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Soil Tillage and Application of Organic Materials on Oil Palm Plant Disc and Their Effects on Soil Properties

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ABSTRACT

Various efforts have been made to achieve sustainability of oil palm plantations. The decline in soil fertility has reached an alarming limit in specific locations in North Sumatra. This research investigates the effect of modified palm discs through tillage and application of organic matter (OM) on the physical, chemical, and biological properties of the discs of oil palm plants. The experiment was conducted at two estates with different soil types, Ultisol and Inceptisol. The study design used was a factorial randomized block design with two factors. The first factor was tillage, no-tillage, and tillage. The second factor was doses OM; 0, 50, 100, and 150 kg OM tree^{-1}. Locally available sources of OM, such as empty fruit bunches and cow dung compost, were applied. The results showed that soil tillage increased porosity, organic C, and N availability of P, K, Ca, and Mg in inceptisol soil and decreased porosity, organic C content, and K by 0.26-1.47%, and fauna population in ultisol soil. Increasing the dose of OM increased the C and K content, but the same pattern was not obtained for other soil chemical properties. The soil fauna population increased with increasing OM dose. The impact of providing organic matter and soil tillage differed for different soil types.

Keywords: soil type, organic matter, oil palm, tillage, soil properties

INTRODUCTION

Land for agriculture is limited; it is often used continuously without regard to maintenance and does not allow the soil to renew itself naturally (self-resiliency) (Weidhuner *et al*. 2021). Continuous land use without proper management causes a gradual decrease in fertility (Filippi *et al*. 2016; Mhete *et al*. 2020), thereby reducing soil productivity. To reduce and anticipate land damage, it is necessary to take the right, safe actions without spending a lot of money, for example, by providing organic material into the soil. Giving organic matter to the soil can improve the soil's physical, chemical, and biological properties (Gamage *et al*. 2023) and strengthen the process of soil aggregation (Mandi *et al*. 2014). Compost is the type of organic material most widely used soil amendment. Compost can improve the physical and chemical properties of soil and enhance soil quality. For instance, adding compost rich in OM can markedly decrease soil bulk density (Qian et al., 2023).

There is an increase in soil fauna activity because organic material is used as an energy and food source for survival (Hagner *et al*. 2023). Soil fauna is one of the biological components of the soil that plays a vital role in the soil-forming process. The active role of mesofauna and soil macrofauna in decomposing organic matter can maintain and restore soil productivity supported by surrounding environmental factors (Sparling, 1997; Pankhurst, 1997). Brussaard *et al*. (2007) explained that the presence and activity of mesofauna and soil macrofauna can increase aeration, water infiltration, soil aggregation, and distribution of soil organic matter, so an effort is needed to increase the diversity of mesofauna and soil macrofauna. The diversity of mesofauna and soil macrofauna is closely related to plant organic matter added to the soil. Oil palm has been cultivated for a long time, but research to increase sustainable and environmentally friendly production, especially the emphasis on soil biological properties, is still limited.

From a survey of various oil palm plantations, Sabrina *et al*. (2009) obtained populations and diversity of earthworms with a range of 0 - 42 individual m^{-2} and were dominated by *Pontoscolex corethrurus*. Providing various forms of organic matter in various ways on the discs of oil palm plants successfully attracts earthworms to be in the disc (Sebayang *et al*. 2015). Similarly, Ananda (2016) obtained that the population of mesofauna increases in the palm plant discs that are applied evenly with oil palm empty bunches on the disc compared to those without the application of organic matter. No action has been taken to improve the physical properties of the soil in the disc area. The soil fertility improvement on oil palm plantations is usually done by adding inorganic fertilizer. For this reason, it is necessary to conduct research concerning the effect of tillage in the oil palm tree disc area and applying organic fertilizers. The study aimed to examine changes in physical, chemical, and fauna populations due to tillage and the application of organic matter on the palm oil disc.

MATERIALS AND METHODS

Time and Place of Research

The study was conducted at two estates: the Adolina estate in Serdang Bedagai district, whose soil type was inceptisol with a sandy clay texture, and the Bukit Sentang estate in Langkat district, which has an Ultisol soil type. This research was conducted on oil palm trees planted in 2006. Observations were carried out after 1 year of treating organic material and tillage.

Materials preparation

The material used in this study was oil palm empty bunches (EFB) of oil palm mills at Adolina PTPN 4 estates and cow manure compost in Bukit Sentang estate. The characteristics of cow manure compost was pH=7.7, C= 3.16%, N= 1.01; P-available: 23.46 ppm; CEC= 19.62 cmol(+)kg^{-1}, K-exch= 19.8 cmol(+)kg^{-1}, Ca-exch=4.55 cmol(+)kg^{-1}, Mg-exch= 21.24 cmol(+)kg^{-1}, Na-exch= 5.01 cmol(+)kg^{-1}, base saturation= 256.6%. The cow dung compost was very mature, as shown by its organic carbon content. The characteristics of oil palm empty bunch were C=40%, N= 0.2%, K_2O= 2.9%, and P_2O_5=0.22%. The local availability of cow dung and EFB on plantations was the rationale behind their selection. This study used hoes (farmers use a hand plowing instrument) and other tools to analyze physical, chemical, and soil macrofauna properties.

Method

The research experimental design was a factorial randomized block design (RBD) with a demo plot system (demonstration plot). The treatment that will be tested consists of 2 factors: Factor 1 was tillage (T), which consists of 2 treatments: T0: The disc was cleaned according to the standard treatment of the estate, and T1: The disc was carried out by tillage. Factor 2 was dosage of organic matter (D): oil palm empty bunches (EFB) for Adolina estates and cow manure compost for Bukit Sentang with four treatments. D0: The disc was applied 0 kg $tree^{-1}$; D1: The disc was applied to EFB or compost cow manure 50 kg $tree^{-1}$; D2: The disc was applied to EFB or compost cow manure of 100 kg $tree^{-1}$ and D3: The disc was applied to EFB or compost cow manure 150 kg $tree^{-1}$. Each treatment plot consists of 10 trees, with several as border and recorded trees. Each plot has three repetitions.

Implementation of Research Determination of research plots

Oil palm discs were ploughed manually using a hoe on plots treated with tillage. After tillage, organic matter (oil palm empty bunches or composted cow manure) was applied to the oil palm discs according to the dosage treatment. They were distributed evenly around the tree.

The parameters observed in the study include soil chemical properties and biological properties of the soil, with details of each parameter as follows: a. Soil physical properties: particle density (PD), bulk density (BD), soil porosity, and soil permeability. Soil samples were collected to observe soil physical properties 4 months after the tillage treatment and EFB application. Soil samples were taken from each treatment plot, and as many as 3 points were taken in the disc (100 cm from the base of the tree). b. Soil chemistry: soil pH, organic matter, soil nutrient content. Soil samples were taken compositely from each treatment plot, and as many as 3 points were taken in the disc (100 cm from the base of the tree). c. biological properties of soil: soil fauna population active on the surface. Sampling of soil fauna at the soil's surface with "pitfall" traps installed on a full day. Soil sampling for observing all parameters was carried out 4 months after tillage treatment and organic matter application.

Data analysis

Statistical analyses were performed using Microsoft Excel 2016 and SPSS 25.0. Two-way ANOVA tested differences among treatments. After ANOVA (analysis of variance) analysis shows that there are significant differences between treatment groups using Duncan's multiple range test (α= 0.05).

RESULTS AND DISCUSSION

Effect of tillage and application of organic matter on soil physics

The results of the variance test on soil physical properties showed that the treatment of adding cow manure and tillage only significantly affected soil porosity and permeability. Tillage did not affect particle density and bulk density in the inceptisol soil, and the treatment only significantly changed the percentage of soil porosity in the ultisol soil (**Table 1**).

Tillage increased the permeability of the soil in the palm oil disc (6.57 cm h^{-1}) significantly, almost twice from no-tillage (3.81 cm h^{-1}) at inceptisol soil (Table 1). The application of organic matter, in this case EFB, also increased the permeability of the land significantly more than twice compared to without the application of EFB. Applying 100 kg EFB on no-tillage increased permeability up to 7.65 cm h^{-1}.

The evidence did not happen in the Bukit Sentang estate, which has soil type Ultisol, where tillage in the palm oil disc decreased soil permeability. Maybe the OC applied was the cow manure compost spread on the field that had a fine texture. Meanwhile, ultisol soil has more clay particles than sand. Fine particles of clay and cow dung compost compact the ploughed soil, reducing soil permeability.

The long-term effects of manure application on soil water characteristics, including irrigation depth, frequency, and crop water availability, were examined by Tanha *et al*. (2024). They found that the structural characteristics of soil aggregates remained unchanged when the manure application rate was increased from 168 to 672 kg N/ha. In contrast to the control sample, Horizon A's specific volume, water content, and accessible water all rose with the application of the treatment.

The particle density and bulk density values of the Adolina estate with Inceptisol soil types were lower than the particle density and bulk density of the Bukit Sentang estate with Ultisol soil types. Tillage and application of several organic matter dosages (EFB and cow dung compost) on the palm oil disc did not affect both values.

Soil tillage significantly increases the porosity of inceptisol, but it is not for ultisol (**Table 1**). The possibility of tillage causing damage to the soil aggregate in the ultisol results in compaction due to aggregate grains entering the soil pore. In contrast to the results of a study conducted by Holthusen *et al*. (2018), which studied the effects of non-tillage on Hapludox, Hapludalf, and

Quartzipsamment soil types in southern Brazil where the results of the study showed differences in changes in physical properties for each different soil type. In Hapludox clay, no-tillage produces the most extensive solid layer. Soil Hapludalf has a clay sand texture, and the soil layer remains permeable below without tillage.

Table 1: Effect of Soil tillage (T) and application of organic matter bunches (D) on the physical properties of inceptisol at Adolina estate and Ultisol at Bukit Sentang Estate

Treatment	Inceptisol soil				Ultisol soil			
	permeability	PD	BD	porosity	permeability	PD	BD	porosity
	--- cm/h --	--- g/cm^3 --		--- % ---	--- cm/h --	--- g/cm^3 --		-- %--
No till	3.81 b	2.83	1.22	56.95 b	0.32	3.01	1.38	54.19
Tillage	6.57 a	2.85	1.15	59.56 a	0.28	3.04	1.40	53.69
0 kg tree$^{-1.}$	2.13 c	2.85	1.19	58.16	0.26	2.91	1.40	51.83 b
50 kg tree^{-1}	4.33 bc	2.86	1.15	59.65	0.32	2.98	1.45	51.47 b
100 kg tree^{-1}	7.65 a	2.80	1.17	58.16	0.28	3.08	1.35	56.18 a
150 kg tree^{-1}	6.66 ab	2.85	1.22	57.04	0.35	3.13	1.36	56.29 a
T0-D0	2.04	2.85	1.18	58.72	0.30	2.90	1.42	50.90
T0-D1	5.25	2.85	1.24	56.49	0.43	3.02	1.40	53.88
T0-D2	5.03	2.85	1.17	57.61	0.25	3.00	1.35	55.12
T0-D3	2.94	2.87	1.28	55.00	0.32	312	1.34	56.86
T1-D0	2.22	2.77	1.21	57.60	0.22	2.93	1.38	52.77
T1-D1	3.42	2.84	1.06	62.81	0.22	2.94	1.49	49.05
TI-D2	10.27	2.85	1.17	58.72	0.30	3.16	1.35	57.23
T1-D3	10.37	2.85	1.16	59.09	0.38	3.13	1.39	55.72

Note: T0= no tillage; T1= tillage; D0= 0 kg tree^{-1}; D1= 50 kg tree^{-1}; D2= 100 kg tree^{-1}; D3=150 kg tree^{-1}. Different letters in the same column and same treatment indicate a significant difference at α 0.05 according to Duncan's multirange test

Intensive tillage systems can disrupt soil structure; tillage affects the percentage of carbon (C) and nitrogen (N) associated with aggregates. Intensive tillage systems using moldboard plows (MP) or chisel discs (CD) can reduce soil structure. No-till (NT) can improve soil structure and can increase soil carbon (C), but the increase is only concentrated C, N, and POXC in the topsoil (0-5 cm). Alternate tillage (no-tillage for 2 years followed by moldboard plow) resulted in some aggregate size and stability improvements compared to continuous moldboard. However, it did not significantly increase yields compared to no tillage (Weidhuner *et al*. 2021).

Effect of tillage and application of organic matter on soil chemistry

The effect of tillage and application of soil organic matter (EFB and composted cow manure) on the palm oil disc on the soil chemical properties in Adolina and Sentang Hills (**Tables 2** and **3**). The addition of organic material doses on both estates with different soil types increased the organic C content of the soil from both estates significantly.

The amount of organic C, N, and CEC in Inceptisols was considerably raised by increasing the rate at which empty fruit bunches were applied to oil palm discs. Oil palm discs on Inceptisol soil at Adolina Estate showed a significant loss in organic C and N as a result of tillage. Although the effect was not statistically significant, tillage raised base saturation (BS), exchangeable K, P-available, and CEC (**Table 2**).

The impact of increasing the EFB dosage on organic C differed based on the tillage method. With a 150 kg EFB tree^{-1}, soil organic C in the no-till treatment increased, while in the tillage treatment it decreased (**Table 2** and **Figure 1a**). Both Inceptisols and Ultisols showed a statistically significant interaction between the application of organic matter and tillage on soil organic C. Similarly, organic C in the Ultisol soil type at the Bukit Sentang estate showed the same results due to the interaction of cow dung treatment with tillage (**Table 3** and **Figure 1b**).

Table 2: Effect of tillage and application of organic matter (EFB) to the chemical properties of the oil palm disc in Inceptisol (Adolina estate)

Treatment	C-organic	N	Available P	Exch - K	Ca	Mg	CEC	Base saturation
	-------- %	---------	- ppm -	---------	cmol c kg^{-1}	---------		%
No till	0.83 a	0.13	96.64	1.52	1.46	0.74	6.31	66.75
Tillage	0.76 b	0.13	98.84	1.54	1.72	0.95	7.06	64.50
0 kg $tree^{-1}$	0.66 b	0.11 b	93.36	1.37	2.42	1.04	5.93 b	82.00
50 kg $tree^{-1}$	0.64 b	0.11 b	99.02	1.60	1.85	0.82	6.25 b	68.50
100 kg $tree^{-1}$	0.95 a	0.14 a	95.54	1.32	1.56	0.64	6.78 ab	51.50
150 kg $tree^{-1}$	0.94 a	0.14 a	103.05	1.83	2.05	0.86	7.79 a	60.50
T0D0	0.69	0.11	92.67	1.50	2.65	1.24	5.63	96.00
T0D1	0.63	0.10	111.77	1.37	1.67	0.66	6.10	61.00
T0D2	0.97	0.14	80.94	1.53	1.3	0.52	6.42	52.00
T0D3	1.04	0.16	101.19	1.68	1.91	0.51	7.10	58.00
T1D0	0.62	0.11	94.05	1.24	2.18	0.84	6.22	68.00
T1D1	0.65	0.12	86.26	1.84	2.03	0.98	6.40	76.00
T1D2	0.93	0.15	110.14	1.10	1.82	0.75	7.15	51.00
T1D3	0.84	0.13	104.91	1.98	2.18	1.21	8.49	63.00

Note: T0= no tillage; T1= tillage; D0= 0 kg $tree^{-1}$; D1= 50 kg $tree^{-1}$; D2= 100 kg $tree^{-1}$; D3=150 kg $tree^{-1}$. Different letters in the same column and same treatment indicate a significant difference at α 0.05 according to Duncan's multirange test

Soil tillage on plant discs tended to reduce soil organic C content in inceptisol (decreasing from about 0.83% C to 0.76% C on average) and ultisol (decreasing from about 1.35% C to 1.27% C on average) significantly. Upon examining each tillage treatment, it is clear that not all soil organic carbon values in the no-till treatment exceed those observed in tillage-treated soil. Many researchers have found that soil cultivation can reduce soil organic carbon in studies with various types of soil (Engell *et al*. 2024; Hao *et al*. 2013; Li *et al*. 2025; Lv *et al*. 2023). High organic carbon on the soil surface in no-till is due to low disturbance of organic carbon; tillage will accelerate decomposition and distribute it to deeper layers (Zang *et al*. 2023). While a long-term study (19 years) by Hao *et al* (2013) found that the effect of tillage on soil organic carbon (SOC) was observed, and the SOC concentration was much greater under non-tillage than the other three tillage methods (conventional tillage with rotation of rice and winter fallow system; conventional tillage with rotation of rice and rape; and tillage and ridge culture with rotation of rice and rape system) at all soil depths from 0 to 60 cm.

There was no change in soil N content on the disc treated with no tillage in inceptisol, but in the ultisol, there was a decrease of 0.01-0.18% N for each treatment (**Table 2**). Zhang *et al*. (2023) found that the total nitrogen, available nitrogen, and potassium contents of no-tillage + straw and tillage + straw were higher than those of tillage, indicating that straw return increased available nutrients.

Table 3: Effect of tillage and application of organic matter (cow dung) to the chemical properties of the oil palm disc in Ultisol

Treatment	C-organic	N	Available P	Exch - K	Ca	mg	CEC	BS
	---- % ----		- ppm -	--------	cmol c kg^{-1}	--------		%
No till	1.35 a	0.21 a	116.23	0.60	5.02	3.48	18.14	50.75
Tillage	1.27 b	0.16 b	114.61	0.91	5.11	3.70	17.21	56.25
0 kg $tree^{-1}$	1.08 d	0.21 a	111.12	0.82	4.73	3.20	15.58	15.58
50 kg $tree^{-1}$	1.20 c	0.17 b	120.42	1.08	5.39	4.04	19.16	19.16
100 kg $tree^{-1}$	1.34 b	0.17 b	113.99	0.67	5.09	3.76	17.02	17.02
150 kg $tree^{-1}$	1.62 a	0.19 ab	116.14	0.45	5.07	3.37	18.94	18.94
T0D0	1.03	0.30	113.75	0.89	5.28	3.94	16.27	62.00
T0D1	1.13	0.15	106.87	1.02	5.15	3.86	19.88	50.00
T0D2	1.36	0.17	129.27	0.27	4.86	3.47	15.96	54.00
T0D3	1.86	0.21	115.02	0.21	4.8	2.66	20.47	37.00
T1D0	1.12	0.13	108.49	0.75	4.17	2.46	14.88	50.00
T1D1	1.27	0.19	133.96	1.13	5.62	4.22	18.45	59.00
T1D2	1.32	0.16	98.71	1.06	5.31	4.04	18.08	58.00
T1D3	1.38	0.17	117.26	0.69	5.34	4.09	17.41	58.00

Note: T0= no tillage; T1= tillage; D0= 0 kg $tree^{-1}$; D1= 50 kg $tree^{-1}$; D2= 100 kg $tree^{-1}$; D3=150 kg $tree^{-1}$. Different letters in the same column and same treatment indicate a significant difference at α 0.05 according to Duncan's multirange test

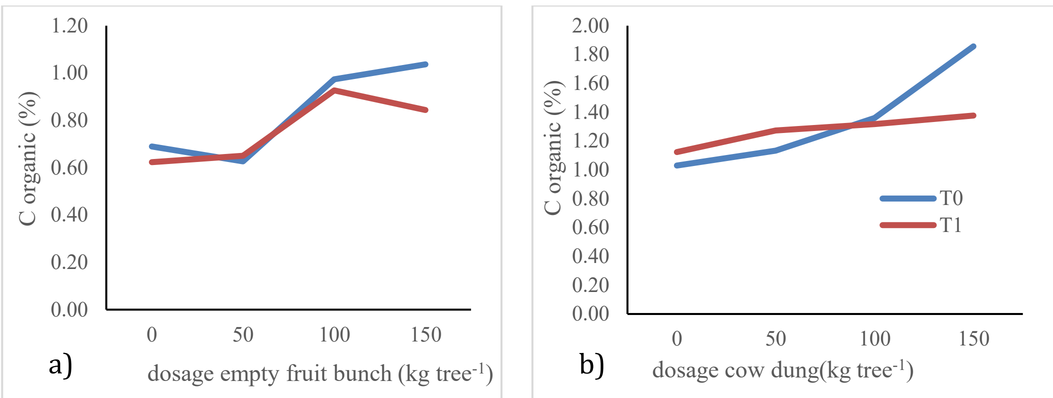

Figure 1. Significant different effects of applying organic material on C organic in inceptiol (a; left) and ultisol (b; right) soil caused by tillage treatment

Phosphorus, potassium, calcium, and magnesium are essential mineral nutrients for plant growth. Therefore, it is an important criterion for evaluating the soil quality. The soil's average P, K, Ca, and Mg content in inceptisol increased due to treatment with tillage on the disc. Similarly, this happened in ultisol, except for P available in the soil, which decreased at the tillage treatment. Tillage increases the mineralization of organic nutrients in the soil, distributes organic C, and provides more significant opportunities for soil microbes to use. Three years of field research found that tillage practices significantly positively affected available nitrogen, phosphorus, microbial biomass carbon, nitrogen content, protease, and urease activities (Liu *et al*. 2011). Lv *et al*. (2023)

investigate the effects of conservation tillage on soil chemical properties by using a systematic meta-analysis based on comprehensive global datasets. They found that compared to conventional tillage, conventional tillage with straw stubble covering, no-till with straw stubble covering, and no-till without straw stubble covering increased the topsoil organic matter, organic carbon, total nitrogen, total phosphorus, and available phosphorus, respectively. Meanwhile, no-till with straw stubble covering increased the topsoil total carbon, available nitrogen, Ca^{2+}, Mg^{2+}, and cation exchange capacity (CEC) compared to conventional tillage without straw stubble covering. They argued that a lower soil pH may adversely affect the soil nutrient availability, resulting in lower yields. Compared to conventional tillage without straw stubble covering, conservation tillage improves the chemical environment of soil in croplands.

Applying organic matter (EFB) at the highest dosage (150 kg EFB tree^{-1}) to the oil palm disc increased the soil's organic C, P, and K content, specifically for the inceptisol. However, the increase in the soil's nutrient and other chemical properties (Ca and Mg) did not show the same pattern with the addition of EFB doses.

The cation exchange capacity of inceptisol increased with tillage treatment but decreased in ultisol soil. The cation exchange capacity of ultisol soil was almost double that of inceptisol soil due to the percentage of clay in the soil. Increasing the dose of empty oil palm bunches increases the CEC value. The CEC on ultisol with the highest cow dung compost was not found at the highest dose but at a dose of 50 kg per tree. Differences in organic matter are one of the causes. The results of Sabrina (2007) study showed that EFB decomposition would produce higher humic acid (8%) than oil palm frond decomposition (3.6%). Lu *et al*. (2024) found that the humic acid content in cow dung compost ranged from 5.39 ± 0.07 - 6.49 ± 0.05%, depending on the treatment. Humic acid increases the soil's cation exchange capacity (Troeh and Thompson, 2005). They illustrated that if dark-colored loamy soil is estimated to contain 4% organic matter and 20% clay (half smectite and half illite), the soil has a calculated CEC of 21 meq 100g^{-1}. However, soil containing much higher organic matter (15%) and clay (30% smectite and 10% illite) have a calculated CEC of 63 meq 100g^{-1}. The soil's average P, K, Ca, and Mg content in inceptisol increased due to treatment to tillage on the disc. Similarly, except for P total in the soil, the ultisol decreased at the tillage treatment. Tillage increases the mineralization of organic nutrients in the soil, distributes organic C, and provides more significant opportunities for soil microbes to use.

Effect of tillage and application of organic matter on soil fauna population

Table 4 shows observations of the soil fauna population on the palm oil disk. The laboratory results show that the soil fauna population in tillage was less than without tillage. The type of fauna in non-tillage without application of EFB was more varied than that in EFB application. The fauna population in the treatment of EFB application was not in line with the increase in EFB dose, and the results obtained differed from the publications of the following studies.

Increasing the dose of cow dung compost increases the fauna population in areas no-tillage and with soil tillage. Increasing the dose of EFB does not consistently increase the soil fauna population. Sabrina (2007) found that EFB application hurts the number of earthworms; the phenolic compound content in EFB causes this. The same incident occurred in this study.

The results of the research by Hsiao-Hang *et al*. (2016) show that eating soil fauna in the soil increases with the application of EFB, which may be related to increased abundance or changes in the composition of fauna communities living on the ground. Their results align with previous findings from nearby oil palm sites, suggesting that the abundance of soil macrofauna, including ants, earthworms, and beetles, is increased by EFB applications (Carron *et al*., 2015). However, for Bukit Sentang Estates with Ultisol soil types, an increase in the dosage of cow manure compost increases the fauna population in the soil, with the application of 100 g per kg of soil mass on the changes in chemical soil properties (primary macronutrients; N, P, and K contents) over a period of 1 to 7 days and microbial activities (Sung-Inthara et al., 2024).

Table 4: Population of soil fauna due to treatment of tillage and application of organic matter

Treatment	No-tillage (T0)	tillage(T1)
	------------------ individual cm^{-2}	------------
Inceptisol (Adolina estate)		
0 kg EFB $tree^{-1}$	40	31
50 kg EFB $tree^{-1}$	42	27
100 kg EFB $tree^{-1}$	60	26
150 kg EFB $tree^{-1}$	26	42
Ultisol (Bukit Sentang estate)		
without compost cow dung	64	69
50 kg compost cow dung $tree^{-1}$	72	74
100 kg compost cow dung $tree^{-1}$	114	86
150 kg compost cow dung $tree^{-1}$	125	116

CONCLUSION

Tillage on palm tree discs significantly changed the permeability, specific gravity, and porosity of soil in Adolina plantations with Inceptisol soil, but not in Ultisol soil in Bukit Sentang Plantation. Soil organic C content decreased in both plantations due to tillage and N in Ultisol soil. Application of organic matter (EFB or cow dung) in both plantations significantly increased organic C and N. Increasing the dose of empty fruit bunch compost in Adolina plantations increased soil CEC. Available P, exchangeable K, Mg, base saturation, and soil fauna population changed due to tillage treatment and organic matter application but were not statistically significant. Nevertheless, this was a short-term study; results may vary in longer-term studies.

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REFERENCES

Ananda, R. 2016. Population dynamics and diversity of soil mesofauna are due to applying several organic matter types and methods to the palm oil disc. Bachelor Thesis. Universitas Sumatera Utara

Brussaard, L., Pulleman, M.M., Oue´draogo, E., Mando, A and Six, J. 2007. Soil fauna and soil function in the fabric of the food web. *Pedobiologia* 50 : 447—462

Carron, M.P., Pierrat, M.A., Snoeck, D.A., Villenave, C.C., Ribeyre, F.D., Marichal, R., Caliman, J.P., Suhardi, E.R.M., Caliman, J.P., 2015b. Temporal variability in soil quality after organic residue application in mature oil palm plantations. *Soil Res.* 53, 205–215.

Engell, I., Gerigk, J., Linsler, D., Joergensen, R.G. and Potthof, M. 2024. Tillage and land use management effects on soil organic matter and soil microbial biomass in a field network of practical farms in France, Romania, and Sweden. *Applied Soil Ecology* 202:105584

Filippi, P., B. Minasny, B., S.R. Cattle, S.R., and Bishop, T.F.A. 2016. Chapter Four - Monitoring and Modeling Soil Change: The Influence of Human Activity and Climatic Shifts on Aspects of Soil Spatiotemporally. *Advances in Agronomy* Volume 139, Pages 153-214

Gamage, A., Gangahagedara, R., Gamage, J., Nepali Jayasinghe, N., Kodikara, N., Suraweera, P., and Merah, O., 2023. Role of organic farming for achieving sustainability in agriculture. *Farming System* 1: 100005

Hagner, M., Pohjanlehto, I., Nuutinen, V., Setala, H., Velmala, S., Vesterinen, E., Pennanen, T., Lemola, R. and Peltoniemi, K. 2023. Impacts of long-term organic production on soil fauna in boreal dairy and cereal farming. *Applied Soil Ecology 189:104944*

Hao,Q., Cheng, B., and Jiang, C. 2013. Long-term tillage effects on soil organic carbon and dissolved organic carbon in a purple paddy soil of Southwest China. *Acta Ecologica Sinica* 33:260–265

Holthusen, D., Brandt, A.A., Reichert, J.M. and Horn, R. 2018. Soil porosity, permeability, and static and dynamic strength parameters under native forest/grassland compared to no-tillage cropping. *Soil & Tillage Research* 177: 113–124.

Hsiao-Hang T, Slade, E.M., Willis, K.J., Caliman, J.P and Snaddon, J.l. 2016. Effects of soil management practices on soil fauna feeding activity in an Indonesian oil palm plantation. *Agriculture, Ecosystems and Environment* 218 : 133–140

Li, J., Li, S., Rui Zhao , R., Xing, S., Chen, H., Huang, Y.,Zhang, L., and Li, J. 2025., Soil organic carbon dynamics (2008–2020) across different cultivated landuse types in a subtropical region. Geoderma Regional 40:e00926.

Lu, M., Lin, B., Zhang, Y., Hao, Y., Li, K. and Huang, Z. 2024. Insight into the molecular transformation pathways of humic acid in the co-composting of bagasse and cow manure after adding compound microorganisms. *Process biochemistry* 143:23-33

Lv, L., Gao, Z., Liao, K., Zhu, Q. and Zhu, J. 2023. Impact of conservation tillage on the distribution of soil nutrients with depth. *Soil & Tillage Research* 225: 105527. https://doi.org/10.1016/j.still.2022.105527

Mandi, S., Shivay, Y.S., Chakraborty, D., Shrivastava, M., Nayak, S., Baral, K., and Reddy, K.S. 2024. Fifteen-years of continuous application of organic materials improve the soil aggregation, organic carbon status and sustain the productivity of the basmati rice-wheat system. *Soil & Tillage Research* 239 :106058.

Mhete, M., Peter N. Eze, P.N., Teddie O. Rahube, T.O. and Akinyemi, F.O. 2020. Soil properties influence bacterial abundance and diversity under different land-use regimes in semi-arid environments. Scientific African 7:e00246

Pankhurst, C.E. 1997. Biodiversity of soil organisms as an indicator of soil health. In C.E. Pankhurst, B.M. Doube, B.M. and V.V.S.R. Gupta (eds). *Biological indicators of soil health*. CAB International

Qian, S., Zhou X., Fu, Y., Song, B., Yan, H., Chen, Z., Sun Q., Yea, H., Qina, L. and Lai, C. 2023. Biochar-compost as a new option for soil improvement: Application in various problem soils. Science of the Total Environment 870 : 162024.

Sabrina, D.T. 2007. Enhancement of phosphorus solubilization from phosphate rocks and plant nutrient availability through vermicomposting. PhD thesis. Universiti Putra Malaysia

Sabrina, D.T., Hanafi, M.M., Azwady A.A.N. and Mahmud T.M.M. 2009. Earthworm population and cast properties in the soils of oil palm plantations. *Malaysian Journal of Soil Science* 13, 29-42

Sebayang, N.U.W., Sembiring, M., Darlan, N.H., Hidayat, F and Sabrina D.T. 2015. Distribution of Earthworm Populations on Palm Oil Disces for Giving Organic Materials. In *Proceedings of the XI Congress of the Indonesian Soil Science Association and National* Seminar. Brawijaya University, Malang.

Sparling, G.P. 1997. Soil microbial biomass, activity and nutrient cycling as indicators of soil health. In C.E. Pankhurst, B.M. Doube, B.M. and V.V.S.R. Gupta (eds). *Biological indicators of soil health*. CAB International

Sung-Inthara, T., Juntahum, S., Senawong, K.,Katekaew, S. and Laloon, K. 2024. Pelletization of soil amendment: Optimizing the production and quality of soil amendment pellets from compost with water and biochar mixtures and their impact on soil properties. Environmental Technology & Innovation 33 : 103505.

Tanha, M., Mohtar, R.H., Assi, A.T., Awal, R, and Fare, A. 2024. Soil hydrostructural parameters under various soil management practices. *Agricultural Water Management* 292 :108633.

Troeh, F.R. and Thompson, L.M. 2005. *Soils and soil fertility*. Blackwell Publishing

Weidhuner, A., Hanauer, A., Krausz, R., Crittenden, S.J., Gage, K and Sadeghpour, A. 2021. Tillage impacts on soil aggregation and aggregate-associated carbon and nitrogen after 49 years. *Soil & Tillage Research* 208:104878. https://doi.org/10.1016/j.still.2020.104878

Zhang, X., Wang, J., Fen, X., Yang, H., L,Y., Yakov, K., Liu, S. and Li, F. 2023. Effects of tillage on soil organic carbon and crop yield under straw return. *Agriculture, Ecosystems and Environment* 354 :108543.