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Agriculture and Agricultural Science Procedia 11 (2016) 14 – 19

Agriculture and Agricultural Science Procedia

International Conference on Inventions & Innovations for Sustainable Agriculture 2016, ICIISA 2016

Advanced Soil Hydrological Studies in Different Scales for Sustainable Agriculture

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Abstract

A comprehensive study of interactive processes between soil, water, plant, animal and atmosphere to protect the natural resources requires knowledge of parameters and processes in different scales. Soil hydrological studies in North-East Germany were carried out in different scales, starting with laboratory, lysimeter measurements and in the field. The measurements of soil hydrological properties were executed with the Extended Evaporation Method (EEM) and the HYPROP device. A method for quantifying deep seepage and solute leaching under field conditions was developed, tested and applied at more than 40 soil hydrological field plots in NE Germany. The hypothesis was confirmed that arable land constitutes the main source of deep drainage and groundwater recharge in Northeast Germany. Deep seepage was strongly reduced under forest. For decision support on landscape renovation and land rededication by afforestation in NE Germany the seepage reduction under forest is to be taken into consideration, especially with respect to the conservation or restoration of wetlands in regions with negative climatic water balance. The EEM and the soil hydrological field method so called “virtual lysimeter” have the potential for the improvement of soil hydrological studies in Asia as a whole.

Peer-review under responsibility of the Faculty of Animal Sciences and Agricultural Technology, Silpakorn University

Keywords: soil hydrological measurements; soil hydraulic functions; lysimeter; soil hydrological field measurements; deep seepage; nitrate leaching; soil water balance

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Peer-review under responsibility of the Faculty of Animal Sciences and Agricultural Technology, Silpakorn University
doi:10.1016/j.aaspro.2016.12.003

1. Introduction

Protection of the natural resources soil, water, habitat and other means the long-term conservation of its functions. These include the filter and buffer properties of the soils and retaining a sustainable habitat function for human, animals and plants. The loss as well the reduction of productive soils by erosion, sealing and degradation of soils and contamination of ground and open waters must be avoided. A comprehensive study of interactive processes between soil, water, plant, animal and atmosphere to protect the natural resources requires knowledge of parameters and processes in different scales.

Laboratory measurements provide information to soil data and soil water and solute transport processes in the mini scale. These data are required input data for simulation models. Lysimeters give the opportunity to study the interaction between soil, water, plant, management and atmosphere in larger soil columns and under defined random conditions. They provide a good basis for the development and test of methods and the validation of simulation models. Investigations and simulations in the field, catchment and landscape scale are influenced by a large number of single processes. These studies aim to expand the knowledge and understanding to the process interactions. Simulation models help to combine all the single processes to support management decisions for preservation a productive but sustainable landscape.

This research presents the Extended Evaporation Method (Schindler et al., 2010a; Schindler et al., 2010b), an advanced laboratory method for quantifying soil hydraulic properties and we studied soil hydrological processes in the field using special designed soil hydrological field plots, so called "virtual lysimeters" (Schindler and Mueller, 1998).

2. Material and Methods

2.1 Laboratory measurements

Measuring soil hydraulic properties in the laboratory with classical methods (sand box, sand-kaolin box, pressure plate extractor, multi-step outflow method) is time consuming and the results are strongly influenced by uncertainties (Dane and Hopmans, 2002; Bitelli and Flury, 2009). The Extended Evaporation Method (EEM) enables the simultaneous quantification of the water retention curve and the unsaturated hydraulic conductivity function of 100 cm^3 or 250 cm^3 soil samples in the laboratory (Schindler et al., 2010a, Schindler et al., 2010b). The measurement ranged from saturation down to near permanent wilting point and the measurement time is strongly reduced. Instead 2 or 3 month only between 3 and 10 days are required. Additionally, the quantification of shrinkage and hysteresis is possible (Schindler et. al., 2015a; Schindler et al., 2015b).

In a soil sample (100 or 250 cm^3, height 5 cm) two tensiometers are installed at depths of 1.25 and 3.75 cm. The sample is saturated with water from the bottom, sealed at the bottom and placed on a balance. Its surface remains open to free evaporation. Tensions (Ψ) and sample mass (m) are recorded at consecutive times. Single points of the water retention curve are calculated on the basis of the water loss per volume of the sample at time t and the geometric mean tension of the sample at that time. The hydraulic conductivity (K) is calculated according to the modified Darcy-Buckingham's law (Eq. 1) where the evaporated water volume per time interval relates to half the sample height versus hydraulic gradient as determined by the tensiometers (Schindler, 1980). The flux (q) is derived from the soil water volume difference ΔV (1 cm^3 of water = 1 g) per surface area (A) and time unit (Δt). The mean hydraulic gradient (i_m) is calculated on the basis of the mean tensions in time intervals.

$$K(\overline{\psi}) = \frac{\Delta m}{2A\rho_{H2O}\Delta t i_m} \quad (1)$$

where $\overline{\psi}$ is the mean tension geometric averaged over the upper and the lower tensiometer and the time interval, Δm is the sample mass difference in the time interval (assumed to be equal to the total evaporated water volume ΔV_{H2O} of the whole sample in the interval), ρ_{H2O} is the density of water and is assumed to be 1 g cm^{-3}, A is the cross sectional area of the sample, Δt is time interval, and i_m is the mean hydraulic gradient in the interval.