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Predicting Penetration Resistance on Sandy Loam Soil at Different Tractor Pass using Simple Regression Model

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Abstract: *Mechanized farming has been advocated over conventional system in order to meet the demand of an increasing population, which tractor plays a major role in agricultural mechanization. The study was carried out on sandy loam soil at the Institute of Agricultural Research and Training, Rivers State University, Port-Harcourt, Nigeria. The tractor was allowed to run on a 6m x 6m experimental plots to compact the soil using 0, 2, and 4 tractor passes (0TP, 2TP and 4TP). The compaction levels arising from the several tractor passes were measured with a cone penetrometer. Based on existing experimental data for cone index values of different passes in statistical analysis for the data gathered was conducted. The analysis revealed a model for predicting the cone index at different passes of tractor wheel for seven months with the help of two constant X and Y. The constant X is introduced as the time (monthly). Where as, Y are defined for cone index. . The simple linear regression model for 0, 2 and 4 passes of tractor were 0.028–0.001X, 0.00028–0.04312X and 0.067–0.00225X respectively. The mean cone index for 0TP were 0.026MN/m^2,0.027MN/m^2 ,0.023MN/m^2,0.029MN/m^2,0.021, 0.021MN/m^2 ,0.021MN/m^2, 2TP are 0.043MN/m^2,0.042MN/m^2 0.042MN/m^2, 0.044MN/m^2,0.043MN/m^2 ,0.042MN/m^2,0.04MN/m^2 while 4TP are 0.063MN/m^2,0.066MN/m^2 ,0.066MN/m^2,0.054MN/m^2 , 0.054MN/m^2, 0.057MN/m^2 and 0.052MN/m^2 at different time (monthly) after compaction.*

Keywords - cone index; tractor pass; regression model; mechanization; soil compaction**.**

1. Introduction

Mechanized farming has been advocated over conventional farming system, in order to meet the demand of future global challenge of food security. In Nigeria there is a drift from dependence of crude oil to agriculture to enable self-sufficiency in food production with the use of tractor for farming [1]. Between mid-2014 to 2016, the global economy faced one of the biggest oil price collapse in modern history. Upon the oil price decline created the need for diversification into agricultural practices driven by mechanized farming to boost food production. With the upsurge in demands for food and shelter which have resulted in mechanization of forests and farms in almost all the 36 states of the nation [2]. Nigeria's food security hangs on mechanized farming as tractor plays a major role to improve productivity and timeliness of agricultural operations as well as to improve the efficient use of resources among other advantages [3]. However, from empirical evidence on the use of tractors and equipment, soil compaction has contributed to increasing uncertainty of plant growth.

Studies have shown that mechanized farming have direct bearing on agricultural soils as a result of tillage equipment during cultivation or from heavy weight of field equipment [4] causing soil pore spaces to become smaller. Soil compaction increases soil strength, which means plant roots must exert greater force to penetrate the compacted layer. Detailed research from [5], [6], [7] on farm machinery, grazing animals and other load application mechanisms contributed to increase in bulk density, low porosity and low rate of infiltration into soils. In a related study [4] illustrates on loam to clay loam soils have a bulk density of 1.3 to 1.4g/cm^3, and sandy loam to loamy sand soils have a bulk density of 1.4 to 1.6 g/cm^3. Soil compaction can occur at the soil surface in the form of soil crusting, or it can occur when applied stress exceeds the soil strength [8]. Soil compaction is the compression of soil particles together by an external force, thereby eliminating the pore spaces and reducing the soil volume and causing problem on the productivity of the soil and quality [9].

There is notable change in most of the physical properties of soil when the soil is subjected to tractor compaction. [10]States that Physical change as a result of soil compaction has also changed the microhabitats for soil microorganisms by inhibiting their ability to recycle soil nutrients and reducing microbial activity. Soil compaction is dependent on the duration of the applied load. This implies that for tractors and other harvesting machinery that move relatively fast, soil compaction is worsened by the repeated passes of tractor [11].Compaction of soil can be attributed to the weight of farm machines, especially tractors has been recognized as a severe problem. [12]Asserted that plant height and yield of maize decreased with the number of tractor compaction, as well as influencing many soil properties and processes including crop yield. This averred the statements of [13], [1] that increase in tractor passes reduces the growth and yield of cassava plant on sandy loam soil. There are different criterions and methods to determine soil compaction in an agricultural field [6], [14]. Among these methods, cone penetrometer has more acceptance due to more accuracy and easy operational techniques. Furthermore, this method supplies the variability of soil mechanical resistance relative to depth contrarily with other approaches [15], [16]. The cone penetrometer were applied in different cases such as getting site information from variability of soil mechanical resistance [17] due to soil physical properties that has been altered by the element of mobility from wheeled vehicle traffic [18], [19], [2]. This study predicts the effects of different tractor passes on sandy loam soil using simple regression model..

2.0 Methodology

2.1 Experimental Setup

The study was conducted at the research and demonstration farm, Rivers State University, Port Harcourt, Nigeria. This farm is located at 4.806199 °N latitude and 6.979971°E longitude characterized by tropical rainforest and increased vegetation with a rainfall ranging from 2000-2484 mm per annum of which 70% occurs between the months of May and August. The soil type is ultisol (USDA classification) and its soil texture with a scale degree of sandy loam [20]. The experiment was laid out in a randomized complete block design (RCBD), with three replicates. The plot size was 6m x 6m, and then divided into three subplots, each 2m x 6m with drain to demarcate between subplots. Regression analysis was deployed to ascertain the relationship between set of variables. These analysis were used to identify the relations of independent and dependent variables. Regression techniques adapted to statistical measures like mean or average between the set of variables to identify the relationship between them.

Simple linear regression is the simplest regression analysis technique, where a line equation (Y = cX + cX + ….. cX + b) is used to relate the predictor variables (X, X…, X) and response to the predictor (Y). Simple linear regression is a statistical technique that fits a straight line to set of (X, Y) data pairs. The slope and intercept of the fitted line are chosen so as to reduce the sum of squared differences between observed response values and fitted response values, a method of ordinary least squares is used to fit a straight line model to the data [21]. Several attempts have been made to model this process and a number of improved prediction techniques have been proposed including empirical or computational modeling, statistical technique, and artificial intelligence approaches such as multivariable regression model, and finite element analysis to improve prediction accuracy.

Statistical models are attractive because of its line of best fit, and can generate regression coefficient much more quickly than other modeling techniques and are relatively easier to implement in software. Apart from its simplicity, statistical modeling has two advantages over other techniques: it is mathematically rigorous and it can be used to define confidence intervals for the predictions. These advantages are particularly apparent when comparing statistical modeling with artificial intelligence techniques. Statistical analysis can also provide insight into the key factors influencing penetration resistance of the soil at different tractor passes through correlation analysis. For these reasons, statistical analysis was chosen as the technique for strength prediction in this study.

2.2 Cone Index Determination

Increase in soil mechanical strength in develops; due to forces applied during tillage or traction; particle aggregation has been partially lost by excessive tillage or organic losses, and soil cohesion has been increased by loss of soil water in the impeding zone [22], [23]. Cone penetrometer have been used to a great extent for determining the rate at which soil can resist penetration. The penetration resistance values obtained were usually employed in characterizing soil in terms of crop growing ability and in the determination of resistance to root penetration and seedlings emergence [22], [24]. Atractor (SWARAJ 978 FE) was used to effect the required compaction level in each subplot. The treatment combinations were control, with no compaction which represented the natural condition of the soil (0TP), two tractor passes (2TP), and four tractor passes (4TP) indicated the other combinations. Cone index was determined using a cone penetrometer and the equation given below [1].

Cone Index (CI) = $(F)_i/(SA)_i$ (KN/m^2)

SA = $\pi Ø(Ø/2 + d_i)$ (m^2)

Where:

Number tractor passes, I = 0. 2 and 4

F = Probe resistance force reading (KN)

SA= Surface area (m^2)

d = Depth of penetration (m)

π = 3.142

Ø = Diameter of probe (mm)

3 RESULTS

Table 1 Mean values of cone index at different tractor passes.

Table 1. Mean Values of Cone Index at Different Tractor Passes CI (MN/m^2)

Period (Monthly)	Tractor Passes		
	0TP	2TP	4TP
1	0.026	0.043	0.063

2	0.027	0.042	0.066
3	0.023	0.042	0.066
4	0.029	0.044	0.054
5	0.021	0.043	0.054
6	0.021	0.042	0.057
7	0.021	0.040	0.052

Table 2 presents the average values of cone index at 0, 2 and 4 passes of tractor wheel at different months after compaction

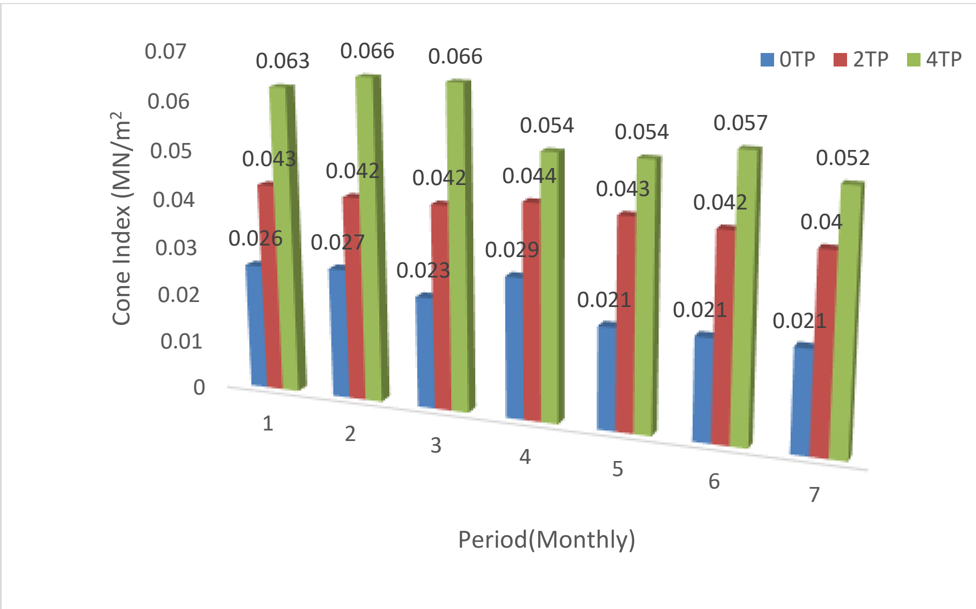

Figure 1: Mean Cone Index of Varying Tractor Wheel Passes at Different Time(Month)

The regression model adapted in this study was illustrated by (Gomez &Gomez, 1984)

$$Y = a + Bx$$

Where b= nΣXY – (ΣX)(ΣY) / [nΣX^2 – (ΣX)^2]

Y average = ΣY/n

X average = ΣX/n

The regression equation therefore is given by the equation below:

a = Y avr – b(Xavr)

Table 3: Modeling the Results Obtained using Regression Analysis for 0 Tractor Pass

X	Y	XY	X^2
1	0.026	0.026	1
2	0.027	0.054	4
3	0.023	0.069	9
4	0.029	0.116	16
5	0.021	0.105	25
6	0.021	0.126	36
7	0.021	0.147	49

Σ2	0.168	0.643	140

Table 4: Modeling the Results Obtained using Regression Analysis for 2 Tractor Pass

X	Y	XY	X^2
1	0.043	0.043	1
2	0.042	0.084	4
3	0.042	0.126	9
4	0.044	0.176	16
5	0.043	0.215	25
6	0.042	0.252	36
7	0.04	0.280	49
Σ 28	0.296	1.176	140

Table 5: Modeling the Results Obtained using Regression Analysis for 4 Tractor Pass

X	Y	XY	X^2
1	0.063	0.063	1
2	0.066	0.132	4
3	0.066	0.198	9
4	0.054	0.216	16
5	0.054	0.27	25
6	0.057	0.342	36
7	0.052	0.364	49
Σ28	0.412	1.585	140

Table 6: Regression Model at Different Tractor Passes

No of Tractor Passes	Regression Model
0	0.028 – 0.001X
2	0.00028 –0.04312X
4	0.067 – 0.00225X

Table 1 & 2 shows the mean cone index with different passes of tractor wheel (0, 2 and 4) at various time (Monthly). The penetration resistance test was carried out to determine the sandy loam soil ability to resist load which tends to compress it knowing its impact on the growth and yield of plants. The cone index was determine with the use of cone penetrometer at different level of tractor compaction. Table 3, 4 & 5 indicated the calculation derived from the data using excel spreadsheet. Rapid determination or prediction of penetration resistance could be attained by suitable mathematical model capable of predicting the cone index at 0, 2 and 4 traction compaction.

The final form of the regression proposed in this study was:
$Y = a + bX$
Where $b = n\Sigma XY - (\Sigma X)(\Sigma Y) \div [n\Sigma X^2 - (\Sigma X)2]$
Where $a = Y\ avr - b(Xavr)$
$Y=\Sigma Y/n$
$X= \Sigma X/n$
Where n = number of observations
X = Time(Monthly)

Y = Cone Index.

The variables used in the mathematical model of this study are: no compaction which represented the natural condition of the soil (0TP), two tractor passes (2TP), and four tractor passes (4TP) for a period of seven months. The basic concept of this model is that it produces a reliable relationship between the cone index and tractor passes at 0, 2 and 4.

Conclusion and Recommendation

This result obtained in this experiment on a sandy loam soil showed that penetration resistance increases as number of tractor pass increases indicating that the higher the number tractor passes influences the soil cone index. The cone indices of the sandy loam as shown in Table 6 were predicted with the use of simple regression model. The model presented in this study will help mechanized farmers to determine the performance of crop growth and yield on a sandy loam when subjected to 0, 2, and 4 passes of tractor wheel and also consider prevention of compaction by reducing the level of tractor traffic.

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