Food and Agriculture Organization of the United Nations

Standard operating procedure for soil moisture content by gravimetric method

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GLOBAL SOIL LABORATORY NETWORK

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Standard operating procedure for soil moisture content by gravimetric method

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SOIL MOISTURE CONTENT BY GRAVIMETRIC METHOD

VERSION HISTORY

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1. Introduction to soil moisture content

Soil moisture content is one of the fundamental properties used in making decisions related to soil management, such as land preparation, design of irrigation and drainage systems, construction, and risk management.

Analytically, determination of air-dry moisture content (i.e. remaining moisture in soil, dried for laboratory analysis) is important, since it is used to express the results of other tests (e.g. carbon, nitrogen, phosphorus, etc.) on an oven-dry basis.

Soil moisture content analyzed by the gravimetric method has low operational difficulty and can be used for multiple purposes. These include quantifying the soil moisture content or quantifying the soil's moisture retention capacity (a property associated with other properties such as texture, organic matter content or structure and porosity). In general, a low moisture content is associated with sandy soils, whilst a higher content is usually found in soils with higher clay or organic matter content.

2. Scope and field of application

This method covers the determination for all types of soils by the gravimetric method at a temperature of 105 °C ± 5 °C.

For soil samples containing significant amounts of organic matter, drying at the standard temperature for this method can result in organic matter decomposition, which can contribute to error in the calculation of soil moisture. For such soils, oven drying at 60 °C to constant mass, which can take up to 24 hours, should be considered.

Structural water (crystallized water retained between soil minerals), which is not released below 105 °C, is outside the scope of this method. This structural water may be released during combustion analysis (e.g. the so-called “loss on ignition method” at 550 °C) when analysing soil organic matter content.

3. Principle

The gravimetric method allows the quantification of the soil moisture content based on the loss of weight (mass) due to the loss of water by heating the soil to a temperature of 105 °C ± 5 °C until constant mass is achieved.

Soil moisture is expressed as a percentage of the mass of water in a given soil mass (e.g. grams of water per 100 grams of oven-dry soil) (Rasti *et al.*, 2020).

Before analyzing air-dry moisture content, the sample must have been pre-treated by drying to a constant mass, either at room temperature, or in an oven at a maximum temperature of 40 °C.

4. Apparatus

- Balance, with a precision ±0.001 g or higher;
- Drying oven, capable of maintaining a temperature of 105 °C ± 5 °C (forced circulation is optional, but preferable);
- Vacuum pump (optional).

5. Materials

- Soil drying container with a lid, made of glass (such as Petri dishes) or aluminium. A container height of at least 10 mm is recommended;
- Metal clips;
- Desiccator with lid, containing dry desiccant (and valve for vacuum – optional);
- Spatula;
- Wash-bottle;
- Deionized water/distilled water- It should have a specific conductivity not higher than 0.2 mS/m at 25 °C and a pH greater than 5.6 (e.g. Grade 2 water or Type II water according to ISO 3696 and ASTM D1193-06 respectively, if this is the quality of water produced in the laboratory) (ASTM International, 2018; ISO, 1987).

6. Health and safety

Safety glasses, gloves, and lab coats must be worn when preparing the sample and performing this analysis. The unknown potential hazards from the soil chemical and biological hazards should be kept in mind throughout the procedure.

During work with samples potentially contaminated by volatile chemicals (e.g. with hydrocarbons or acids), a notice must be visible in the drying work area indicating this, and analysts must use an appropriate protective mask or respirator fitted with filters designed for volatile chemicals.

Wearing of a mask, particularly during sample preparation, as well as for sample disposal and container cleaning, should be encouraged. The inhalation of fine particles (such as those generated while soil pulverization) can cause medical conditions such as silicosis (American Lung Association, 2020).

Check the correct handling and operation instructions of the equipment involved before starting its use. Always handle Petri dishes with safety tweezers, such as when placing them in and removing them from the drying oven.

7. Sample preparation and storage

When moisture content is required for expressing results of other soil analysis on an oven-dry basis, the pre-treatment consists of air-drying the soil or drying it in an oven at a maximum temperature of 40 °C. Then it is passed through a 2 mm sieve (or another sieve of a smaller aperture, depending on the objective of the analysis), and, if necessary, the sample is quartered (depending on the size of the sample), and finally stored in a clearly labelled, airtight container (made of any material that does not allow moisture into the sample, nor can cause contamination of the sample). Ensure that the milling equipment (used to break down soil aggregates), sieves, and other equipment and materials used in the soil preparation (and storage) do not introduce contamination to the samples.

Prior to determining moisture content, soils should be stored in an air-tight container, away from direct sunlight, at a temperature between 3 °C and 30 °C.

For further details regarding this part of the procedure, refer to the GLOSOLAN SOP for soil sample preparation (FAO, 2019).

8. Procedure

8.1. Sample container preparation

Prior to their use, sample containers (e.g. Petri dishes) must be properly labelled and free of moisture. To do this:

8.1.1. Wash the container, rinsing with abundant deionized or distilled water;

8.1.2. Dry the container, including its lid, in an oven at 105 °C ± 5 °C for at least 1 h;

8.1.3. Transfer container (with its lid in place) to a desiccator, close the desiccator lid valve and keep it there until the container reaches room temperature.

Note: Handle the container with suitable tweezers and/or suitable gloves throughout the procedure.

8.2. Analysis

8.2.1 Place the drying container (including its lid) on the balance, and record its mass (*Mc*) to an accuracy of at least ± 0.001 g;

8.2.2. Tare the balance;

8.2.3. Weigh between 10 g and 50 g of moist soil (depending on the objective of the analysis) into the drying container and record the moist soil mass (Mms) to an accuracy of at least ± 0.001 g. Immediately cover the container with the respective marked lid.

Note: The sample containers should be placed on a clean surface to prevent external solids from adhering to it, influencing the result;

8.2.4. Place the uncovered container inside the drying oven at 105 °C ± 5 °C;

Note: The lid should be placed underneath its corresponding container to maintain the relationship between the two. The lid should be labelled in the same manner as its corresponding container;

8.2.5. Maintain the sample and its container under these conditions for a period of approximately 24 h, until a constant dry mass is achieved (meaning that after that time, for 1 h of heating of the sample, less than 0.1 percent of additional loss of the soil mass is measured).

Note: The required drying time to constant mass depends on the sample being dried, the mass of the sample, the type and capacity of the oven, and other factors;

8.2.6. After the sample has dried to constant mass, remove it and its container from the oven and immediately secure the lid on the container;

8.2.7. Store in desiccator until it cools to room temperature.

Note: It is important that samples are allowed to reach room temperature before weighing (e.g. cooled for a minimum of 2 h), to prevent the balance being affected by convective currents or heat transfer;

8.2.8. Weigh the cool dry sample and container.

Note: Weighing must be carried out in the shortest possible time after removal from the desiccator to minimize the time in which the sample can absorb moisture from the air. To reduce the opportunity for samples to absorb moisture due to ambient environmental conditions, it is recommended to take the closed desiccator (holding the dry samples and their containers) to the weighing area, before opening the desiccator and weighing the samples.

Note: Weighing should be carried out with the lid on the container, preferably using the same balance throughout the procedure;

8.2.9. Record the mass of oven-dry soil sample and container (Mcds) to an accuracy of at least ± 0.001 g.

Note: It is recommended to control fluctuations in the relative humidity during weighing.

9. Calculation

The soil water content is calculated and expressed as a percentage of the oven-dry soil (ICONTEC, 2013), as shown in equation 1:

$$W\ \% = \left\{\frac{M_{cms} - M_{cds}}{M_{cds} - M_c}\right\} \times 100 \qquad (1)$$

Where:

W = water content (dry weight basis with ± 0.1 percent or higher accuracy) expressed in units of percentage (%) or g/100 g of the oven-dry soil

Mms = mass of moist soil, in g

Mcms = mass of container and moist soil, in g (Mcms = Mc + Mms)

Mcds = mass of container and oven dry sample, in g

Mc = mass of container, in g

The result must be reported to a minimum accuracy of one decimal place.

10. Quality assurance / quality control

10.2. Precision test

Perform replicate analysis (duplicate) every 10–20 sample in each testing batch. The relative percent difference (RPD) of duplicate samples should not be greater than 10 percent.

$$RPD\ \% = \frac{M_1 - M_2}{\left(\frac{M_1 + M_2}{2}\right)} \times 100$$

Where:

M_1 = result of sample

M_2 = result of sample's duplicate

RPD = relative percent difference

10.3. Control chart

It is desirable to produce a chart to track RPD values of testing batches over time. The chart should include the limit RPD value established by the laboratory. A maximum 10 percent of RPD is recommended.

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10.4. Other methods

The equipment's performance (i.e. the balance and oven) should be verified periodically for quality assurance of the results. Balances can be verified using calibrated test masses before use, or on a daily basis, but must be verified in this manner on a monthly basis. An annual calibration of the balance and oven verification is suggested, or for accredited laboratories at the interval required by their national accreditation body.

Note: When equipment calibrations are not available, verifications are useful to maintain quality control.

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Appendix I – Acknowledgments

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GLOSOLAN would also like to thank the experts who were part of the Review Panel and who ensured the finalization of the SOP (appendix II) and all the laboratories that provided inputs for the harmonization of this method (appendix III).

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Appendix III - Contributing laboratories

GLOSOLAN thanks the following laboratories for completing the GLOSOLAN form on the method and providing information on their standard operating procedure for soil moisture content by gravimetric method. This information was used as a baseline for the global harmonization.

From the African Region:

- Department of Agricultural Research, **Botswana**
- Bureau National des Sols (BUNASOLS), **Burkina Faso**
- Laboratoire de Pédologie - CERD, **Djibouti**
- Soil Research Laboratory, **Eritrea**
- Triomf Eswatini Holdings Agriculture Laboratory, **Eswatini**
- Soil Research Institute - Analytical Services Laboratory, **Ghana**
- Imara Analytical Lab, **Kenya**
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- Agriculture Research Institute of Mozambique, **Mozambique**
- Laboratory of CIAT-STP, **Sao Tome and Principe**

From the Asian Region:

- Central Laboratory, Soil Resource Development Institute, **Bangladesh**
- Soil and Plant Analytical Laboratory, **Bhutan**
- Agri-Biochem Research Lab , Subsidiary of M/s Pushpa J Shah, **India**
- Laboratorium Pengujian, Balittanah (Soil Test Laboratory, ISRI), **Indonesia**
- Institute for Agro-Environmental Sciences, NARO (NIAES), **Japan**
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- Department of Agricultural Research, **Myanmar**
- Soil Science Division - Agricultural Research Council, **Nepal**
- Office of Sciences for Land Development,Land Development Department, **Thailand**

From the Eurasian Region:

- Research Center of Ecology and Environment of Central Asia (Almaty), **Kazakhstan**
- Institute of Biology of Komi Science Centre of the Ural Branch of the Russian Academy of Sciences (IB Komi SC UB RAS), **Russian Federation**
- Laboratory of Instrumental Soil Research Methods of the National Scientific Center "Institute for Soil Science and Agrochemistry Research-named after O.N. Sokolovsky", **Ukraine**

From the European Region:

- Federal Agency for Water Management - Institute for Land and Water Management Research, **Austria**
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- Department of Agroecology, Aarhus University, **Denmark**
- Estonian Environmental Research Center, **Estonia**
- Institut de Recherche pour le Développement (IRD), **France**
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- AGRARIA Department - Mediterranea University, Reggio Calabria, **Italy**
- Kosovo Institute of Agriculture, **Kosovo**
- Latvian State Forest Research Institute "Silava", **Latvia**
- State Plant Protection Service, Agrochemical Laboratory, **Latvia**
- AgroCares Golden Standard Laboratory, **Netherlands**
- Laboratório de Solos e Fertilidade da Escola Superior Agrária de Castelo Branco, Lab-Solos/ESACB, **Portugal**
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- Laboratorio Quimico Agricola Rebelo da Silva (INIAV/SAFSV/LQARS), **Portugal**

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- Laboratorio de FUSADES, **El Salvador**
- Soil Health Plant Tissue Water Laboratory, **Jamaica**
- Colegio de Postgraduados, Campus Montecillo (LABFER -CPM), **Mexico**
- Instituto de Ecología, A.C., **Mexico**
- Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, **Mexico**
- Instituto Tecnológico del Valle de Oaxaca, **Mexico**

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From the Pacific Region

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- CSBP Soil and Plant Lab, **Australia**
- DES Chemistry Centre Queensland Government, **Australia**
- Dual Chelate Fertilizer Pty Ltd, **Australia**
- Soil and Water Environmental Laboratory, **Australia**
- Landcare Research, **New Zealand**
- University of Technology, **Papua New Guinea**

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GLOSOLAN is a Global Soil Laboratory Network which aims to harmonize soil analysis methods and data so that soil information is comparable and interpretable across laboratories, countries and regions. Established in 2017, it facilitates networking and capacity development through cooperation and information sharing between soil laboratories with different levels of experience. Joining GLOSOLAN is a unique opportunity to invest in quality soil laboratory data for a sustainable and food secure world.

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