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Bulk density by Proctor test as a function of texture for agricultural soils in Maputo province of Mozambique

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Abstract

Soil degradation processes may be of various kinds, including soil compaction. The present study was carried out with the objective of assessing the sensitivity of agricultural or recently abandoned soils in Maputo province of Mozambique to compaction. The assessment is based on the maximum of bulk density attained using the Proctor test (MBD).

In this study the soil texture is expressed by silt plus clay (S + C) or clay (C). The relations between the soil texture and MBD, and between soil texture and critical water content (CWC—soil water at which MBD is attained) were determined. Selected soils range from 10 to 74% of S + C and 9 to 60% of C.

The results suggest there is a relationship between the considered parameters, being that between S + C and MBD or CWC, the best. For MBD the relationship is represented by two quadratic equations with the boundary in between these being a S + C value of 25% and C value of 20%.

Based on the obtained results, one can conclude that the selected parameters may be a useful basis for estimation of the sensitivity to compaction of the Maputo province's soils. It is recommended that similar studies be carried out for soils under forest land and for soil of other provinces to establish the national physical degradation hazard as a function of soil parameters determined routinely and at low cost. The suggested parameters are texture and soil organic matter (SOM).

Keywords: Soil compaction; Soil bulk density; Critical water content; Silt plus clay; Mozambique

1. Introduction

Compaction is the compression of a non-saturated soil resulting in reduction of the volume and increase in the density of a given mass of soil (Bodman and Constantin, 1965; Gupta et al., 1989). The process is accompained by the reduction of air fraction. According to Bradford and Gupta (1986) the

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maximum bulk density resulting from an application of a certain quantity of energy on the soil mass is called compactibility (Bradford and Gupta, 1986). On the other hand, Håkansson (1990) used the term compactness to define the final state reached in a soil after application of an external force.

The soil compaction is not always harmful. Sometimes it is beneficial, for instance to increase the contact area between roots and soil particles to increase nutrient and water uptake. This can be achieved by using 'press wheels' or tractor wheels with low ground pressure. In order to be able to distinguish the needed compaction from the harmful, Gupta and Allmaras (1987) proposed the term excessive compaction.

Excessive compaction is one of the causes of soil degradation. Lal and Stewart (1990) cited a report from FAO/UNEP (1983), which estimated that 10 million ha/year of what they termed 'biologically agricultural productive area' of soil have been converted to a degraded condition up to the year of 2000.

Changes in the state of compactness lead to changes in the physical, chemical and biological properties in the soil (Håkansson et al., 1988). This phenomenon can result in accumulation of chemical toxic compounds (Lal and Stewart, 1990) and adverse changes of soil nutrients availability, which can lead to a decrease in productivity of agricultural soils.

The reduction of agricultural areas in many countries can lead to social and political instability as it affects the economical structure (Taylor, 1992). It is difficult to evaluate the economic impact caused by excessive compaction due to many factors involved but it is well known that the recovery of degraded soils is a very expensive and slow process (Gill, 1971). Excessive compaction must therefore be avoided (Soane et al., 1982).

Compaction can be influenced by internal and external factors (Bennie and Krynauw, 1985). Internal factors of importance are the mineralogical composition, texture, organic matter and water contents during the compaction process; the external factors are mainly the energy applied over the soil mass. This energy can be natural, for example rain drops (Mckyes, 1985; Hodara and Slowinska-Jurkiewicz, 1993), caused by animals (Tanner and Mamaril, 1959) and humans. Human activity can compact the soil during agricultural activities through their movement as well as the use of agricultural equipment (Hadas, 1994). The wheels of the equipment as well as human feet produce a mechanical stress in the soil mass resulting in packing of the soil particles (Bennie, 1998—personal communication).

Harmful compaction can occur in soil with different textures, but the chance of its occurrence in soils with the same texture can differ (Bodman and Constantin, 1965). Fine sandy loam and loamy fine sand with high content of fine fraction of sand and low contents of organic carbon, are more susceptible to compaction (Bennie and Krynauw, 1985).

The water content affects the compaction of soils (Bigner and Wells, 1992). During the Proctor test procedure a moisture content is determined at which the soil reaches the highest bulk density, commonly called maximum bulk density (MBD). This moisture content is called the critical water content (CWC), due to its negative effect (Etana et al., 1997).

The agricultural practices in Maputo province of Mozambique are undertaken in soils covering a wide range of texture, including those referred to by some authors as being susceptible to degradation through excessive compaction. Considering that there is not yet any countrywide study on compaction of the agricultural soils of Mozambique, this research aims to study the compaction sensitivity of the Maputo soils.

This paper has two specific objectives namely, to express the relationship between the MBD-Proctor test and texture and to show the relationship between the CWC and texture. In both cases, the texture is expressed as silt plus clay (S + C) or clay (C). The relationship between soil organic matter (SOM) and MBD was also investigated.

2. Material and methods

2.1. Sampling and preparation

The study was carried out on samples from 22 agricultural soils over five districts of Maputo province. The selected plots were under crops or less than 2 years old fallow conditions. Sampling selection was deliberately made to cover a wide textural range using the 1:250.000 soil map of Maputo and Gaza