan Tanah pada Tanah Regosol Kelabu. In E-Journal Undip, 2004.

[26] M. Awal, and W.I. Ishak, "Measurement of oil palm LAI by manual and LAI-2000 method" Asian Journal of Scientific Research 1(1) (2008) 49–56.

[27] R.H.V. Corley and P.B. Tinker, The oil palm. John Wiley & Sons, 2008.

[28] W.D. Xin, X.Q. Yin, and B. Song, "Contribution of soil fauna to litter decomposition in Songnen sandy lands in northeastern China", Journal of Arid Environments 77(1) (2012) 90–95. https://doi.org/10.1016/j.jaridenv.2011.10.01

[29] Y. Hidayat, K. Murtilaksono, and N. Sinukaban, "Characterization of Surface Runoff, Soil Erosion and Nutrient Loss on Forest-agriculture

Landscape", Journal of Tropical Soils 17(3) (2012) 259–266. https://doi.org/10.5400/jts.2012.17.3.259

[30] S. Wang, H.Y.H Chen, Y. Tan, H. Fan, and H. Ruan, "Fertilizer regime impacts on abundance and diversity of soil fauna across a poplar plantation chronosequence in coastal Eastern China", Scientific Reports 6(2016) (2016) 1–10. https://doi.org/10.1038/srep20816

[31] N.M. Suin, Animal ecology of the soil. Bumi Aksara Jakarta, 2003.

[32] M.A.S. Arif, A. Niswati, S. Yusnaini, and N.P. Ardiyani, "Population and Diversity of Soil and Leaf Litter Mesofauna in Arable Soils at The Agriculture Experimental Field of University of Lampung", Journal of Tropical Soils 22(1) (2017) 55–66. https://doi.org/10.5400/jts.2017.v22i1.55-66

[33] Fitrahtunnisa and M. Ilhamdi, "Perbandingan keanekaragaman dan predominansi fauna tanah dalam proses pengomposan sampah organik" Jurnal Bumi Lestari 13(2) (2013) 413–421.

[34] O. Andrén and J. Lagerlöf, "Soil Fauna (Microarthropods, Enchytraeids, Nematodes) in Swedish Agricultural Cropping Systems" Acta Agriculturae Scandinavica 33(1) (1983) 33–52. https://doi.org/10.1080/00015128309435350

[35] J. Barus, D. Meithasari, J. Lumbanraja, H. Sudarsono, K.F. Hidayat, and Dermiyati, "Soil mesofauna amount and diversity by returning fresh and compost of crops biomass waste in ultisols in-situ" Biodiversitas 22(1) (2021) 92–98. https://doi.org/10.13057/biodiv/d220113