SOIL COMPACTION: CAUSES AND CONSEQUENCES

Uno, U. E.[1] & Adelabu, J.S.A.[2]
[1]Department of Physics, Federal University of Technology, Minna, Niger State, Nigeria
[2]Department of Physics, Faculity of Science, University of Abuja, Nigeria

Abstract
Investigation of causes, effects and control of soil compaction is being carried out in five area councils of Abuja FCT, Nigeria. It is observed that soil compaction occurs when soil particles are pressed together, reducing pore space between them. Heavily compacted soils have been found to contain few large pores and have a reduced rate of both water filtration and drainage from the compacted layer. Those that occur between large pores are the most effective in moving water through the soil when it is saturated. In addition, it has been observed that as the space is decreased within the soil, the bulk density is increased.

Introduction
Compaction refers to the increase in density of a soil as a result of applied loads or pressure. This means that the soil has a certain density or state of compaction before the load or pressure is applied. In other words, soil compaction is a dynamic soil behaviour by which the state of compaction is increased (Gill and Vanden-Bery, 1967). The total volume of soil is made up of the volume of soil mineral grains and the volume of the pore between the grains . The pore volume is usually partially filled with water and the rest with air. Soil is compacted when the proportion of total pore volume (or air filled pore volume) to total soil volume is inadequate for maximum' crop growth or efficient field management. Soil compaction can be considered in 'terms of soil porosity and density, water infiltration or penetrometer resistance (Gill and vaden 1967, Carter and Smith; 1997, Arridsson, 1998).

Soil compaction can be caused by a number of factors, such as natural characteristics of soil formation,. Which causes a dense layer, or trampling of livestock (Bouyoucos, 1913). Cases have been known (Baver, 1954) in which trampling has caused an increase in dry bulk density from 1.22 to 1.43 x 10-^{3} kg m-^{3} kg m-^{3}, and a decrease in air-filled porosity from 17.3 to 7.2%. The reduction of air filled porosity below 10% indicates that compaction by animals can affect plant growth. A third factor, which can cause soil compaction, is the natural shrinkage of some soils upon drying. Gill found out that the dry bulk density of pressed samples increased upon drying and aging from 1.54 x 10^{-3} kg/m^{4} at 25% moisture to 1.75 kg/m^{-3} at 20% moisture. The soil had originally been pressed together at a high moisture content, which may have produced a soil structure that permitted the sizable amount of shrinkage upon drying.

A fourth cause of soil compaction is the soil response to pressure and deformations imposed by wheels and tracks, and soil engaging tools (Baver 1954). In this paper, our discussions are limited to compaction from mechanically applied forces.

Experimental Methods and Measurement
Loamy sandy soil samples were collected from Bwari Area Council of Abuja, FCT, Nigeria. Varying quantities of water were sprinkled evenly over well spread loamy sandy soil samples, which were air-dried. The samples were then thoroughly mixed to ensure uniform moisture distribution. The samples were packed into PVC tube of different bulk densities. The method of AL-Nasha Bandi and Kohnke (1965) was used in packing the soil samples. Every two spoons full of soil put into the tube is followed by a gentle tap on the floor, hereby ensuring even compactness. The measurement of soil compaction was done by determining the bulk densities of the compacted tubes by calculation.

Theoretical Consideration and Calculations

Large pores are usually occupied by air, while pores are occupied by water. The determining pore size decreases as soil water content decreases. The most direct quantitative measurement of soil compaction is the dry bulk density (DBD) of the soil. Dry bulk density is the weight of dry soil material per unit of total soil volume in kg/m^{-3}

$$Porosity = \frac{DBD}{DSG}$$

Where DBD is the dry bulk density of the soil and DSG is the density of individual soil grain.

Total volumes occupied by air filled by air pores, PA, is given by

$$PA = \frac{volume\ of\ air\ filled\ pores}{total\ soil\ volumes}$$

$$= \frac{Porosity - BD\ x\ MC}{Density\ of\ water}$$

Where MC is the moisture content given as:

$$MC = \frac{Weight\ of\ Water\ in\ a\ Soil\ Sample}{Dry\ Weight\ of\ soil\ sample}\ x\ 100\%$$

The product (DBD x MC/Density of water) is the proportion of the total soil volume, which is composed of water-filled pores.

Results and Discussions

Soil density increase is a function of both the comp-active efforts and the water content. These relationships are well illustrated in the compaction curves in Fig. 1.

The force required to compact a soil to a given density decreases exponentially with the moisture content (Curve A), The density of a soil at a given moisture content increase exponentially with the force applied (curve B). Both of these effects are related to the orientation of particles. The moisture content of the soil in Curve B is approximately that of the plastic limit.

The density of the soil under a constant camp active effort increases progressively with the water content to a maximum and then decreases with further addition of water. This maximum is known as the optimum water content for the compaction. These effects are depicted in Fig. 2.

The curves point out that the maximum density levels become higher as the camp active effort is greater. Moreover, the optimum moisture content decreases as the force of compaction increases. In other words, the loci of the maximum density values are shifted toward the dry side, as the compactive effort becomes greater. The shape of the density moisture curve is explained on the basis of the development of the diffused double layer and the orientation of particles. In the B curves, there is insufficient water present at W1 to form a double layer.

The soil is flocculated and the particles are randomly organized. From W1 to W2, the double layer expands, the water films become thicker to produce a lubrication effect between the particles which become oriented so that the slide over each other and form a denser mass. From W2 to W3, there is further expansion of the thickness of the water films and the density decreases because of the dilution effect of the water on the concentration of particles per unit volume. There is some displacement of air in the system but not as much as between W1 and W2. The higher densities obtained with increased compactive effort are due to the greater orientation of particles under the augmented forces of compaction. Greater orientation of particles and higher densities are obtained from kneading compaction than from static application of force.

Fig.3 shows that effect of weather on crop yield response to compaction levels (Soan et al 1994). In a dry year, at very low bulk densities yield gradual increases with an increase in soil compaction. Soon yield reach a maximum level at which soil compaction is also optimal for the specific soil, crop and the climatic conditions. However, as soil compaction continues increase beyond optimum, yields begin to decline with wet weather, yields are decreased with any increase in compaction.

The effect of compaction on plant growth and yield depends on the crop grown and the environmental conditions that crop encounters. In general, under any condition, some compaction is beneficial but under wet condition, compaction decreases yield (Voorhees et al 1986).

Soil compaction in wet years decreases soil aeration. These results, in increased denitrification (loss of nitrate-nitrogen to the atmosphere). There can also be a soil compaction induced nitrogen and potassium deficiency. Reduced soil aeration affects root metabolism. There can also be increased risk of crop diseases. All these factors results in added stress to the crop and ultimately, yield loss (Soane et al, 1994).

Conclusion

In the discussion on compaction above, facts have been presented to show that the application of compressive and shear forces to cohesive soil results in the decrease in the void ratio and increase in soil density and soil strength. The use of agricultural machinery, transportation vehicles and harvesting of crops is accompanied by application of pressure to the soil. The distribution of this pressure in relation to soil compaction and plastic flow is of major importance in analyzing the impact of machines and vehicles on soil properties both from the standpoint of growth of plant and of machine design to minimize these effects.

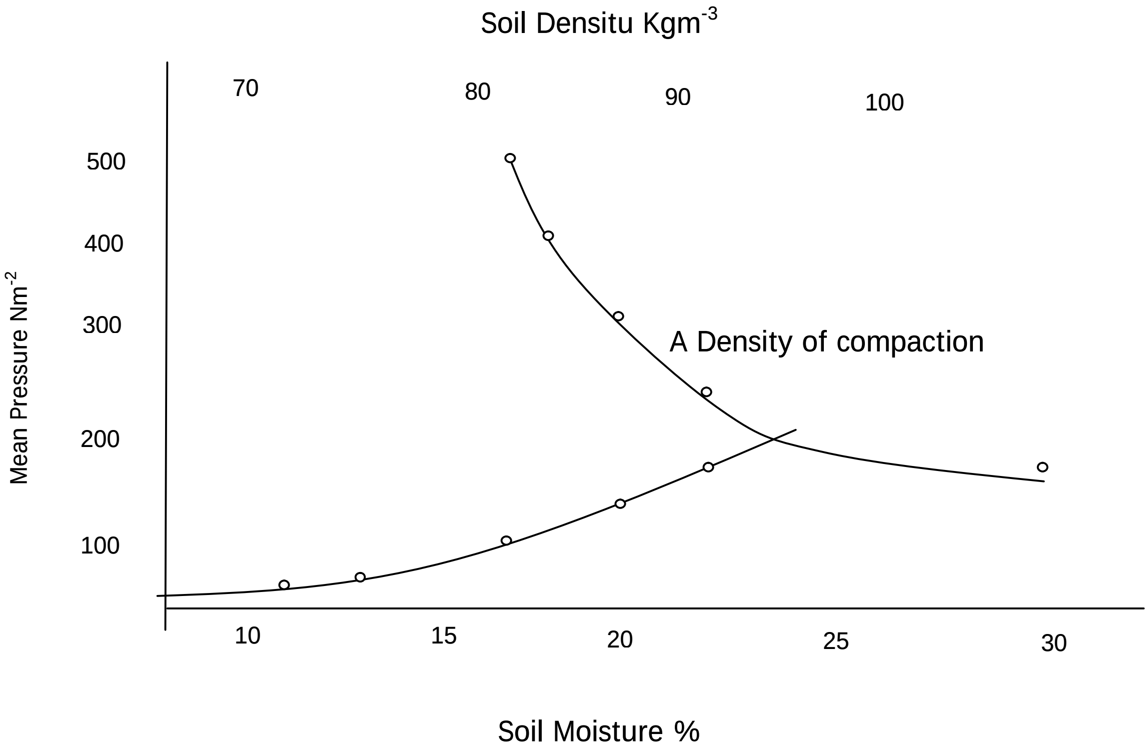

Fig.1: The effect of pressure on soil compaction

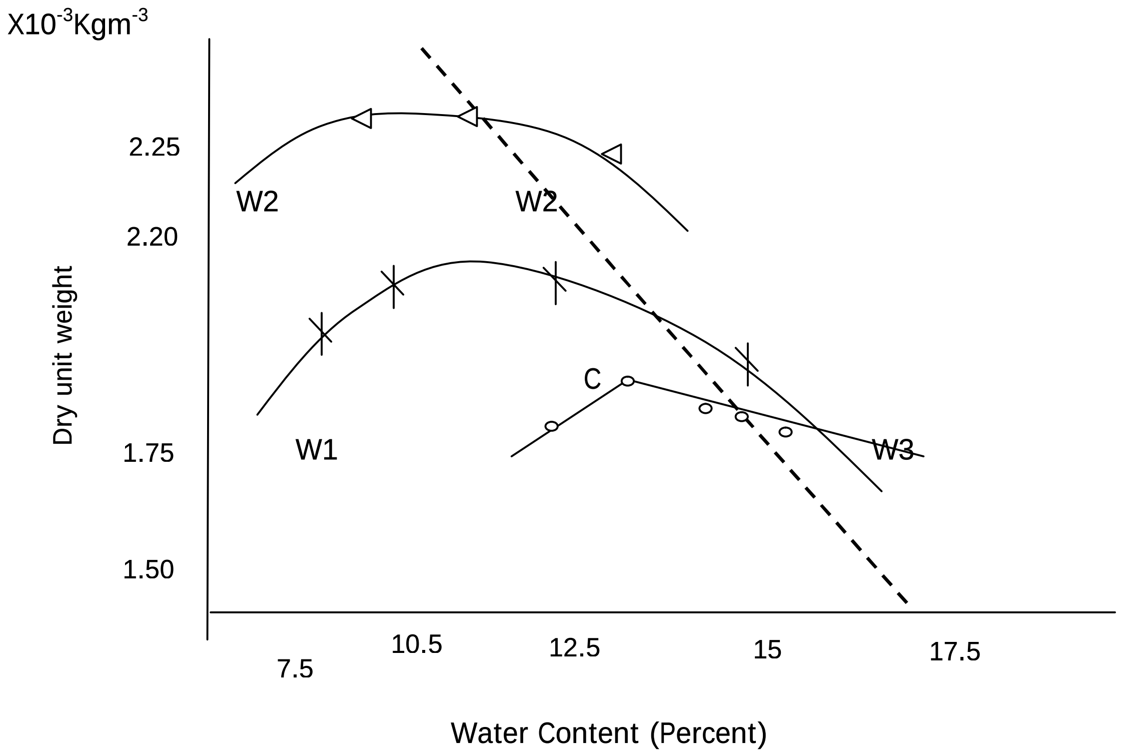

Fig.2: Density – water relationships during soil compaction

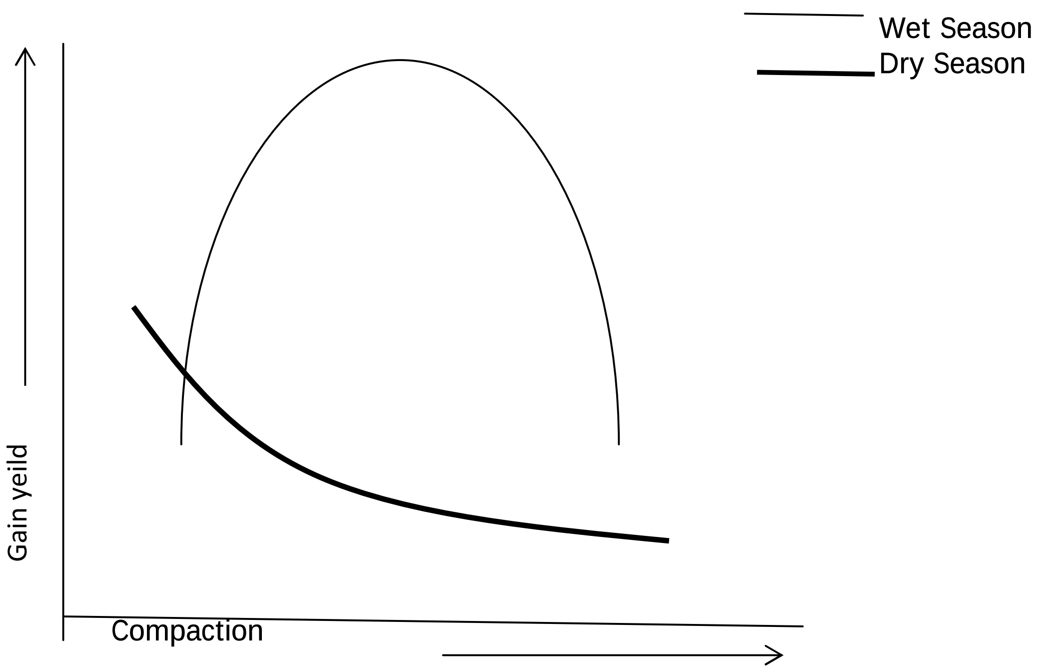

Fig.3: Effects of weather on crop yield response to compaction level

References

Adelabu, J. S. A. & Uno, U. E. (2003). Combined effect of soil moisture and soil compaction on maximum soil temperature. *NJP,15(2).*

Al Nashabandi, G. & Kohnke, H. (1965). Thermal conductivity and diffisivity of soils as related to moisture tension and other physical properties. *Agre Meteorol, 2,271-279.*

Arridsson, J. (1998). Influence of soil texture and organic matter content on bulk density, air content, compression index and crop yield infield & laboratory compression experiments. *Soil and Tillage Research, 49, 159.*

Baver, L. D. (1954). *The meterological approach to irrigation control*, Hawaiian Planters' Rec., 54,291-298.

Bouyoucos, G. J. (1913). An investigation of soil temperature & some of the most important factors infleucing it. *Mich. Agr. Exp. Sta. Tec. Bull 17.*

Carter, M. R. (1997). Assessing the compaction susceptibility of South Africa Forestry Soils. Soil properties affecting compatibility and compressibility, S*oil and Tillage Research 43,335-354.*

Gill, A. J. & Vanden, B. (1967). Compaction pattern of Hawaiian soils. *Agric. Met. 4,30-47.*

Soane, J., Voohees, V. & James, C. (1994). Effects of weather on crop yield response to compaction level.

Voarhees, W. W., Senst, C. G. & Nelson, W. W. (1986). *Effect of surface compaction on yield*. Communication and Educational Tech. Services, University of Minnesota Ext Services.