

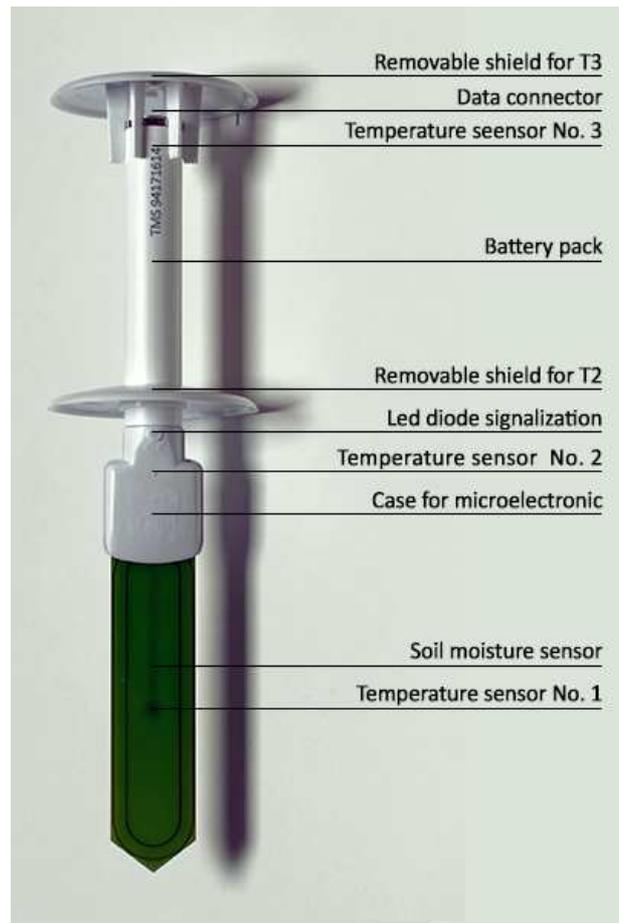
# Soil Measurement System TMS-4

- handbook -

The TMS offer a unique possibility to measure soil and air temperature and soil moisture in any extreme conditions. Single measuring units are completely autonomous – can collect and store data for over 10 years without battery replacement and data extraction (up to 524 000 events ~ 10 years of measurements every 10 minutes). Data are easily extracted with a device of the size of a small cell phone in a minute. Temperature is measured using the temperature sensor MAXIM/DALLAS Semiconductor. TMS are cheap compared to other commercial data loggers and thus allow measurements over large spatial scales.

The TMS data loggers have a wide range of applications for research in the fields of biology, ecology, soil sciences, hydrology, climatology etc. They can also be used in agriculture, horticulture and forestry – monitoring growing conditions in the field, greenhouse, growth chambers etc. Other possible applications include monitoring conditions in grain stores and any other places where it is important to monitor the course of moisture and temperature.

Currently, we have wide experience with their use in a several research projects in Europe, South America, Africa, Australia and Asia. Peer reviewed description of TMS loggers have been published in prestigious scientific journal [Agricultural and Forest Meteorology](#).



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# Technical specification:

**Size:** 29 cm

**Weight:** 108g

**Memory:** 524.288 events ~ 14 years in 15 min intervals

**Battery:** lithium (3,6 V; 2600 mAh) ~ 10 years

**Connector:** Touch probe for settings and extraction of data into PC via USB adapter

**Temperature sensors:** 3x MAXIM/DALLAS Semiconductor DS7505U+, with resolution of 0.0625 °C and with accuracy of  $\pm 0.5$  °C

**Range of measurement:** -40 to +60 °C. The datalogger is capable of measuring even in temperatures ranging from -60 to +85°C, but this can have a negative impact on the lifespan of the battery.

**Moisture sensor:** 1x soil moisture sensor

**Software:** Lolly Manager (Free)

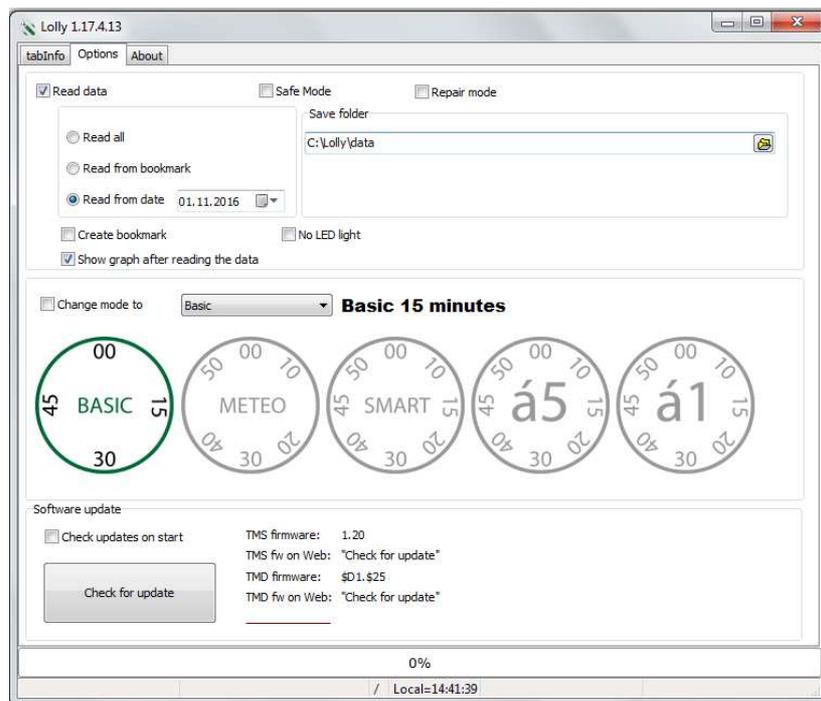
## Basic use:

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### How to install the Lolly Manager application

Download and install Lolly Manager, the program guide will automatically guide you through the installation. Connect the TMD adapter via the USB port of your computer. Attach the sensor to the adapter. At that point, the basic information about the current condition and settings of the sensor will be displayed on the “tabInfo” window.

The current version can be found at: <http://tomst.com/web/en/systems/tms/software/>



## Settings options

In the second window (Options) you may opt for the following settings of the program as well as the TMS sensor itself.

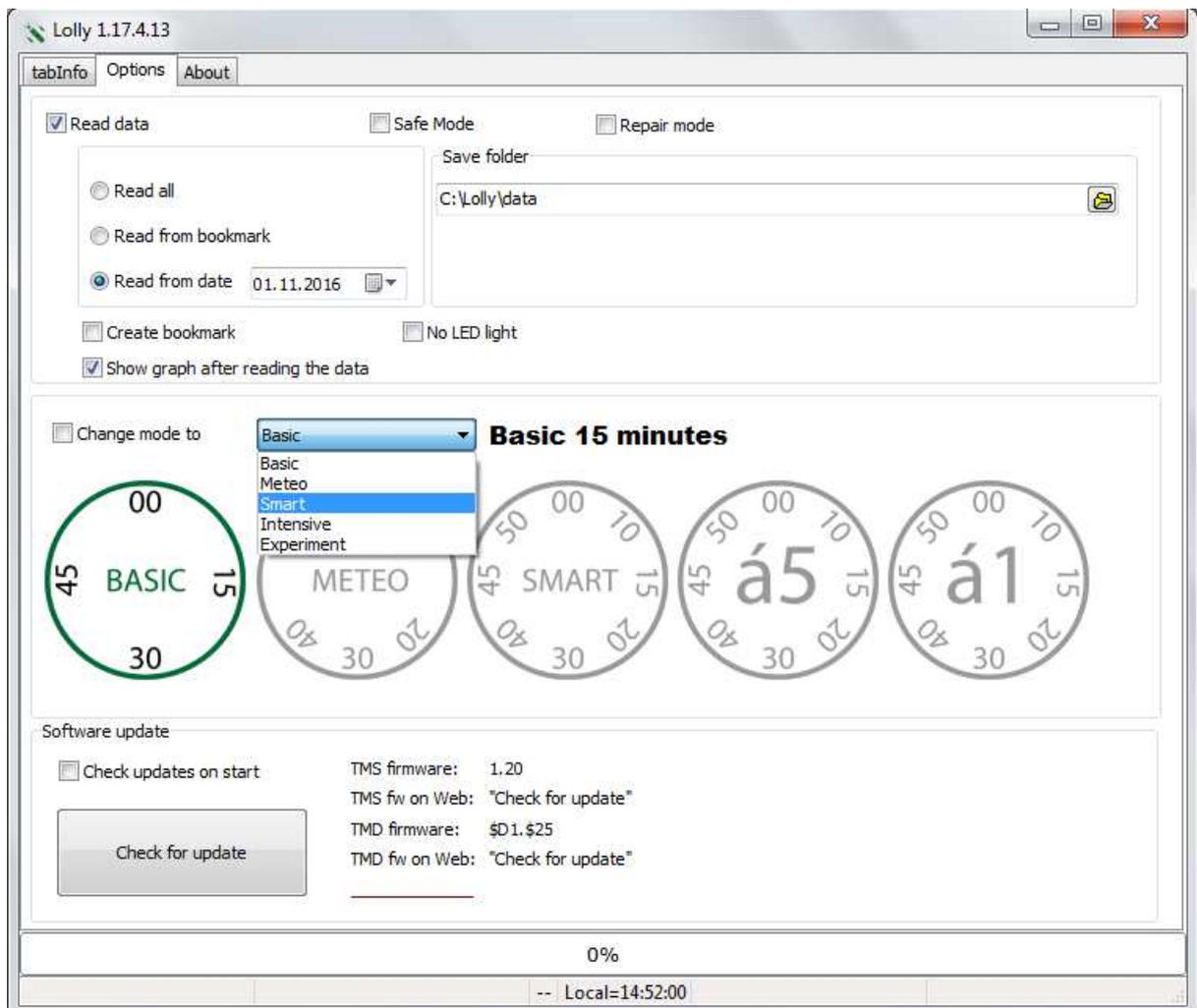
In the first row you can choose to automatically begin downloading data after attaching the TMS adapter by ticking off the box. In case of any problems you may use Safe mod and/or Repair mod for downloading.

This is followed by an option of downloading all the data, from a certain day or from a bookmark and only download data from that point onward. You can also specify the folder into which the data will be saved. In standard settings they are saved into C:\Program Files (x86)\Lolly\DATA.

Here you can also find the alternative of displaying a graph after downloading as well as an option to turn off the led lamp.

## Intensity of measurements settings

After that comes the selection of the mod with the intensity of measurements that best suits your project. There are five possible options:



### **Basic Mode**

Measurements occur every 15 minutes.

### **Meteo Mode**

Measurements occur every 10 minutes.

### **Smart Mode**

Measurements occur 8 times per hour during the 10<sup>th</sup>, 15<sup>th</sup>, 20<sup>th</sup>, 30<sup>th</sup>, 40<sup>th</sup>, 45<sup>th</sup>, 50<sup>th</sup> and 60<sup>th</sup> minute.

### **Intensive Mode**

Measurements occur every 5 minutes.

### **Experiment Mode**

The sensor measures during every minute. This is however recommended only for short-term intensive experiments.

If you only need to change the mode without having the data to be read out, do not leave *“Read data”* ticked off and instead tick off *“Change mode to”*. Then select the required mode from the dropdown menu. After that you just have to attach the sensor to the USB adapter and wait for the change to occur in the window *“tabInfo”*.

Provided that you have access to the internet it is recommended to tick off *“Check updates on start”*- the automatic control of new updates of the Lolly manager application. The newest firmware will also be downloaded and this will enable you to update specific sensors whilst downloading data.

## **How to use the TMS sensor**

After selecting the required mode you may commence your measurements with the sensor.

When you stick the TMS sensor into the ground and later pull it out proceed with caution! If too much force is used the construction of the sensor may be damaged thus leading to a possibility of losing the measured data.

## **Installation tips**

For the data logger to measure properly, make sure that the entire surface of the belowground part (of green color) is in contact with the soil. This can usually be achieved by simply shoving it directly into the soil; however, sometimes air pockets occur, preventing precise measurement. Drying out soils (e.g. clay soils), the soil can shrink or swell, which might cause the loss of contact with the logger thus causing collected values of soil moisture to be lower.

Adjust the installation to the type of soil you are working with. In especially rocky soils, simply shoving the logger into the ground could damage the sensors. Therefore, consider creating a hole for the logger and only then placing it into the soil. You can either shove a metal plate of some kind into the ground and then insert the logger; or you could create a larger hole, which you would then cover up with soil. Beware of the later option, you could slightly alter the composition of the soil.

When the soil is frozen, do not work with the data of soil moisture from that period. Whether the soil is frozen or not can be easily distinguished by looking at the data from the thermometers.

Protection from wild animals

From our experience, most damage occurs due to wild animals, which manipulate with the devices. Therefore, we suggest protecting the TMS using wire cages. These prevent wild animals (e.g. deer, wild boar, bears) from moving or damaging the devices.

## Working with data

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### How to download data into PC

Data downloading is once again done using the USB adapter and the Lolly Manager program. Do not forget to check that in *“Options”* the *“Read all”* is ticked off, or possibly the *“Read from bookmark”*, if you have created it beforehand.

After attaching the sensor to the adapter you will be able to see the download progress. If you have selected *“Show graph after reading data”* in *“Options”* a graph will be displayed after the downloading is finished. You can view this graph even later via an encased built-in tool Long view.

The data is saved into a set folder, most often *„C:\Program Files (x86)\Lolly\DATA“*. It is saved in a text format csv in a binary form. You can open csv files in standard applications such as but not limited to: Microsoft Office, LibreOffice etc. this format is also suitable for many other ways of working with the collected data or to be exact with their processing. For example by using TMS Calibr Tool (more on that below).

### Using the bookmark

If you do not have to download all the collected data but only a certain portion during a certain period, you can utilize the function bookmark. This is useful especially in terrain when you wish to download data from the last measurements and keep the sensors at their given places. This will save you time since downloading all the data can take up to several minutes. How should you proceed?

- 1. Creating the bookmark**

You may only create a bookmark for downloading data. In case you have not established it yet for the given sensor you must tick off *“Read data”*, *“Read all”*, *“Create bookmark”*. If there already is a bookmark formed from beforehand you only have to select *“Read from bookmark”* and *“Create bookmark”*.

- 2. Downloading data from bookmark**

You may proceed as you would with standard data download only instead of *“Read all”* you shall select *“Read from bookmark”*. After that you will only find data from the bookmark onward in the csv file. At the same time you can tick off *“Create bookmark”* and after data download a new bookmark will be formed, which you may use for data download in the future.

## Data download according to time period

You can download data from a certain time period. In the window „*Option*“ select „*Read from date*“ and choose a date from which onward you want the data to be downloaded.

## Structure of data

The data in the csv file are structured in the following order. Each measurement has its own separate row and has the following format.

```
0;31.10.2015 11:45;0;21.5625;22.0625;23.125;148;1;0
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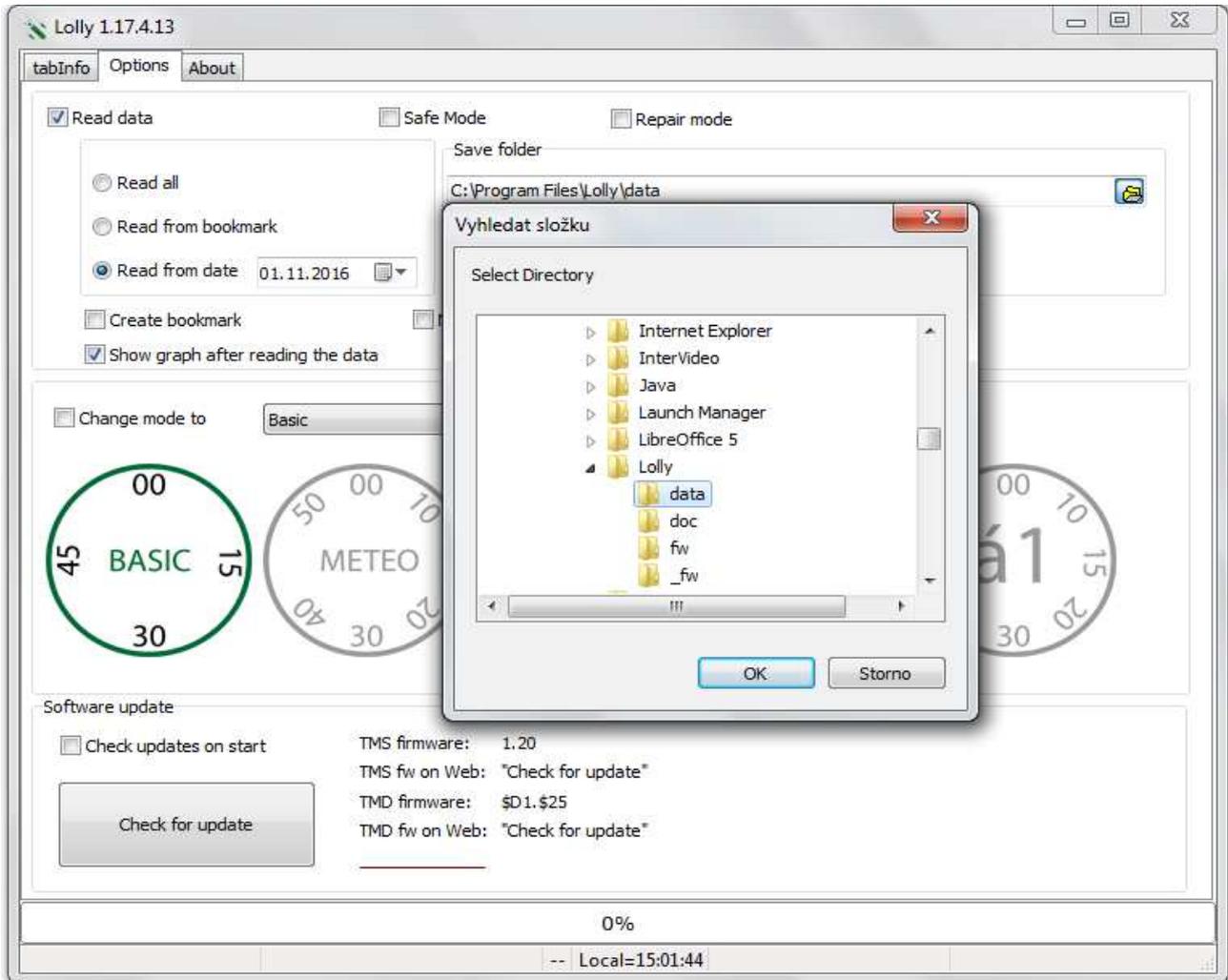
Individual data is separated by a semicolon and are ordered in the following manner:

index number of the measure, date and time in UTC, time zone, T1, T2, T3, soil moisture count, shake, errFlag (if =1 the device couldn't convert time from PCF chip)

All measurement runs in UTC, please use time zone parameter for recalculation to the local time. A shake sensor is placed on the device, values can only be 1 (shake) or 0.

## Viewing data – Log view

Lolly Manager also includes a simple data viewer (Log view), which will help you monitor the data directly in terrain and study the graph for measured temperatures and humidity. First check the setting of the data file. In the „Options“ window be sure to click on the path to your installation (otherwise you will not reach it), which is standardly located in C:\Program Files (x86)\Lolly\ click on „data“ and confirm „ok“.

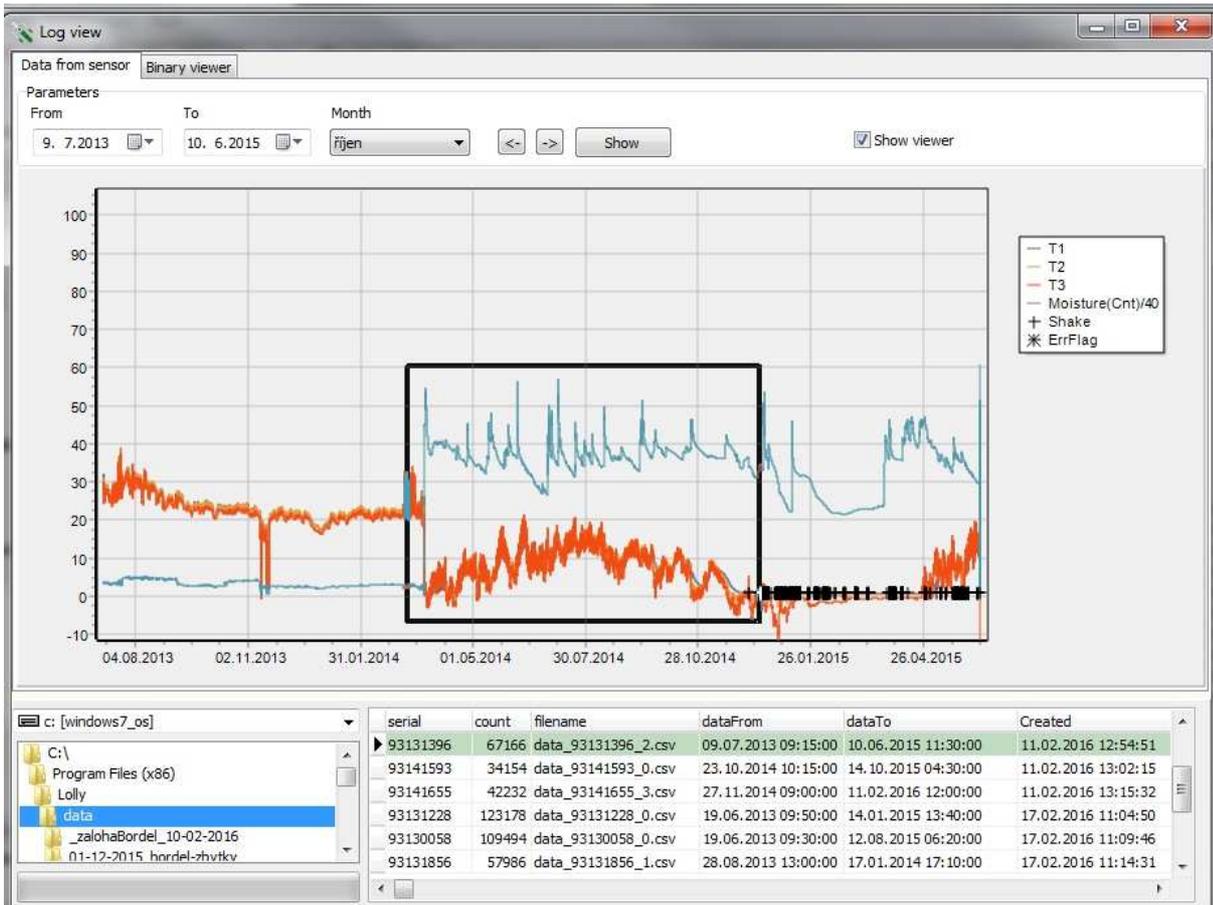


Then you can return to the window „tabInfo“ and click on „Show data“. The data viewer Log view will display itself.

In the lower part you will see a list of downloaded data from the „data“ file. You may orientate yourself primarily thanks to the unique number of the TMS sensor or for instance according to the date of the data download (date of file formation).

By clicking on a given file, data in the form of a graph will be displayed. This graph contains data from all three thermometers, humidity sensor and movement sensor.

For greater clarity you can set up a time period From – To (in the left upper corner) or simply drag the cursor directly onto the graph, marking the required area, which will then automatically enlarge.



# Converting Data of Humidity

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## **TMS Calibr Tool**

You can download it from: <http://tomst.com/web/en/systems/tms/software/>

This tool is in a user-friendly format Excel (xslm) and grants the user a wide range of options to convert data of humidity collected from TMS stations into real values of volume soil humidity.

## **How to use Calibr Tool**

In order to convert the field data please use „Import“ data button to upload the data produced and downloaded from the TMS station using Lolly Manager software.

Knowing your soil class you may utilize the given choice offered in green field (C8) of the “Input“ sheet of soils presented on Fig. 2.3 as a roll up menu when clicked there. Two additional options are possible: „Using soil properties“ uses a knowledge database of curves presented in fig. 2.3 (except peat) and interpolates the calibration equation based on the bulk density and clay, silt and sand fractions of the sample in grey fields of line 44. However, due to limited knowledge of the database in this version, the user is advised to use this option with extra caution.

User may enter option of „Enter your own calibration“. In such a case the orange fields on line 40 are activated.

When one of the default soil classes is chosen, user may modify the curve by fixing the specific calibration in air and water (lines 29+30).

Calibration Addition of one or two known pairs of values (raw soil moisture count-signal and known volumetric soil moisture related to it) can be entered. User may utilize soil core samples taken during installation and processed in the soil lab for field instant volumetric soil moisture (seek advisory of soil lab on how to sample soil cores and how to process them in lab, if you are not a soil hydrologist). At the moment of sampling, raw count of the TMS sensor must be known, i.e. recorded from the station at the given time (synchronicity of TMS values recorded and volumetric soil moisture measured independently in the lab is required to obtain calibration curve as well).

Using one or two additional points may significantly shift or even tilt the default curve chosen, which is an operation advised to do, if such data exist.

Calibration3Output sheet produces calibration curve used and replaces raw moisture count with volumetric soil moisture. This database can be further processed or saved as \*.csv file for further processing by other software, e.g. viewTMS for processing large datasets from multiple sensors.

In a similar but much simpler manner, calibration for TMS sensor working as a gauging station can be performed by recording known penetration in the water (from the tip of the sensor) and raw moisture count.

## **Citing TMS datalogger in scientific publications**

When referring to TMS dataloggers in scientific literature, please cite

*Wild J., Kopecký M., Macek M., Šanda M., Jankovec J., & Haase T. (2019) Climate at ecologically relevant scales: A new temperature and soil moisture logger for long-term microclimate measurement. Agricultural and Forest Meteorology, 268, 40–47.*