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Multimedial Study Guide of Field Hydropedological Measurements

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Abstract: Soil hydropedological data measured in situ provide an essential base for basic and also applied research in hydrological, water management, landscape and environmental disciplines. Quality of the measured data is a critical value determining the quality of results and derived conclusions. The knowledge and practical experience of the technician performing the measurements is presenting the "human factor", which affects the quality of measured data most. The Multimedial Study Guide of Field Hydropedological Measurements (further referred to as "the Guide") was created to present and explain selected field measurements determining soil physical and hydro-physical properties in a comprehensive, didactical and user-friendly way. The following topics are introduced: i) Soil sampling (disturbed and undisturbed soil samples), ii) Soil moisture content measurement using indirect non-destructive methods, iii) Determination of tensiometric soil water potential, iv) Measurement of saturated soil hydraulic conductivity in-situ with available groundwater level in measured layer and without available groundwater level in measured layer, v) Measurement of unsaturated soil hydraulic conductivity, and vi) Basic presentation of lysimetry. The Guide was for students, and also for academic workers and other interested members of the public. The English version enables everyone to use these guidelines and carry out each particular measurement, as well as evaluate and present the measured data correctly. The students of the Czech University of Life Sciences Prague use this Guide as a regular learning material in subjects dealing with soil and water relationship since 2012. Now, the 2nd revised edition is presented. The Guide is available on the internet (http://hydropedologie.agrobiologie.cz) and DVD (on request).

Keywords: Hydropedology, study guide, field measurement

1. Introduction

Field methods in hydropedology are developing together with new advances in science and engineering. New devices and technologies are being used, and they need to be operated by well instructed technicians. Classical study materials such as books include valuable information and provide detailed theoretical background. Study of the theory before going to the field is very important, however, it may not lead to the proper completion of the practical part. An incorrect field installation of the devices or incorrect measurement performance can still provide some data for further analysis, but the quality of the data and their informative value can be disputable.

Field hydropedological measurements and soil sampling are irreplaceable base for further research work considering not only a characterization of the specific site, but also using these data as input parameters for hydrological, water management, landscape and environmental modelling in local or regional scale. The quality of the measured data plays a key role in determining the quality of conclusions which are derived based on the available measured data. The quality of the measured data depends mostly on a "human factor"; the knowledge and practical experience of the technician performing the measurements.

The aim of the presented Guide (Báťková et al., 2013) is to present several field measurements related to soil physics in a comprehensible, didactic and user-friendly way in order to explain methodologies of these measurements so they are easily understood and repeated. Moreover, possible analysis and interpretation of the measured data is included together with some practical experience notes, possible mistakes, and references for more detailed study.

The Guide includes information about the following field measurements: i) Soil sampling (disturbed and undisturbed soil samples), ii) Soil moisture content measurement using indirect non-destructive methods, iii) Determination of tensiometric soil water potential, iv) Measurement of saturated soil hydraulic conductivity in-situ with available groundwater level in measured layer and without available groundwater level in measured layer, v) Measurement of unsaturated soil hydraulic conductivity, and vi) Basic presentation of lysimetry.

2. Materials and Methods

The Guide is composed as a webpage written in HTML language. A graphical structure is created using Cascading Style Sheets (CSS). The webpage is optimized for the screen resolution 1680 x 1050 px, or optionally 1440 x 900 px, but at least 1280 x 1024 px. It was tested and evaluated in common browsers Internet Explorer 8, Mozilla Firefox 6, Google Chrome 14. The webpage is also well readable on mobile devices, however the present version was not designed for browsing on mobile devices.

The Guide was created in two language versions, English and Czech. Both language versions are identical. The switch button for switching between English and Czech version is located only on the home page. Both language versions look exactly the same after switching. It means that both language versions are separated and independent.

The web structure is clear and easy to follow. The whole web is composed from 11 separate webpages in each language version. That means a home page and 10 pages for the 10 presented methods of field hydropedological measurements. Each page contains in its upper part a pictorial button line (Figure 1) which allows an easy access to all other parts of the Guide. The pictorial buttons are also described with text labels showing up when a user hovers over the button.

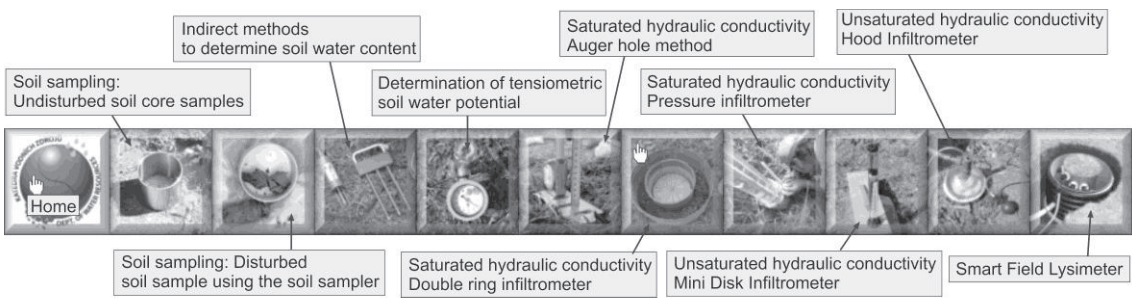

Figure 1. The pictorial button line for easy orientation in the Guide

The home page contains a general introduction, information and acknowledgement, contact information to the authors, and technical and publishing information.

The page for each particular measurement contains the following information. There is a short theory background, list of necessary and useful equipment for carrying out the measurements, description of the measurement procedure including some practical tips and warnings to avoid possible mistakes. Furthermore, there is an example of real data and their processing and evaluation, including formulas, tables, graphs and detailed description. Where applicable, the methodology includes also a practical form for field data records. References for further more detailed study are also included at the end of each page.

In addition to the text part, there are many commented photographs taken by the authors and instructive pictures. For better overview, the photographs and big schemes are showed as previews with hyperlinks. The width of the previews varies, but the height is always equal to 200 px. Text labels with comments are visible after hovering with the mouse.

Each described method includes an instructive video sequence (several minutes). The video sequences are in flash format (*.flv) with integrated flvplayer (Figure 2 on the left). This enables playing of the video independently on the players supported by the internet browser being used. The source code of the flvplayer is available on the internet (code.google.com/p/flvplayer/) and it is used in agreement with the Mozilla Public License (www.mozilla.org/MPL/). The size of the window with the video sequence is 320 x 240 px, however the source video sequences are rendered in resolution of 720 x 544 px. It allows also the fullscreen watching in acceptable quality. The sequences are commented using subtitles (parallel Czech and English) with no sound (Figure 2 on the right).

The presented field measurements were carried out on two localities in the Czech Republic. Most of them were carried out on the Experimental Terrain Station of Soil Moisture Dynamics of the Department of Water Resources and its close vicinity. It is located in the campus of the Czech University of Life Sciences Prague. Elevation is approximately 279 m. a.s.l., the average annual air temperature is around 9 °C, average annual precipitation of around 500 mm. The soil at the site is Udic Haplustoll (Anonymous, 1999) or Haplic Chernozem (Anonymous, 2006) of loamy texture on an aeolic loessial substrate. A groundwater level is not available. The second locality is situated in the Kunratice district of Prague, where a big fish pond used to be maintained in past and thus the groundwater level is available close to the soil surface.

Figure 2. The flash format with integrated flvplayer is used for video sequences (on the left). Subtitles are used to describe the procedures in the video sequences (on the right).

3. Results and Discussion

The presented Guide contains information about the following field methods, which are shortly described below:

3.1. Soil sampling

3.1.1. Undisturbed soil core sample

This method is the most basic and most important method of soil sampling. However, from our experience, students often do not have any or very limited opportunity to learn how to take the undisturbed soil sample. Commented video and photo documentation is followed by a practical calculation of basic soil physical properties.

3.1.2. Disturbed soil sample using the soil sampler

Two basic tools for soil sampling are demonstrated, a gauge soil sampler and an Edelman auger, in order to complete the information about soil sampling from previous chapter.

3.2. Indirect methods to determine soil water content

Indirect methods to determine soil water content are widely used in research and practical applications as an alternative to gravimetrical determination. When the sensors are well calibrated and properly installed, the measured data are accurate enough for most applications. Two indirect methods to determine soil water content which are nowadays widely used are presented: 1.Time Domain Reflectometry (TDR), represented by sensors TDR Trime - FM (Imko, GmbH., Germany; www.imko.de) and Aqua-Tel-TDR (Automata, Inc., USA; www.mccrometerconnect.com), and 2. Frequency Domain Reflectometry (FDR), represented by sensors ECH2O–EC-5, ECH2O–EC10 (Anonymous, 2014) and Theta Probe Soil Moisture Sensor ML2x (Delta-T Devices, Ltd., United Kingdom; www.delta-t.co.uk).

A simple example of calibration by comparison with the gravimetrical method is introduced.

3.3. Determination of tensiometric soil water potential

Tensiometers are the only instruments that can provide a direct measurement of "soil suction"; the force that plants have to overcome in order to acquire needed water, and the force that determines the moisture distribution and transport within the soil. For a basic understanding of tensiometry, an experiment with filling and field installation of an easy standard mechanical tensiometer (type Soilmoisture 2710 ARL; Soilmoisture Equipment Corp., USA; www.soilmoisture.com) is demonstrated. Interpretation of tensiometer readings for practical application in the soil-water-plant system is included.

3.4. Measurement of saturated hydraulic conductivity

3.4.1. Auger hole method

Measurement of saturated hydraulic conductivity at a locality with available groundwater level in measured layer is best performed by using the auger hole method. This method is quick and easy and does not demand any expensive equipment. Moreover, naturally present water from the place being investigated is used for the experiment.

Calculation of saturated hydraulic conductivity is demonstrated using three methods, according to Hooghoudt (1936) and Ernst (1950), then according to Kirkham and Van Bavel (1948) and Hvorslev (1951) method.

3.4.2. Double ring infiltrometer

The infiltrometer consists of two concentric metal rings which are driven into the soil, and of a perforated metal plate. One nail point or two nail points of different lengths are fixed to the metal plate. They are used for observation of decreasing water level during the infiltration. The double ring infiltrometer (Parr and Bertrand, 1960) is a widely used method of infiltration test used in many applications; i.e. design of land drainage pipes, design of sports surfaces, isolation layers of the communal waste, etc. Results from the double ring infiltrometer measurements can be taken only as indicative information; however they can be considered as accurate enough for many applications.

There are several options how to evaluate the measured data. The Guide contains data analysis based on the Philip infiltration equations (Philip, 1957) using the Solver add-on of Microsoft Excel.

3.4.3. Pressure infiltrometer

Pressure infiltrometer by Matula and Kozáková (1997) is a relatively simple pressure infiltrometer of a Mariotte type. The device uses the mechanical-hydraulic principle without need of an external energy supply. The device is portable and easy to set up and can be operated by one or two technicians. The device enables measurement with acceptable accuracy of the cumulative infiltration of ponded water from the infiltration ring. The metal infiltration ring (inner diameter of 15 cm) is equipped by its own water gauge for reading the constant water level in the infiltration ring at a certain time after the start of the infiltration experiment. The infiltrometer can supply water during the experiment up to the amount corresponding with saturated hydraulic conductivity of 9E-04 m s^{-1}.

Data analysis based on solution of Reynolds and Elrick (1991) is described in details.

3.5. Measurement of unsaturated hydraulic conductivity

3.5.1. Mini disk infiltrometer

The Mini Disk Infiltrometer (Decagon Devices, Inc.) is a very handy, manually operated device to measure the unsaturated hydraulic conductivity at pressure heads between -0.5 cm and -6 cm. It has recently became very widely used as the producer provides a complete manual for evaluation of the measured data (Anonymous, 2014) by the method proposed by Zhang (1997).

3.5.2. Hood infiltrometer

The Hood Infiltrometer IL-2700 (Umwelt Geräte Technik, GmbH., Germany; www.ugt-online.de) is a device used for determination of saturated and unsaturated hydraulic conductivities in-situ. Compared to other infiltrometer designs (Perroux and White, 1988; Ankeny et al., 1991; Vandervaere et al., 1997; Špongrová et al., 2009), infiltrating water is in direct contact with the infiltration surface, there is no need for any contact material, and only cutting the vegetation cover to the approx. 5 mm height is needed. The contact material creates an additional layer, which can affect the infiltration process and makes the subsequent data analysis more complicated.

It is not easy to operate the Hood Infiltrometer, thus the measurement procedure demonstrated step by step on the video has become very usefull. An example of steady-state data analysis according to Wooding (1968) and Reynolds and Elrick (1991) is provided.

3.6. Basic presentation of lysimetry: Smart field lysimeter

Smart Field Lysimeter SMF-30 (UMS GmbH, Germany; www.ums-muc.de) is a relatively available small field lysimeter. The soil monolith placed in a stainless steel cylinder is of 30 cm in diameter and 30 cm height. Soil water potential sensors MPS-2 and sensors ECH2O 5TE are installed in three different depths of the soil monolith. The sensors are reading the soil moisture, temperature and electrical conductivity (both sensor types produced by the Decagon Devices, Inc.). The sensors enable to study the dynamic changes of these soil properties in the soil profile in a vertical direction and in real time.

This lysimeter was installed on the above mentioned Experimental Terrain Station in 2013. Some experience from the installation and functioning of the lysimeter are presented in the Guide, as well as the examples of measured data (Matula et al., 2014).

4. Conclusions

The 2nd revised edition of the Multimedial Study Guide of Field Hydropedological Measurements is presented in this study. The Guide was created for students to present and explain some selected field measurements related to soil physics in a comprehensive, didactive and user-friendly way. It is used since 2012 by students of the Czech University of Life Sciences Prague as a regular learning material in subjects dealing with soil and water relationships. The Guide is composed as a webpage and it is available on-line and on DVD in two language versions, English and Czech. Each from 10 described methods includes an instructive video sequence in flash format, many commented photographs and schemes, basic theory and evaluation of the measured data in order to explain each method properly and understandably so it can be easily repeated. The authors would be grateful for any feedback from their colleagues' teachers.

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