Long term field observations to estimate the soil water balance

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Abstract

The availability of electronic components made the development of a "tailor made" data acquisition system for long term observations with a reasonable effort possible. The information chain, beginning with the interaction of sensors and data logger till the final results are available at the desk is pointed out. Two field sites are described to illustrate the use of the observation system.

1. Introduction

In the past field measurements of soil moisture due to high labor costs usually were taken once a week. For a better understanding of the dynamic of processes or to confirm that weekly readings are sufficient a greater measuring frequency was desired. To meet that requirement a complex data logging system as well as the process and communication software was developed at the institute of hydraulics and rural water management. First experiences were gained with the measurement of the pressure distribution in a hydraulic scale model - sector model to simulate the flow towards a well - and with the recording of the velocity of a rising water table in an auger hole (Mikulits, [1]). Development continued to a prototyp of a reliable field observation system for the recording of soil physical parameters.
2. Concept of the data acquisition system

Analog to communication systems the data acquisition concept may be split into hardware and software. The data logger is as much as possible assembled from industrial components. The core of the hardware is a programmable microprocessor (CPU-8052) which handles the process control, real time and standby functions. Sensor signals are connected via an interface to the data logger. This interface comprises inputs for standard signals and for resistance or conductivity measurements. With this configuration it is possible to measure temperature, soil moisture content either with TDR-Sensors or indirect with gypsum blocks, water pressure (positive and negative) and to some extend salinity. The analog signals are converted by means of a A/D, 4 channel - 12 bit converter into digital signals and stored in this form at via a decoding unit on a chip card. The same I/O-unit takes care of the data transfer via a standard RS232C-interface with a personal computer. The data logger is developed as stand alone unit and therefore supplied with a LCD-display and operation keys. Electrical power may be provided either from a net, a battery alone or a solarpanel-battery combination, The data transfer is performed on the spot via the RS232C-interface or by changing of the chipcard and read it out later at the office. A connection to a modem is possible.

To operate the data acquisition system a software package for managing the stand alone unit (process software), for handling the data transfer and for converting the raw data from simple digits into appropriate physical quantities, like temperature, resistance, moisture content etc. was developed (Sokol, [2]). As a final step the presentation of the data, by means of a common graphic package is added. The concept as described above is summarized in Figure 1.

The most crucial parts of the data acquisition system are the sensors. Much attention has to be paid to the sensitivity of a probe to the value to be measured and to other influences, like temperature. In any case before using new sensors under field conditions laboraty tests and calibrations are adviseable.
3. Field observation

The goal of the work so far was not to develop an other data logger but to create a complete data acquisition system for the needs in our observation locations. Priority was given to the measurement of the physical quantities under consideration. The system is installed at two sites in the vicinity of Vienna. One example is the hourly observation of the soil moisture in a vineyard to evaluate differences caused by various soil conservation practices. An other example is the continuous recording of soil parameters on the experimental farm of the University.

3.1 Soil moisture and temperature observation in a vineyard

Soil erosion is one of the main threats to the natural resources of the world. About 12% of the agricultural lands of Austria are endangered. Besides corn and sugar beets, grape production is one of the most erosive practices. Very often vineyards are on south facing hill slopes, where the climate is better suited to the production of high quality grapes.

About 2,500 vinestocks per hectare are planted in Austrian vineyards. To reduce the competitive water consumption of weeds, the soil between the vinestocks and the rows is cultivated very frequently. Therefore 75% of the soil surface is bare during the whole year. This leads to some erosion.
One aim of the cultivation practices is the creation of optimal conditions for the plants. This means that the natural fertility of the soils must not only be maintained, but needs to be improved in many cases. It is essential in viticulture to emeliorate the soil by adding organic matter. Because the loss of organic components proceeds at a faster pace in intensive tilled vineyards as in cropland, a sufficient replenishment of organics must be assured.

To protect the soil from soil erosion, practices that reduce the impact of the kinetic energy of the raindrops on the soil surface and diminish surface runoff are most often used. For several years, this has been attempted by putting grass cover between the rows. In regions where precipitation barely meets the water needs of grapevines the grass can become an undesirable competition for the water. Besides temporary greening, the practice of covering the bare soil with plant residue (straw) or manure is an option.

In the vineyards in Klosterneuburg, about 10 km north of Vienna, several tillage systems designed for reduction of erosion were investigated (Klik and Cepuder [3]). Four different practices on a 35% sloping vineyard were compared. The difference consisted of a bare soil and a soil covered either by straw, manure or grass. The straw coverage was carried out in fall 1990 by a continuous layer of app. 1.5 kg of straw per m².

For the investigation of the soil water balance in the different plots, gypsum blocks were installed in three different depth (10 cm, 30 cm, 50 cm) over the 70 cm deep profile. The soil temperature was measured in 2, 5 and 10 cm depth. The data were measured every hour and recorded on the data logging system.

The effect of straw cover versus bare soil on the soil water content is shown in Figure 2. The graph shows daily values of the soil water content in the root zone (0-70 cm) during the growing season 1991. The soil water content is at field capacity (200 mm for the root zone) at the beginning of the growing season in May and there is no difference between the covered and the bare plot. Subsequently during May the soil water content for the bare plot decreases but remains constant for the straw covered plot. As the water consumption of the vinestock is nearly zero in May, the decrease in soil water under bare conditions is a result of soil evaporation. With the beginning of the plant transpiration in June soil water decreases for both plots. If the transpiration is the same for both treatments, the higher soil water content for the straw covered plot can be
explained by the smaller evaporation from the soil surface. In July the slope of soil water decrease is nearly the same for both practices. During this time period plant transpiration is the main part of the evapotranspiration. The graph shows that during the whole growing season a coverage of the soil by straw leads to higher soil water contents. Especially in dry years like 1991, soil water for plant growth is longer available when conservation is practiced. This, consequently leads to higher yields and better quality of the grapes.

In Figure 3 the soil temperature in 5 cm depth between bare soil and straw covered soil is compared. The graph shows daily values of soil temperatures and air temperature measured at 7 a.m., 2 p.m. and 9 p.m.. While the mean daily soil temperature is the same for both practices, there is a big difference in amplitude. The straw cover results in a more constant temperature during the whole day and therefore in more suitable conditions for microbiological activity.

### 3.2 Water balance estimation

This site is located near an already existing metereological observation station on the experimental farm of the "Universitaet fuer Bodenkultur" in Vienna. The set up of the measuring site is established similar to the U.S. Global Change Programm. In each of six levels (5 cm, 10 cm, 20 cm, 50 cm, 100 cm, 185 cm) there are a temperature probe, a Watermark and a Cooleman sensor installed. Below 185 cm the underlying gravel begins. The measuring site serves two purposes. The first is to establish a long term observation point for the estimation of the soil water balance and further it serves for testing the data acquisition system, especially of the sensors. Figure 4 provides an example of measurements for the year 1993. All values are daily means of hourly measures. The soil temperature related to the air temperature show very clearly the expected damping of the daily fluctuations with depth. Besides the fact that the temperature itself is of interest, it is needed for interpretation of the soil moisture data; Thomson et. al. [4] describes the temperature dependence of the gypsum block resistance.

At the beginning of 1993 there was a period of freezing temperature. During that time the top layer was frozen down to a depth of 20 cm. Consequently the watermark sensors were inoperable as indicated by their high resistance. With a
rise of the air temperature the frozen soil layer thawed and the sensors came back to operation. All watermark sensors in a deeper position show a very low resistance for the first three month, equivalent to a high water content. At day 90 a significant rise of the resistance is visible in the top layers. A short rain interrupted the dry period, the top layer sensors reacted as it can be seen in Figure 4. The dry period lasted then until May. The precipitation needed to accumulate for quite some time for a wetting front to penetrate to a depth of 20 to 50 cm. Reaching the 50 cm level took about 30 days. Then the soil started to dry again until the next precipitation event. Due to the fact that the soil was not as dry as in the first described event, the precipitation formed a wetting front visually in the top layers as well as in 50 cm.

4. Conclusions

The data acquisition concept proofed to be very useful for long term observations. There is no doubt that a greater measuring frequency contributes to a better insight what happens in the soil. The two described field measuring sites show very clearly that the recorded date can be used for the estimation of the soil water balance and for the investigation of soil conservation measures.

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References

Fig. 2 Soil water in the root zone and accumulated precipitation during the growing season 1991.

Fig. 3 Air and soil temperatures in 5 cm depth.
Fig. 4 Temperature, precipitation and change of water content