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SHORT NOTE

Dry bulk density of Gezira Vertisol as determined by X-ray computed tomography

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Soil bulk density is an important parameter indicating the aeration of the soil, the extent of its compaction, its permeability and the state of ease of tillage. It is as well important for expression of gravimetric soil moisture values as volumetric. Current measurements of soil bulk density depend on methods that, to some extent, disturb the soil. In the case of cracking soils, sampling of soil by cylinders probably results in an imprecise determination of the bulk density considering the possible bias in placing the core samplers away from large cracks. The clod method also results in siY1ificant overestimation of the field bulk density of soils because of the small sample used and hence less number of cracks accounted for.

Under continuous cultivation and cropping as practiced in the Gezira for more than 80 years, it is quite possible that the repeated wetting and drying of the soil could cause an adverse effect on soil structure that is possibly envisaged in effects on soil bulk density. X-ray computed tomography is a non-destructive imaging technique to construct a 3-dimensional image of the scanned object (Crestana et al., 1985; Hopmans et al., 1994; Phogat et ale, 1991; Rogasik et al., 1994, 1999). The computed tomogaphy scan has shown so far a considerable improvement in quantification of soil morphological parameters (Rogasik et al., 1994, 1999).

The objective of this study is to demonstrate the usefulness of the X-ray computed tomography in determination of the narrow spaced differences in the bulk density of cracking soils and to use the results btained to examine the effects of continuous cropping on soil physical properties. Results obtained were compared to those of the paraffin wax method.

Intact soil clods were collected at the end of the dry season (end of April 1999) from both the continuously cropped land and the permanent fallow of the Gezira Research Station Farm in Wad Medani, Sudan. The soil is cracking clay that contains more than 60% clay. Soil samples were scanned when dry using a Siemens Somatom Plus-CT scanner at energy level of 120 kV (165 mA, 330 mAs). The pixel densities determined ranged from -1500 to 3000 Hounsfield materials; 1000 HU indicates air, the Zero HU indicates water and higher HU values are for solids. The soil clods were scanned horizontally with a slice thickness of 1 mm and a slice distance of 2 mm. From the parameter HU of the pixels located inside the 1 mm thick horizontal slices, the arithmetic mean was calculated as a base for calculation of conventional soil physical parameters. The relationship between the measured Hounsfield Units (HU) and the soil physical parameters is described by Rogasik et al. (1999). However, it is sufficient to mention here that the following equation was used for calculation of the bulk density:

$P_O = P_S\, P_W\, (HU_S{+}1000)/\{P_W(HUmatrex{+}1000){+}1000W_SP_S$

Where

PO:	Dry bulk density of horizontal slice (g/cm3).
PS	Particle density of soil (g/cm^3).
PW:	Density of water (g/cm^3).
HUs:	Average Hounsfield Unit of horizontal slice (HU).
HU matrix:	Hounsfield Unit of the solid phase of fragment (HU).
WS:	Gravimetric water content of horizontal slice (g/g).

In both samples, the soil bulk density increased with increasing depth as a result of overburden (Zein El Abdine and Robinson, 1969). The increase was more pronounced in the permanent fallow plot especially at lower soil depths. This noticeable increase of the soil bulk density in the permanent fallow is presumably related to the fact that this soil is continuously relatively drier compared to its irrigated counterpart. The values of the soil bulk density obtained for the permanent fallow plot were invariably lower compared to those of the cropped plot. Fig, 1 shows the plot of bulk density values and soil depth of the examined samples. The vertical solid and dotted lines represent the average bulk density of the entire soil clod. The obtained average values of the soil bulk density of air dry Gezira soils were 1.35 g/cm3 and 1.42 g/cm3 for the permanent fallow and the conf-inuously cropped plot, respectively. It is noteworthy to mention that in

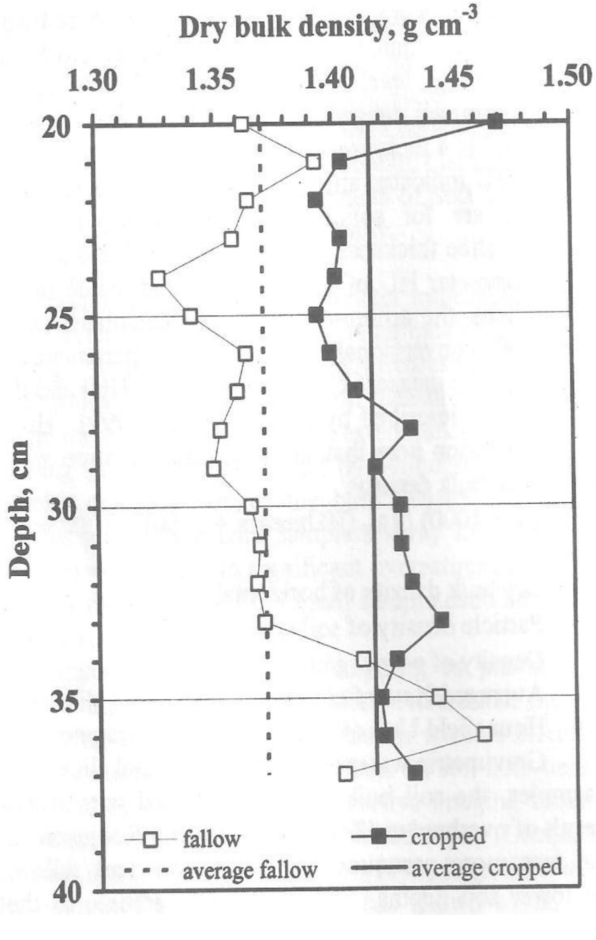

Fig. 1. Dry bulk density distribution within the reference cube of the fragments from the cropped and fallow plots.

41 mapping units of the surveyed Gezira, the bulk density values reported by Idris (2002) showed that the lowest bulk density value

was 1.49 g/cm3 and the highest was 1.9 g/cm3. The average value for the dry bulk density of the 41 mapping units was 1.8 g/cm .

These reported data are probably overestimating the bulk density values in air dry Gezira soils since these values are higher than the acceptable bulk density values suitable for root penetration. The high values of soil bulk density reported by Idris (2002) are probably related to the crude paraffin wax method adopted. It is worth mentioning here that the roots of cotton grown in these soils are able to penetrate down to a depth of more than 50 cm. On the other hand, measurements of bulk density for dry Gezira soils reported by Farbrother (1996) for surface soil (0-40 cm) were lower (1.25 g/cm3) than the values found in this study, However, a value of 1.35 g/cm in the subsoil (40-60 cm) is in conformity with the present results. Braund et al. (2001) has reported that in 2721 soil horizons of mineral soils, the bulk densities of clay, silty clay and sandy clay texture classes were in the range from 1.35 to 1.65 g/cm This study has dealt with soils at the dry end of the moisture retention curve and it is suggested that the present study be further developed by scanning soil clods at different soil moisture contents. In may be obtained at the bulk density values determined by other methods.

It is concluded that the bulk density of the soils of the cropped plots was found to be higher than those in the fallow plots, which is an indication of the effect of long-term cropping and continuous irrigation. It was possible to compare the narrow space bulk density values of cracking soils under cropping against those of the permanent fallow plot in the Gezira using X-ray computed tomography and image analysis. Using this method, there is a great potential to generate bulk density values for the different soil series in the Gezira. These values could be used for calculation of a correction factor to be used for correction of the bulk density values in the archives of the Land and Water Research corresponding soil moisture contents. The method is highly expensive and its direct use could be limited by costs. However, it may be possible to produce a correction factor using regression analysis to correct Centre of the Agricultural Research Corporation (ARC), Sudan, which are thought to be overestimated when determined by the paraffin wax method.

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