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Raising confidence in quality measurements from soil laboratories in Sub-Saharan Africa

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SOIL BULK DENSITY STANDARD OPERATING PROCEDURE Cylinder Method (undisturbed soil)

Practical Run

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Introduction - Definition and Significance of Soil Bulk Density

Definition: *Basically - it is the mass per unit volume of dry soil.*
*Technically - ratio of the mass (oven dry weight) of the soil (M_{solids}) to the bulk volume (V_{soil}) which includes volume of solids & pore space at specified soil water content (see **Fig 1**)*

Significance of Soil Bulk Density (BD)

*- Affects **many soil parameters** viz: Soil strength - thus resistance presented to crop roots penetration i.e. - Higher bulk density >1.6 g/cm^3) tend to restrict root growth Ideal = < 1.5g/cm^3 for optimum air and water movement*

*- AWC INFLUENCES porosity viz. High BD **=>** Low Porosity*

- Convenient in some calculations e.g. mass of slice furrow (for liming etc.), (conc. e.g. kg/ha)

- *Naturally BD increases with depth; Decreases with appreciable increase of OM*
- *Sandy soils are more prone to high bulk density (closer packing of particles)*
- *Some of the management practices tend to affect BD negatively e.g. Heavy equipment combine harvesters, tractors, field irrigation equipment particularly when soil is too wet*

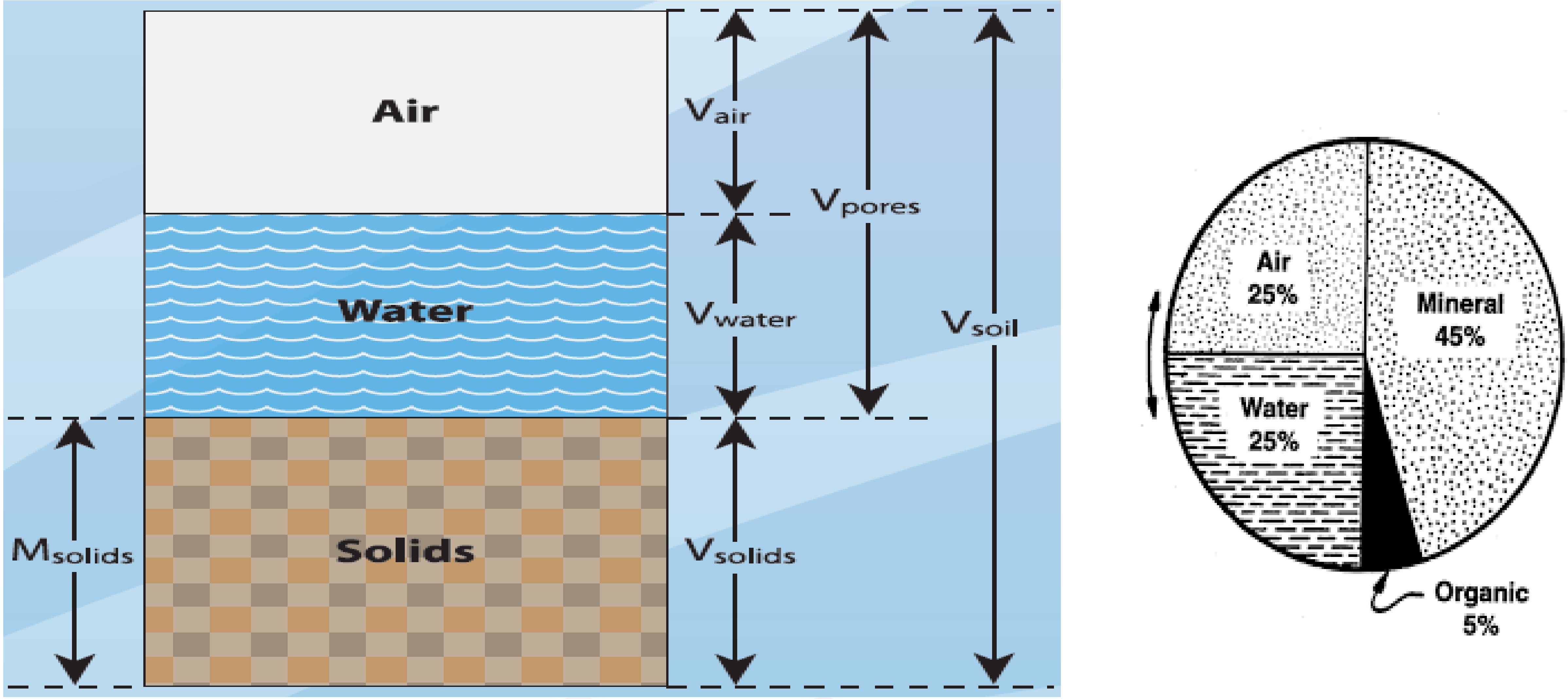

Fig. 1 BULK DENSITY AS A FUNCTION OF STRUCTURAL COMPOSITION OF SOIL

SIGNIFICANCE OF BULK DENSITY (Continued)

- Both Engineering (construction) and Agriculture use Bulk Density as basis of calculations for different purposes though.

Construction-*denser soil is important to lay foundations, so bulk density must be high and compaction is used to achieve lesser volume and higher bulk density.*

Agriculture - *less dense soil is favorable because it helps root development*
To this end more often the soil is plowed, increasing volume and therefore lowering bulk density

- ✓ ***BD*** *is generally expressed in SI units i.e. kg m^{-3}. Derived units e.g. g/cm^3 may be more user friendly i.e. Give values that are self explanatory BD 1.2 is easier understood than if say 1200 kg m^{-3} is used*

GUIDELINES for BULK DENSITY APPLICABLE TO CORE SAMPLING METHOD

While BD procedures might differ - generally BD SOP involves taking a sample that relates to packing of particles, soil moisture at sampling etc. be it Core, Escavation, Clod etc.

COMMON ERRORS INCLUDE

- *Disrupting Soil while sampling*
- *Inaccurate trimming*
- *inaccurate dimensions (volume) of core cylinder*
- *Poor replication demanded by soil heterogenuity*
- *Poor escavation of core (or other samples forms)*
- *If soil has >10 % gravel or the stones are >2 cm conventional bulk density readings will be inaccurate, as most coarse fragments have bulk densities of 2.2–3.0 g/cm^3 - hence Don't use cylinder (Core method)*
- *This is important to note when using bulk density measurements to calculate nutrient levels on an area basis, as an over-estimation will occur.*

GOOD LABORATORY PRACTICE (GLP)

- *Transport samples to the lab with care as may be required by chosen method ASAP*

Conceptualization of Core method (undisturbed sample) for BD

The exact procedure will depend on the kind of available equipment e.g.

- Core sampler equipment availability
- Soil structure
- OR BASIC IMPROVIZATION OF CORE
- horizon in question etc

N.B. Core samplers vary in design with technology from basic chamfered core cylinder to technologically efficient samplers that can not only remove a relatively undisturbed sample from a profile, but also hold the sample during transportation to the laboratory.

A widely used sampler consists of two cylinders one inside the other with the outer one extending above and below the inner to accept the effects of the hammer and also to form a cutting edge at the lower.

It is not necessary to hold the soil undisturbed for transportation as the core sampler and or core might want to be re-used after transferring each sample to a container.

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Considerations when taking a core sample

- *Avoid obviously unrepresentative areas e.g. Irrigation equipment path, tractor pathways, domestic/wild animal pathways - UNLESS OBJECTIVE OF THE STUDY*

- *Avoid core sampling in <u>stony area</u> or high <u>root density</u> area*

- *Ensure that levels inside the sampler and outside remain about the same*

- *Keep in mind that core samples should be taken in soils of medium water content viz:-*
  ***too wet** = friction along sides of cylinder => compression Ideal – AT FIELD CAPACITY (Or determined by Proctor compaction test*

  When sampling sticky wet clay samples - applying slight oil facilitates removal of core
  ***too dry** = hammering can shutter the samples in hard/cemented soils*
  When too dry – might be desirable to wet soil manually first (bottomless drum) and allow to drain for about 24 hrs drain for about 24 hrs
- *Take extra care on trimming soil with lots of gravel... if challenge cannot be easily be overcome take more samples to decrease the inherent error.*

FIELD SAMPLING FINAL EQUIPMENT CHECKLIST

- *Document what is required and conceptualize the sampling sequence and precautions to be made on improvization and create a **Checklist** and tick available equipment.*

Some of the basic sampling equipment includes:-

- *Hammer for cylinder insertion (shock absorbing or sliding hammer type if available*
- *Measuring equipment :- Tape measure and ruler (for core dimensions measurement)*
- *Core and lids if available (note down exact dimensions and core used for each sample).*
- *Flat hard wood wider than core diameter*
- *Plastic sample bags (preferably zipper plastic bags)*
- *Cutting tools :- Soil knife, scissors*
- *Note book; pen; stickers*
- *Spade; trowel*
- *Penetrating oil*
- *Vernier calipers*

Core Sampling Procedure in the FIELD

1. Prepare an undisturbed flat horizontal surface in the soil with a spade at point envisaged to take samples from. In process removing any loose material (if not sampling at the surface of the horizon, a large pit has to be dug to the required depth).

2. Push/gently hammer the steel ring into the soil (a block of wood may be used to protect the ring). Drive in the cylinder just enough and avoid pushing the ring in too far (cut any plants roots off with scissors).

3. Excavate around the ring without disturbing or loosening the soil it contains and carefully remove it with the soil intact .Trimming the upper and lower ends using a soil knife and capping and taping to secure the core. Number the core and take note

4. If core is to be used again, Quantitatively transfer the soil into the plastic bag and seal the bag, marking the sample i.d.; date and location and field sample number where the sample was taken in simple terms duplicated on outside of container and inside by way of label.

LABORATORY ANALYSIS - BULK DENSITY on SAMPLES COLLECTED

Equipment/Apparatus

- *Oven (pre-calibrated) for drying the core soil samples at 105 deg C for min 24 hrs constant weight (Alternatively Microwave Oven can be used for 20 minutes (D. Routledge and Sabey B.)*
- *Oven drying basins*
- *Dessicater with active dessicant (silica gel)*
- *Analytical balance 2 Decimal places (pre-calibrated)*

Procedure - Determining the mass & volume of soil samples collected

- *Transfer quantitatively each sample collected to a pre-weighed ovenproof container that has been pre-heated and allowed to cool in dessicator and record tare weight and gross weight before and after drying.*
- *Use a Vernier calipers to get exact dimensions to the mm of core used for volume inference required to determine sample volume of each core collected for BD calculations. ENSURE INTERNAL DIAMETER IS TAKEN*

Calculations

Bulk density (g/cm^3) = Dry soil weight (g) / Soil volume (cm^3)

Soil Volume= ring volume ***To calculate the volume of the ring:-***

i. Measure the height of the ring with the ruler in cm to the nearest mm
ii. Measure the diameter of the ring and halve this value to get the radius
iii. Ring volume (cm^3) = 3.14 x r^2 x ring height (h)

If ring diameter = 7 cm and ring height = 10 cm :-volume = 3.14 x 3.5 x 3.5 x 10 = 384.65 cm^3

To calculate the dry weight of the soil:
(i) Weigh an ovenproof container in grams (W_1)
(ii) Carefully remove the all soil from the bag into the container. Dry the soil for 24 hours in a conventional oven at 105ºC for 24 hours in a conventional oven at 105ºC (10 minutes in the microwave) after drying cool in a dessicator = W_2
(iii) Dry soil weight (g) = $W_2 - W_1$ ***Hence BD = $(W_2-W_1)/384.65$***

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Quality Assurance/ Quality Control

Generally for laboratory analysis this is determined by how close a specific measurement is to the true or accepted value.
In general analysis – Task is made easier by comparing a standard or Certified Reference Material

For BD, certified reference materials could be Elusive hence difficuly to obtain and or produce. This also affects Proficiency Testing as the constraints faced in this analysis are equivalent to in-situ analysis where the position and time sampled plays the fundamental role to the result. Reproducing the sample to simulate particle packing, transporting, heterogeneity of the sample, variability in moisture content to name a few, are some challenges that must be overcome.

Steps to take for Quality control/ Quality Assurance

- *(i) When taking core sample close gap between replicate cylinders such that there is little room for variability*
- *(ii) Check the results in relation to Soil type and be critical of BD results obtained*
- *(iii) Use quality cores such as camfered steel cylinders*
- *(iv) Ensure not to compact the core through space hammering*
- *(v) Samples must be kept within 15-25 deg C and analysed as priority particulrly for moisture*

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Thank you all very much for sharing various experiences in this practical

May we continue sharing in the same spirit our findings as applicable to this SOP

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