Impact of Mechanisation on Soil Compaction in Oil Palm Plantations

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ABSTRACT

Currently, in Malaysia, several planters in oil palm plantations are concerned about soil compaction, which is mainly related to the deployment of mechanisation and can impact yield performance. The impact of mechanisation on soil compaction in oil palm plantations should be considered, as it may directly affect the productivity of the entire plantation. This review focuses on the impact and effects of mechanisation, specifically whether it contributes directly or indirectly to soil compaction and subsequently affects oil palm yield in Malaysia. It highlights that the use of mechanisation in oil palm plantations has both positive and negative effects on oil palm yield. Therefore, it is vital for the management of oil palm plantations to ensure the suitability of the machinery to be used, following the topography and characteristics of the soil to ensure soil health is maintained.

INTRODUCTION

In Malaysia, oil palm is a valuable crop with many purposes, including the production of palm oil, which is used in food, cosmetics and biofuels. Oil palm is a highly profitable and versatile commodity crop in Malaysia, which significantly adds to the country's economy. It is considered one of the most significant agricultural commodities globally (Parveez *et al.,* 2023). As in any agricultural country in the world, mechanisation helps to facilitate agricultural work and increase productivity. The use of machinery in oil palm plantation activities, especially for transporting fresh fruit bunches (FFB) has helped improve work processes compared to conventional methods.

While the utilisation of technology in agricultural practices enhances efficiency and output, certain studies indicate that mechanisation also has adverse impacts, particularly on soil health and composition. According to a study carried out by Patel *et al.* (2020), one of the issues faced while utilising machinery is the negative effect on soil structure caused by compaction. Results from the study show that the impact of soil compaction caused by heavy machinery during farm activities has reduced yields in corn and soybean crops. Compacted soil also reduces the root length, volume and surface area compared to soil with a lower compaction level (Yu *et al.,* 2024). In addition, studies have found that soil compaction reduces soil porosity and increases bulk density (*Figure 1*), making it more difficult for plant roots to penetrate the soil and access essential nutrients and water.

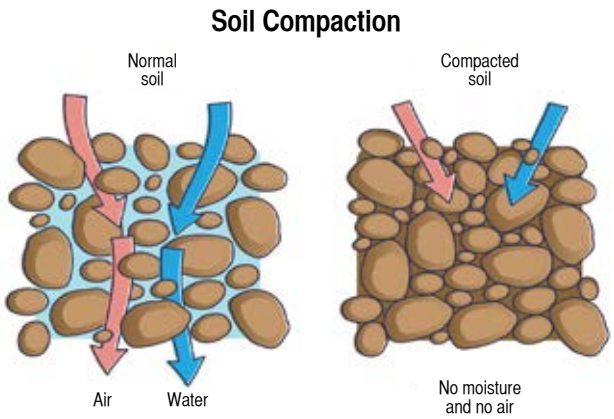


Figure 1. Effects of soil compaction.

Furthermore, it has also been revealed that certain mechanisation practices, if not carefully managed, can

contribute to soil compaction, affecting yield and the productivity of other crops in rotation (Usaborisut and Sukcharoenvipharat, 2011). Understanding the broader implications of soil compaction and mechanisation on various crops is essential for sustainable agricultural practices to ensure that the productivity of the entire agricultural system is not compromised (Soane *et al.,* 1982). By considering the findings of this review, farmers and agricultural machine fabricators can make informed decisions to reduce the adverse effects of soil compaction and implement responsible mechanisation practices to ensure optimal yields across different crops.

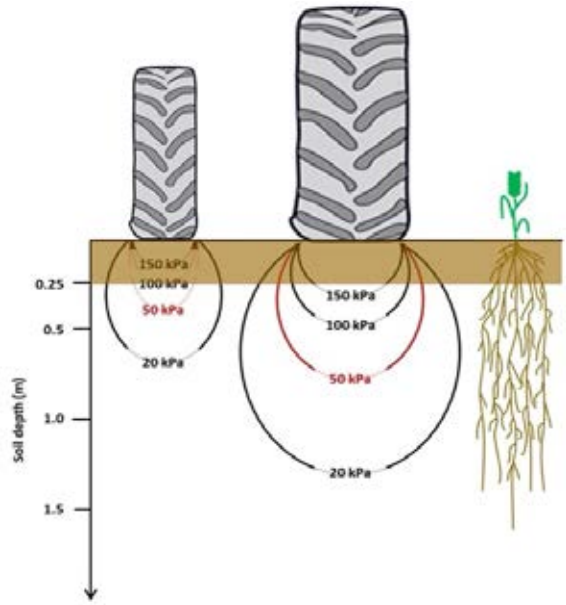
MECHANISATION IN OIL PALM PLANTATIONS

In oil palm plantations, mechanisation is vital in various aspects such as land preparation, planting, harvesting and farm maintenance. The use of machinery has significantly increased the efficiency and productivity of oil palm cultivation, leading to higher yields and reduced labour cost (Aljawadi *et al.,* 2021). Several mechanised transportation technologies such as tractors, trailers, and specialised transport vehicles, are often used for FFB evacuation. These machinery can reduce and minimise damage to the harvested FFB and help in the timely and effective delivery of FFB (Wahyu Krisdiarto and Sutiarso, 2016).

To avoid the effect of soil compaction in the planting area, appropriate mechanisation for FFB evacuation is necessary. In this case, the uncontrolled movement of heavy machinery during FFB evacuation and transport operations may positively affect oil palm plantations, causing soil compaction and degradation. Careful planning and adherence to mechanisation best practices are required to reduce these adverse effects.

Therefore, wheeled and tracked machinery are the two main categories of machinery often used in mechanisation activities in oil palm plantations. Due to their flexibility and manoeuvrability, wheeled machinery such as tractors, single chassis machines and tracked machinery are often chosen for planting and land preparation (Shuib *et al.,* 2020). These vehicles can travel through the fields efficiently, especially in areas with less demanding terrain. However, using tracked machinery in soggy or soft soil can cause compaction as the weight of the machinery can compress the soil, reducing its porosity and inhibiting root growth.

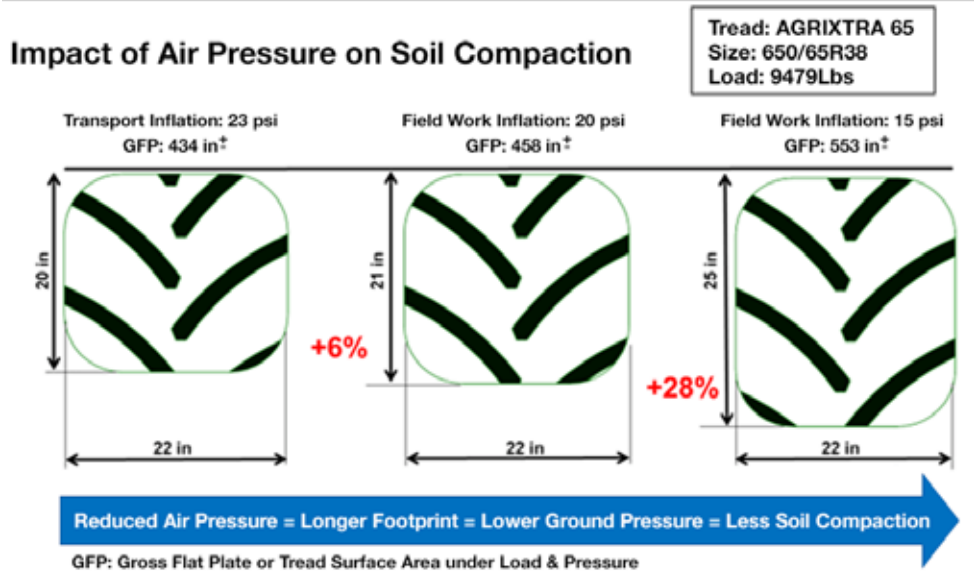
In oil palm plantations, low ground pressure (LGP) tyres and choosing appropriate tyre pressure levels are essential in reducing soil compaction and ensuring better load distribution during farm activities (*Figure 2*). Compared to standard tyres, these special tyres exert less pressure on the ground surface due to the larger contact area, thereby reducing the possibility of soil compaction. LGP tyres minimise soil disturbance and reduce the impact? on the soil structure by spreading the weight of the machinery over a wider surface area. This, in turn increases water infiltration, air circulation and nutrient availability for oil palm trees (Diserens *et al.,* 2011).



Source : Bureau of economic Geology, (2022).

Figure 2. Load distribution on soil profile as generated by farm machinery.

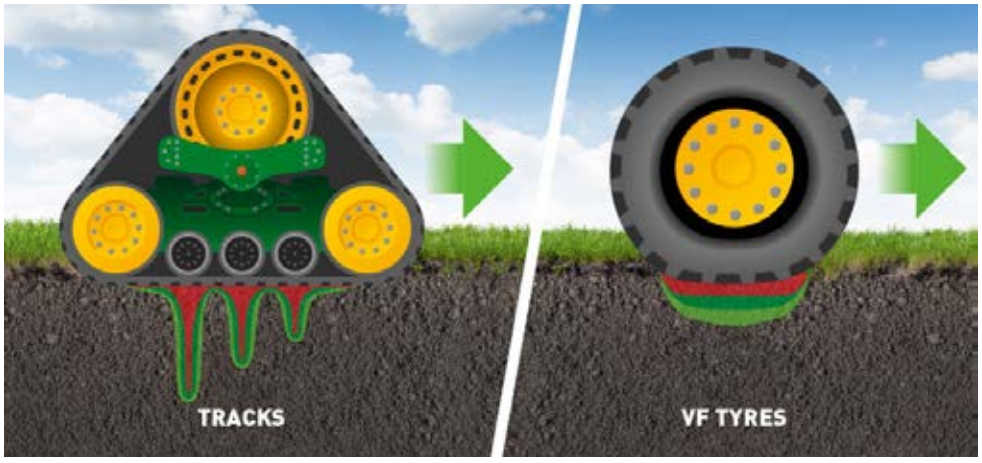
Oil palm plantations may successfully limit the harmful effects of soil compaction while maximising the benefits of mechanisation by incorporating LGP tyres in activities such as FFB transportation. LGP tyres reduce soil compaction and improve load distribution by distributing machinery weight uniformly, thus preventing localised pressure spots that can cause soil compaction and deformation (*Figure 3*). This balanced weight distribution ultimately protects the long-term output of oil palm plantations by promoting healthy root development and soil integrity. Due to its capacity to reduce soil compaction compared to farm machinery equipped with conventional tyres, tracked machinery implementation has also grown in popularity in oil palm plantations (Rahman and Yahya, 2013).



Source: AG Tire Talk, (2021).

Figure 3. Impact of air pressure inside tyre on soil compaction

Tracked machinery, such as crawler tractors, aims to improve weight distribution and reduce the possibility of soil compaction. Due to its wider footprint, which promotes better weight distribution and reduces pressure on the ground, it can reduce the risk of compaction, especially in wet or soft ground conditions (*Figure 4*). Determining the appropriate level of mechanisation for an oil palm plantation requires a thorough understanding of the differences between tracked and wheeled machines. Plantation owners and managers can minimise soil compaction and promote sustainable oil palm cultivation techniques by carefully evaluating the terrain, soil conditions and specific tasks when selecting machinery. By distributing the weight of the machinery over a larger surface area, tracked vehicles reduce the pressure applied to the ground. In oil palm plantations, this leads to less soil disturbance and reduced opportunities for soil compaction, both of which support the maintenance of soil structure and health. The utilisation of tracked vehicles lessens the environmental impact of agriculture by reducing soil compaction and the ensuing environmental deterioration.



Source: Bridgestone Agriculture, (2022).

Figure 4. Agricultural tyres vs *tracks.*

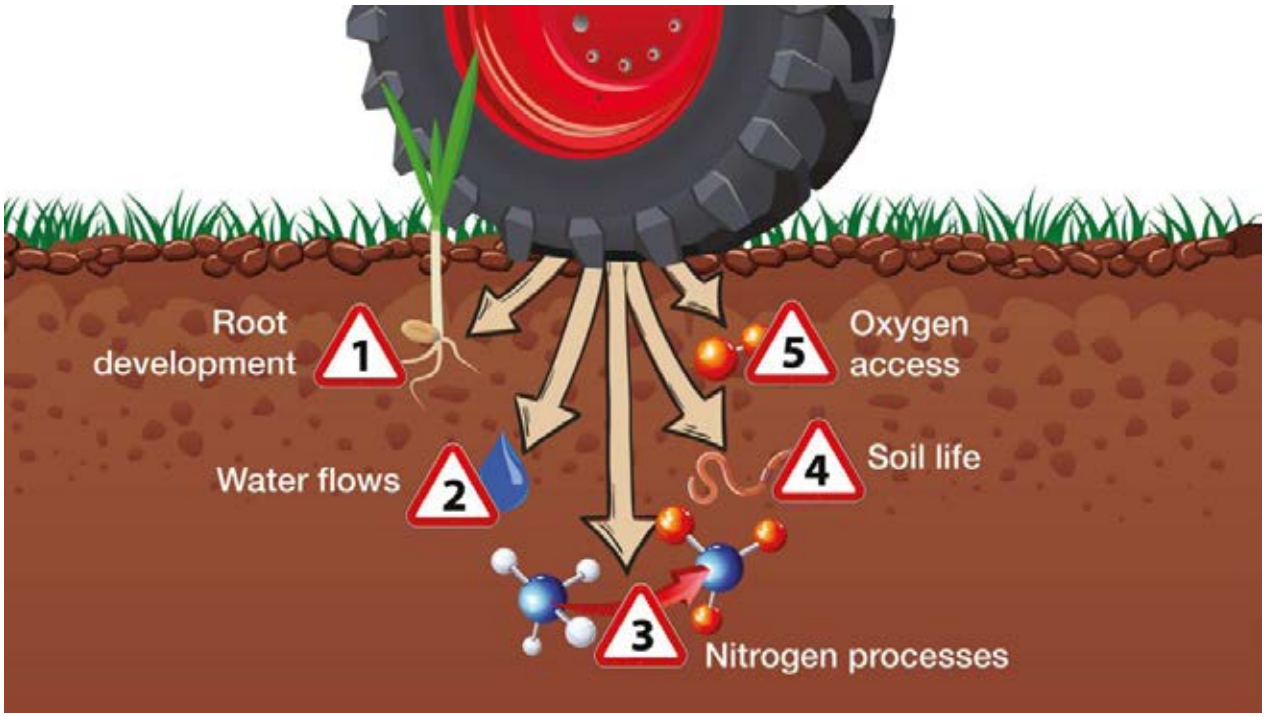
Adopting tracked vehicles in oil palm plantations offers a promising way to decrease soil compaction while maintaining high yields and protecting soil health, unlike standard farm tyre-equipped machinery. Sustainable oil palm agriculture methods can be achieved using mechanisation technology like tracked vehicles, which is significantly increasing as the demand for palm oil rises. Moreover, because low-ground-pressure tyres lessen the environmental impact of mechanised operations, they align with sustainable agriculture methods. Using these specific tyres demonstrates a commitment to responsible mechanisation that puts soil health and total crop productivity first.

Furthermore, the utilisation of machinery has played a significant role in achieving a favourable outcome by enhancing productivity and cost-effectiveness, hence mitigating the possible drawbacks related to soil compaction. By carefully selecting suitable machinery and implementing optimal techniques, oil palm farms may successfully mitigate the adverse impacts of compaction while capitalising on the advantages of mechanisation.

THE IMPACT OF SOIL COMPACTION ON OIL PALM YIELD

In agriculture, the impact of soil compaction is a major concern, as it can significantly affect crop yields. Compacted soil has reduced pore space, limiting the movement of air, water and nutrients (*Figure 5*). Restrictions in soil aeration and nutrient availability can inhibit plant root development and nutrient uptake, ultimately leading to decreased growth and productivity. Additionally, soil compaction can change soil structure, resulting in poor water infiltration and drainage. These poor soil conditions can cause waterlogging, which in turn inhibits root growth and causes reduced nutrient uptake (Hanna H. Mark, 2002).

According to previous studies by Keller *et al.* (2019) and Usaborisut & Niyamapa (2010), soil compaction can harm the yield of crops, reduce pore space in compacted soil, and restrict the movement of air, water, and nutrients, further inhibiting plant development and the uptake of essential resources. These limitations in nutrient availability and root development can lead to decreased plant growth and productivity, ultimately affecting overall farm yield (*Table 1*).



Source: Compaction Prevention System.

Figure 5. Negative effects of soil compaction.

TABLE 1. LIST OF CROPS EFFECTED BY COMPACTION

No.	Crop	Soil Type	Impact to yield (+ve / -ve)	References
1.	Maize	Sandier	Negative	Chen and Weil (2011)
2.	Soybean	Mollisol	Negative	Yue *et al.* (2021)
3.	Sugarcane	Saline	Negative	Rodrígiuez *et al.* (2012)
4.	Wheat	Sandy loam	Negative	Ahmad *et al.* (2009)
5.	Oil Palm	Clay	Positive	Zuraidah (2019)

In oil palm plantations, various factors can contribute to soil compaction. One of the main factors is the repeated traffic on the harvesting path by machinery used for FFB evacuation activities. The effects of soil compaction and mechanisation on oil palm yield have raised concerns among researchers and industry professionals. In addition, some agronomists believe that mechanisation activities will contribute to soil compaction, and prolonged exposure to compacted soil conditions can weaken the resilience of oil palm trees, making them more vulnerable to various pathogens and pests that can further reduce yield and harvest quality. Furthermore, a study conducted by Yahya *et al.* (2010) on the effect of soil compaction has produced fewer primary and secondary roots, but this has been compensated by longer production and thicker tertiary and quaternary roots.

However, the results of the study carried out by Zuraidah (2019) on the effect of soil compaction on clay type soil are different because it shows a positive effect between the average soil bulk density, porosity and oil palm yield. The results clearly show that soil type also affects oil palm yield, even though soil compaction occurs during the implementation of mechanisation in the plantation.

Technological advancements, according to proponents of mechanisation, have facilitated the creation of various techniques and equipment to mitigate the detrimental impacts of soil compaction. For instance, utilising wheeled machinery with low ground pressure tyres and an adjustable tyre inflation system can aid in evenly distributing weight, thereby decreasing the probability of soil compaction. Additionally, providing adequate training and management for machinery operators can mitigate potential detrimental effects on soil health.

Research results show that soil compaction caused by mechanisation can positively and negatively affect oil palm yields. The impact of soil compaction and mechanisation on certain soil types is undeniable and requires careful consideration. Conversely, soil compaction can increase root penetration and nutrient uptake, leading to better plant growth and higher yields. On the other hand, excessive soil compaction can prevent root growth, reduce nutrient availability, and prevent water infiltration, ultimately leading to a decrease in oil palm yields.

Several recommendations can be implemented, such as proper soil management practices, such as regular soil testing and analysis, to monitor soil health and detect signs of compaction. In addition, the implementation of machinery equipped with low-ground pressure tyres and an adjustable tyre inflation system can minimise soil compaction. Establish and maintain proper drainage systems to ensure adequate water infiltration and avoid waterlogging, which can exacerbate soil compaction.

CONCLUSION AND RECOMMENDATIONS

In conclusion, the impact of soil compaction on oil palm is undeniable, as it directly affects the health of the crop. While mechanisation offers numerous advantages, it is crucial to recognise the potential drawbacks and actively mitigate them through responsible soil management practices. Thus, implementing proper soil management techniques, employing low-ground pressure tyres, establishing effective drainage systems, and considering tracked machinery as options are essential steps in minimising the adverse effects of soil compaction on oil palm yield.

REFERENCES

Ahmad, N; Hassan, F U and Belford, R K (2009). Effect of soil compaction in the sub-humid cropping environment in Pakistan on uptake of NPK and grain yield in wheat (Triticum aestivum): I. Compaction. *Field Crops Research*, *110*(1): 54-60.

Aljawadi, R A M; Ahmad, D; Nawi, N M; Kassim, M S M and Ismail, W I W (2021). A review of the in-field transporting machines currently used in oil palm plantations in malaysia. In *Basrah Journal of Agricultural Sciences* (Vol. 34, Issue Special Issue 1, pp. 119-137). University of Basrah, College of Agriculture.

Chen, G and Weil, R R (2011). Root growth and yield of maize as affected by soil compaction and cover crops. *Soil and Tillage Research*, *117*: 17-27.

Diserens, E; Défossez, P; Duboisset, A and Alaoui, A (2011). Prediction of the contact area of agricultural traction tyres on firm soil. *Biosystems Engineering*, *110*(2): 73-82.

Hanna H Mark (2002). Soil compaction may be cutting into your yield. *Integrated Crop Management News*. https://dr.lib.iastate.edu/handle/20.500.12876/18015

Keller, T; Sandin, M; Colombi, T; Horn, R and Or, D (2019). Historical increase in agricultural machinery weights enhanced soil stress levels and adversely affected soil functioning. *Soil and Tillage Research*, *194*: 104293.

Parveez, G K A; Rasid, O A; Ahmad, M N; Taib, H M; Bakri, M A M; Hafid, S R A; Tuan Ismail, T N M; Loh, S K; Abdullah, M O; Zakaria, K and Idris, Z (2023). Oil palm economic performance in malaysia and R&D progress in 2022. *J. Oil Palm Res.*, *35*(2): 193-216.

Patel, S K; Mani, I and Sundaram, P K (2020). Effect of subsoil compaction on rooting behavior and yields of wheat. *J. Terramechanics*, *92*: 43-50.

Rahman, A and Yahya, A (2013). Performance investigation of an advanced tracked prime mover on the low bearing soil. *J. Terramechanics*, *50*(4): 233-244.

Rodríguez, L A; Valencia, J J and Urbano, J A (2012). Soil compaction and tires for harvesting and transporting sugarcane. *J. Terramechanics*, *49*(3-4): 183-189.

Shuib, A R; Radzi, M K F M; Bakri, M A M and Khalid, M R M (2020). Development of a harvesting and transportation machine for oil palm plantations. *J. Saudi Soc. Agric. Sci.*, *19*(5): 365-373.

Soane, B D; Dickson, J W and Campbell, D J (1982). Compaction by agricultural vehicles: A review III. Incidence and control of compaction in crop production. *Soil and Tillage Research*, *2*(1): 3-36.

Usaborisut, P and Niyamapa, T (2010). Effects of Machine-Induced Soil Compaction on Growth and Yield of Sugarcane. *Am. J. Agric. Res.*, *5*(3): 269-273.

Usaborisut, P and Sukcharoenvipharat, W (2011). Soil compaction in sugarcane fields induced by mechanization. *Am. J. Agric. Res.*, *6*(3): 418-422.

Wahyu Krisdiarto, A and Sutiarso, L (2016). Study on Oil Palm Fresh Fruit Bunch Bruise in Harvesting and Transportation to Quality. *Makara J.Technol.*, *20*(2): 67.

Yahya, Z; Haruna Ahmed, O; Husin, A; Talib, J; Othman, J and Boyie Jalloh, M (2010). Soil Compaction and Oil Palm (Elaeis guineensis) Yield in a Clay Textured Soil. *Am. J. Agric. Res.*, *5*(1): 15-19.

Yu, C; Mawodza, T; Atkinson, B S; Atkinson, J A; Sturrock, C J; Whalley, R; Hawkesford, M J; Cooper, H; Zhang, X; Zhou, H and Mooney, S J (2024). The effects of soil compaction on wheat seedling root growth are specific to soil texture and soil moisture status. *Rhizosphere*, *29*, 100838.

Yue, L; Wang, Y; Wang, L; Yao, S; Cong, C; Ren, L and Zhang, B (2021). Impacts of soil compaction and historical soybean variety growth on soil macropore structure. *Soil and Tillage Research*, *214*: 105166.

Zuraidah, Y (2019). Influence of soil compaction on oil palm yield. *J. Oil Palm Res.*, *31*(1): 67-72.