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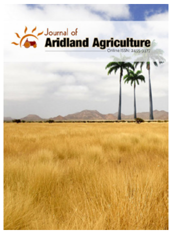

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Modern GPS diagnostic technique to determine and map soil hardpan for enhancing agricultural operation management

Firas Salim Al-Aani[1], Omar Hadeb Sadoon[2]*

[1]Department of Agricultural Machines and Equipment, College of Agricultural Engineering Sciences, University of Baghdad, Iraq, [2]Information Technology Center, University of Technology, Baghdad, Iraq

ABSTRACT

Among the undesirable effects of soil compaction is a measurable reduction in plant growth and crop yield. The prevailing belief is that compacted tillage pans are caused by repetitive farming practices, heavy tractors, tillage tools, and field traffic. This experiment was conducted to determine and map the hardpan layers across an agricultural field through advanced technologies of precision agriculture. These valuable techniques such as data logger, yield map, and data analysis of performance indicators were linked with accurate global positioning systems (GPS) datasets. These important technologies provided the farmers and helped them to identify and manage areas of the fields with higher compacted layers. Three ground speeds 4.3, 5.2, and 6.4 km h^{-1} were performed with two tillage depths 25 and 40 cm of a chisel plow. The effects of these two factors were studied to determine slippage percentage, field productivity, traction power, and fuel consumption. For the first shallow 25 cm depth, the results showed that increasing the speed from 4.3 to 5.2 and then to 6.4 km h^{-1} led to a significant increase in slippage percentage from 7.22 to 10.35 and then to 12.63%, respectively. Increasing the speed increases field productivity from 0.547 to 0.663 then to 0. 749 ha hour^{-1}, and tractive power increases from 9.44 to 11.74, then to 13.24 hp. As a result, there was a significant increase in the fuel consumption rate from 18.44 to 20.15, then to 22.27 L hour^{-1}, respectively. Changing the depth from 25 to 40 cm and increasing the practical speed from 4.3 to 5.2 and then to 6.4 km h^{-1} led to a significant increase in slippage percentage from 10.14 to 12.77 and then to 15.27%, and a significant increase in field productivity from 0.446 to 0.568 and then to 0.640 ha hour^{-1}, respectively. This led to a significant increase in traction power from 12.72 to 13.36, then to 15.87 hp. Increasing the speed also brought a significant increase in fuel rate from 22.14 to 23.54 and then to 26.14 L ha^{-1}, respectively. Based on this study, it was concluded that the use of this powerful approach was a useful methodology to reflect, determine, specify, and manage the regions of induced and hardpan zones by means of dataset analyses provided by the GPS for the desired field.

KEYWORDS: Field productivity, Fuel consumption, GPS, Slip percentage, Traction power

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***Corresponding Author:**
Omar Hadeb Sadoon
E-mail: Omar.H.Sadoon@uotechnology.edu.iq

INTRODUCTION

As population growth increases, the demand for various agricultural products follows suit, and the development of food industries that depend on new techniques to increase agricultural output becomes necessary (Al-Ani & Al-Jboory, 2008; Al-Ani, 2012). This accompanies the necessity to develop the agricultural sector in general, more specifically through increased agricultural mechanization; as well as focusing on increasing its efficiency and productivity and reducing the workforce and enhancing welfare. This can be achieved by using larger machines with higher engine power and heavier tractors with a high capacity and proper use (Al-Aani, 2020). Despite this potential, usage and standardization of this machinery is hindered by the reluctance of farmers regarding the deleterious effects they believe will occur if such innovations are implemented on soil properties. Soil physical properties refer to characteristics of the soil that can influence its behavior and suitability for different purposes (Al-Ani, 2012; Al-Aani, 2020). One important property is soil compaction, which deals with the compression and consolidation of soil particles. Compaction layers are zones within the soil profile where compaction has occurred more intensely compared to the surrounding soil layers. These layers are typically denser and have reduced pore space, resulting in poor water infiltration, restricted root growth, and decreased overall soil health. Compaction layers can be caused by various factors, including heavy machinery or vehicles repeatedly passing over an area, excessive tilling, or natural processes like the deposition of sedimentary layers. These compacted layers often limit the movement of air, water, and roots through the soil, which can lead to drainage problems and decreased crop productivity (Al-Sabagh *et al.*, 2004; Al-Aani, 2020). Recently, GPS (Global Positioning Systems) are becoming a more important technique involved in the conservation of land and water resources (Yang *et al.*, 2022). Advanced GPS technology is used to successfully incorporate the conservation of these natural resources and provide realistic solutions, flexible decision-making tools, and developing data analysis (Stafford, 2013).The implementation of this powerful technique can be utilized to demonstrate the relationship between the soil and some performance indicators. After analyzing the provided datasets from GPS, it was determine that these relationships can be frequently illustrated and represented as yield maps. GPS monitoring performance indicators serves as a useful navigation tool because spatial analyses of the mechanical unit will enhance agricultural operations and improve farming profitability. Several important parameters such as traction efficiency, slip percentage, tractive force, fuel consumption, and others are crucial to evaluate the performance of the agricultural unit These parameters also facilitate better management of mechanized equipment as well as more profitable decision-making (Miu, 2015). Practical speed and operating depth are considered important factors that affect the performance indicators of the tractor while working in the field. Al-Suhaibani and Ghaly (2010) conducted a study on a silty clay loam to evaluated the performance of the unit. It was concluded that increased the depth of the operation from 15 to 25 cm, changed the traction power of the mechanical unit and increased the slip percentage. They also noticed an increase in practical speed led to an increase in the slip percentage. There was a significant effect of changing the practical speeds on field productivity when increasing the speed. Al-Ani (2012) studied the effect of working on higher practical speed on some performance indicators. These results indicated that increasing the forward speeds also increased traction force, increased slippage percentage, and decreased field efficiency. Also Al-Suhaibani and Ghaly (2010) studied the effect of three practical speed to evaluate fuel consumption. The results showed that; when the forward speed was increased from 2.72 to 4.3 km h^{-1}, the practical productivity increased from 0.16 to 0.23 hectares hour^{-1}, because of the fact that the speed is one of the productivity components and is directly proportional to it (Al-Aani *et al.*, 2016). In an experiment, increasing the speed from 4.24 to 5.54 and then to 6.75 km h^{-1}, led to an increase in slippage percentage from 13.52 to 20.16 and then to 23.06%. The increase in speed also led to a decrease in field efficiency from 57.54 to 53.49 and 51.56% (Amer, 2017). Undesirable effects of soil compaction are often a harmful concern that causes reduction in plant growth and crop yield. The common belief is that compacted tillage pans are caused by repetitive farming practices, heavy tractors, tillage tools, and field traffic.

Therefore, the primary aim of this study was to examine the effects of practical speed and working depth on some important parameters for subsoiling operations. Another objective was to map and demonstrate the relationship for soil spatial survey and the influencing factors as an alternative method for determining compacted layers.

MATERIALS AND METHOD

Experimental Design

A state-of-the-art GPS device was used to track the hardpan in the field through studying some performance indicators. Each GPS data has certain characteristics and attributes associated with it which provide real travel speed and time. Geo-referenced yield data collected during the experiment was stored internally on the data logger and recorded as an organized timestamp. Data cards were used to transfer the yield data from the display to a computer for analysis. The experiment was implemented using the Statistical Analysis System program in data analysis to study the effect of different factors on some field performance (Al-shamiry *et al.*, 2020). A factorial experiment (3 X 2) was applied in a completely randomized block design (CRBD), then the significant differences between the means were compared with the least significant difference (LSD) test (SAS, 2012).

The research was carried out to study the effect of two factors at different levels to map some performance indicators in the field such as slip percentage, field productivity, fuel consumption, and traction force for each treatment of speed and depth.The first factor was forward speed which included 4.3, 5.2, and 6.4 km h^{-1}. The second factor wasthe subsoiling with two depth 25 and 40 cm. The indicators were calculated according to the calculations below:

Slip Percentage

It was computed as per the equation proposed by Al-Sahoki and Waheeb (1990), Al-Sabagh et al. (2004) and Al-Aani et al. (2018).

$$SP = \frac{VT - Vp}{VT} \times 100 \tag{1}$$

S_P: slip percentage(%)
V_T: theoretical speed (km h^{-1})
V_P: working speed (km h^{-1})

Theoretical speed is determined by dividing the distance by the theoretical time as follows (Al-Jarrah, 1998; Al-Ani & Al-Ani, 2010; Tekeste *et al.*, 2022):

Theoretical speed by dividing the distance by the theoretical time is determined as follows:

$$Vt = \frac{d}{Tt} \times 3.6 \tag{2}$$

As for the working speed, it is calculated by dividing the distance traveled by the working time, as follows:

$$VP = \frac{d}{TP} \times 100 \tag{3}$$

d: distance (meters)
Tt: theoretical time (seconds)
TP: working time

Field Productivity

The field productivity was calculated as per equation (Al-Ani & Al-Ani, 2010; Tekeste *et al.*, 2022):

$$FE = \frac{EFC}{TFS} \times 100 \tag{4}$$

FE: Field Efficiency %
EFC: Field productivity hectares per hour
TFS: theoretical productivity ha hour^{-1}

Fuel Consumption

Fuel consumption was calculated using the following equation (Al-Suhaibani & Ghaly, 2010; Al-Aani, 2020).

$$\mathrm{Qf} = \frac{\mathrm{Q} \times 10000}{\mathrm{TL} \times \mathrm{WP} \times 100} \tag{5}$$

Qf: the amount of fuel consumed per hectare (L ha^{-1}).
Q: the amount of fuel consumed during the transaction (mL).
D: length of transaction (meters)
Wp: actual plowing width (meters)

Traction power

Horsepower was calculated from the equation proposed by Al-Ani (2012).

$$DP = \frac{Ft \times Vp}{270} \tag{6}$$

Dp = Traction power
Ft= traction force
Vp = Operational speed (km h^{-1})

RESULTS AND DISCUSSION

A hardpan map was generated according to geo-referenced and site-specific subsoiling operations, according to depth and speed. Hardpan soil can be used to predict hardpan zones according to geo-referenced slip percentage, field productivity, traction power, and fuel consumption (Adhab, 2010; Abdul-Rassoul *et al.*, 2012).

Slip Percentage

Figure 1 illustrated that the effect of subsoiling depths of work and different practical speed on slippage percentage. It was observed that the values of slippage percentage significantly increased with an increase in subsoiling depth under all practical speeds. At a 25 cm subsoiling depth, slippage percentage significantly increased from 7.22 to 10.35 and then to 12.63% at practical speeds of 4.3, 5.2 and 6.4 km h^{-1}, respectively. For deeper subsoiling, 40 cm, there were statistically significant differences regarding slippage percentage. These increased from 10.14 to 12.77, and then to 15.27% when practical speeds increased from 4.3 to 5.2, then to 6.4 km h^{-1}, respectively. These results are consistent with the findings of all from Al-Ani *et al.* (2009, 2011a, b), Al-Neami *et al.* (2011), Al-Ani (2012) and Amer (2017).

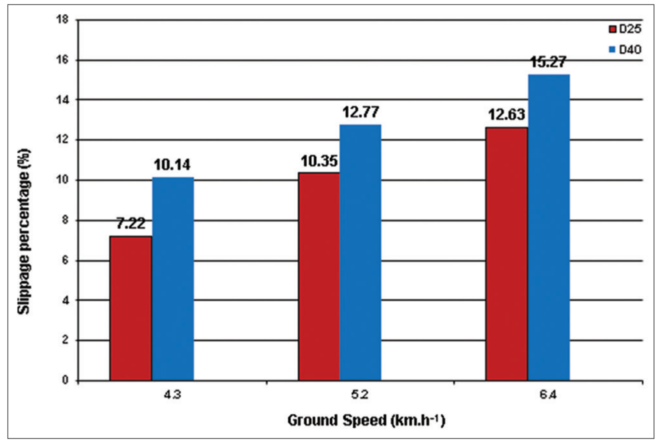

Figure 1: Effect of subsoiling depth and ground speed on slippage percentage

Field Productivity

Figure 2 shows that there was a significant difference for the tractor practical speed and the subsoiling depth on the field productivity of the machine unit. For the 25 cm subsoiling, increasing the ground speed of the unit from 4.3 to 5.2, and then to 6.4 km h^{-1} led to an increase in field productivity from 0.547 to 0.663, and then to 0.749 ha hr^{-1}. Regarding the second subsoiling 40 cm depth, the field productivity increased from 0.446 to 0.568 and then to 0.640 ha hr^{-1}, respectively. These results agree with the findings of Al-Suhaibani and Ghaly (2010).

Traction Power

Figure 3 shows the effect of both the tractor's practical speed and the subsoiling depth on the traction power. Significant differences were observed for both of two factors. For the 25 cm subsoiling depth, increasing the practical speed from 4.3 to 5.2 and then to 6.4 km h^{-1} caused the values of traction power to increase from 9.44 to 11.74 and then to 13.24 hp. At the second depth of 40 cm, the traction power was 12.72, 13.38, and 15.87 hp for velocities of 4.3, 5.2, and 6.4 km h^{-1}, respectively. This agrees with the findings of Al-Suhaibani and Ghaly (2010).

Fuel Consumption

Figure 4 shows the effect of various subsoiling depths and forward speeds on fuel consumption. It was found that fuel consumption was significantly affected by subsoiling depth and operation speed. There is a significant effect of the subsoiling

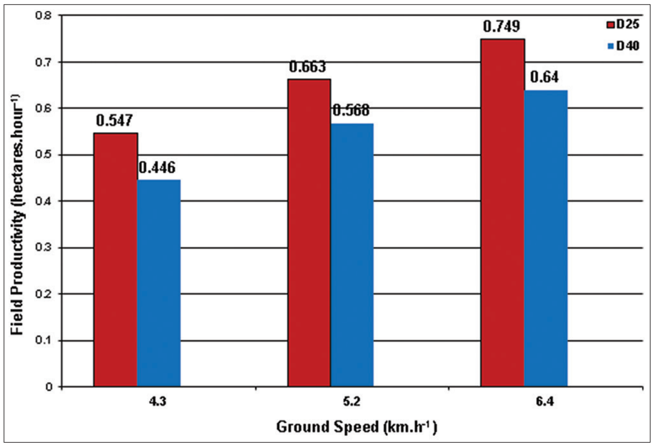

Figure 2: Effect of subsoiling depth and ground speed on field productivity

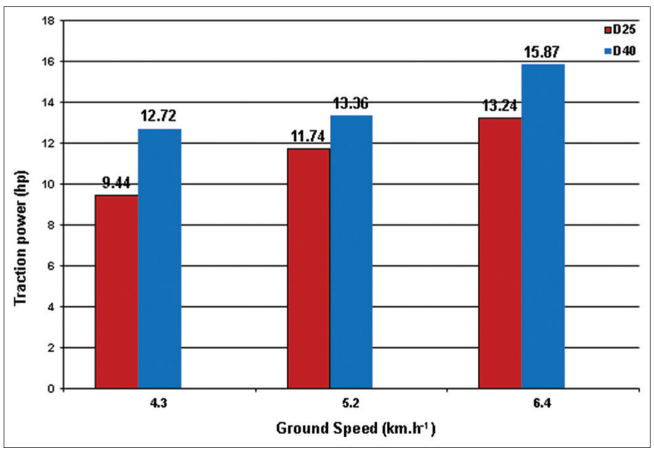

Figure 3: Effect of of subsoiling depth and ground speed on traction power.

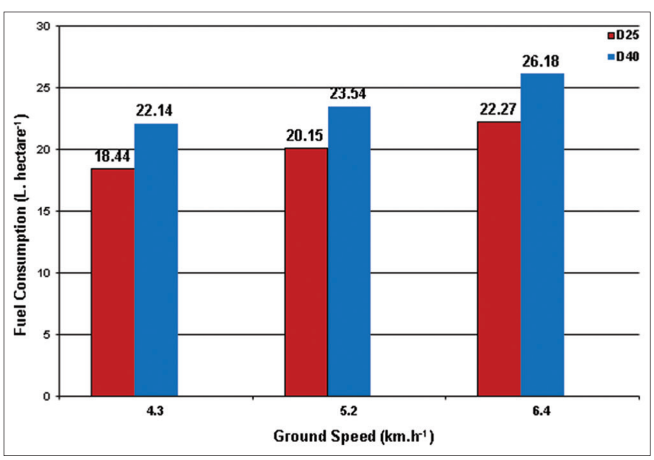

Figure 4: Effect of subsoiling depth and ground speed on fuel consumption

level on the traction power of the agricultural tractor, as the increase in tillage depth from 25 to 40 cm led to an increase in fuel consumption. At 25 cm of subsoiling depth, increasing the practical speed from 4.3 to 5.2 and then to 6.4 km h^{-1}, led to significant differences on the values of fuel consumption from 18.44 to 20.15 and then to 22.27 L ha^{-1}, respectively. At the 40 cm subsoiling depth, the change in practical speed led to increase the values of fuel consumption from 22.14 to 23.54 and then to 26.18 L ha^{-1}, respectively. The reason for this may be due to the fact that increasing subsoiling depth and practical speeds increases the volume of soil to be moved. This consumed more power to overcome the increased resistance of soil. In other words, adding more weight that caused an increase in fuel consumption. These results are consistent with the findings of Al-Jarrah (1998) and Al-Aani *et al.* (2018).

In conclusion, global warming, drought, degradation, and desertification, are threats that, if no working solution can be implemented, will increase hunger worldwide. Scientists are charged with designing procedures and work plans to apply in various aspects, specifically: identifying new pests (Al-Ani *et al.*, 2011a; Chuang *et al.*, 2017; Mohammed *et al.*, 2021; Schoelz *et al.*, 2021; Adhab & Alkuwaiti, 2022), and finding ways to increase food production (Al-Ani, 2010; Al-Ani *et al.*, 2011b; Aguirre-Rojas *et al.*, 2017, 2019; Adhab *et al.*, 2019; Khalaf *et al.*, 2019; Zhao *et al.*, 2019; Khalaf *et al.*, 2020; AlShabar *et al.*, 2021; Baazeem *et al.*, 2022; Khalaf *et al.*, 2023), reducing the effects of imminent famine that appears likely occur in the near future, particularly in less developed countries. This study would provide ways to increase the yield by using new techniques.

The usage of GPS technique is becoming a common application; and merits widespread adoption because it and can be used to effectively determine and map soil hardpan in the fields. The results showed that slip percentage had a significant increase when the subsoiling depth was increased, regardless of the practical speed. Secondly, field productivity witnessed an increase when the ground speed of the unit was increased. Additionally, the increase in practical speed led to an increase in traction power. Lastly, the fuel consumption of a unit was impacted by subsoiling depth and operation speed. Through the data obtained and geo-referenced map, results proved that hardpan zones can be accurately predicted from the result of studying some performance indicators. This technique reduces the effect of starvation that would occur soon, especially in less developed countries. New technology has always helped to make life easier for people. This study would provide ways to increase yield by using new techniques.

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