Soil Compaction Study Due to 4 Wheel Tractor Track in PTPN II Kulmpang Sugar Cane Plantation

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Abstract. Soil compaction can occur due to repeated tractor trajectories in the tillage process. Changes in soil physical and mechanical properties that occur can be seen with changes in soil bulk density, soil porosity, ground pressure and soil penetration resistance. Soil compaction can cause disruption of plant root growth that will reduce crop production. The purpose of this study was to evaluate changes in soil physical and mechanical properties due to soil compaction caused by repeated tractor trajectories. The study was carried out at 20.05\% moisture content, bulk density 1.06 gr/cm\textsuperscript{3}, porosity 53.9\% and an average penetration resistance of 1.32 kgf/cm\textsuperscript{2} (0.13 MPa) with an average tractor ground pressure value of 0.88 kg/cm\textsuperscript{2} crossing the ground as much as 1-8 times the track. The results showed that the number of tractor trajectories affected the value of bulk density, soil porosity and soil penetration resistance. The increasing number of trajectories, causing an increase in the level of soil density which can be seen by increasing the bulk density value by 1.31gr/cm\textsuperscript{3}, decreasing porosity value by 26.63\% while the average penetration resistance increases by 6.88 kgf/cm\textsuperscript{2} (0.67 MPa).

1. Introduction
Soil is a medium for the process of planting and growing plants which are usually solid, liquid and gas that are used where living things, especially plant growing media that have diverse properties, namely chemical, biological and physical properties of the soil, which due to the diversity of these properties that affect fertility land, so that proper land management must be done [1]. Soil processing is an activity that requires a lot of energy, high costs and takes a long time if done manually, so that mechanical aids such as tractors that can facilitate the processing process, but the use of tractors with excessive trajectory can cause soil compaction[2]. Large tractor is a type of tractor used by plantation companies which have a large area usually has the characteristic that there are two axle wheels or four-wheeled which has a power of 20-120 HP, with a length of 2650 - 3910 mm and widths ranging from 1740 - 2010 mm. The New Holland TM 150 tractor is a four-wheeled tractor that is usually used in land processing in large companies [3]. The main cause of soil compaction is due to the tractor wheel trajectory that depends on the pressure of the wheel on the ground surface, gravity, and the intensity of tractor traffic which causes changes in physical and mechanical properties of the soil [4]. Penetrometer is a device used to measure the value of soil compaction, from the soil layer directly in the field which is equipped with a cone, a watch to display the results of penetration resistance, and a watch protective ring [5]. The working principle of a penetrometer is to push or press into the ground slowly at a constant speed to avoid dynamic effects [6]. This study aimed to evaluate changes in soil physical and
mechanical properties due to soil compaction caused by repeated tractor trajectories. Soil compaction can create soil degradation which causes increased soil erosion and decreased crop production.

2. Material and Methods

2.1. Location
This research was conducted from March to May 2019 at PTPN-II Klumpang, Deli Serdang Regency, North Sumatra, at the Research and Technology Laboratory and at the Biosystem Engineering Laboratory of Agricultural Engineering Study Program, Faculty of Agriculture, Universitas Sumatera Utara. Materials and tools used in this study were New Holland TM 150 type tractors, penetrometers, sample rings, scales, ovens, stopwatches.

2.2. Research Procedure
The research was carried out by operating the tractor on a track that was passed repeatedly starting from 1, 2, 3, 4 to 8 times. Tractor movement patterns are shown in Figure 1.

![Figure 1. (a) Operation of the tractor; (b) Tractor movement pattern.](image)

Each time passing through, the soil penetration resistance is directly measured with a penetrometer as well as soil sampling (at a depth of 5 cm, 10 cm and 15 cm from the ground surface) which will be taken to the Research and Technology Laboratory of the Faculty of Agriculture, Universitas Sumatera Utara to determine the texture, moisture content, soil bulk density and soil porosity. This experiment was carried out with 3 repetitions. A scheme for measuring soil strength is presented in Figure 2.

![Figure 2. Soil strength measurement scheme.](image)
To determine the effect of the treatment with the observed parameters, a factorial randomized block design was used consisting of 2 factors: the number of trajectories and the depth of the soil.

3. Result and Discussion

Soil texture in the study area is clay loam (sand 36.45%, dust 29.9%, clay 33.65%), with a moisture content of 20.05%, bulk density 1.06 gr/cm$^3$, and porosity 53.9%

3.1. Bulk Density

The average soil bulk density value that occurs is greater at each depth of land and the number of tractor trajectories. However, the value of bulk density on each number of trajectories is significantly different because of the decrease in soil porosity due to soil compaction. The graph of soil bulk density analysis results is presented in Figure 3.

The analysis showed that the average value of bulk density at 5 cm soil depth was 1.17 gr/cm$^3$, at 10 cm depth was 1.20 gr/cm$^3$ and at 15 cm depth was 1.24 gr/cm$^3$. If the soil is under considerable pressure (external force from mechanical or natural) then the soil volume will change [7]. The decrease in soil porosity value makes the soil bulk density value increase so that the degree of soil density also increases [8]. Higher soil bulk density in compacted soils of surface and subsurface horizons affects root development impeding growth and reducing oxygen availability within the root zone [9].

3.2. Soil Porosity

For each number of trajectories, the average porosity value of the soil at each level of soil decreases. The average porosity values at soil depths of 5 cm, 10 cm and 15 cm are 34.5%, 31.87% and 31.25%, respectively. These results state that the level of soil density increases with increasing soil depth. The graph of soil porosity analysis results is presented in Figure 4.
There are four factors that affect changes in soil volume (density): 1) compression of solid particles 2) compression of liquids and gases in the pore space 3) changes in liquid and gas content in the pore spaces 4) changes in the composition of solid particles [7].

3.3. Ground Pressure

Ground pressure is the pressure exerted by a vehicle passing above the soil surface [10]. The pressure referred to comes from the weight of the tractor plus the weight of the operator divided by the surface area of the wheel touching the soil. Tire contact area on the soil will increase with the depth of the wheel into the soil so that the pressure applied to the soil decreases. From the results of the study obtained an average value of ground pressure of 0.88 kg/cm². The graph of ground pressure analysis results is presented in Figure 5.

With a tractor ground pressure of 0.88 kg/cm², the experimental results show that increasing the number of tractor trajectories will increase soil density so that the depth of the wheel going into the ground decreases. From Figure 5 above it can be explained that the change in the depth of the wheel into the soil is still large at the number of trajectories 1-4 but at the number of trajectories 5-8 the...
change in the depth of the wheel into the soil is very small. This is due to the fact that the 5-8 tracks are solid and strong to withstand the tractor load. However, this can inhibit plant growth due to disturbed root development.

3.4. Soil penetration resistance
Soil penetration resistance is the ability of the soil to withstand the loads above it. The tractor wheel will continue to enter the soil until it gets the same reaction force from the soil so that the wheel can produce traction to carry the tractor and its equipment. Tracks that are traversed repeatedly will increase soil density as presented in Figure 6.

![Penetration Resistance Graph](image)

**Figure 6.** Graph of Soil Penetration Resistance.

In the number of trajectories 5-8, the average resistance of soil penetration in each soil depth increases. Increased soil density is good for increasing the ability to withstand tractor loads so that tractor operation becomes easier but not good for plant root development. Compacted soil will restrict the growth and penetration of roots into the soil so that plants become stunted due to drought and stressed as a result of restricted water and nutrients that can be absorbed by the roots which results in reduced crop yields.

4. Conclusion
Soil compaction occurs due to the repeated operation of the tractor on the same track. This is indicated by an increase in the value of bulk density and penetration resistance but the porosity value decreases. This condition will cause the roots will be difficult to penetrate the soil so that root development will be disrupted.

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