Lehr- und Forschungszentrum für Landwirtschaft
Raumberg-Gumpenstein

13. Gumpensteiner Lysimetertagung 2009, 173 – 176
ISBN: 978-3-902559-31-9

Soil moisture conditions in lysimeter on the Water Pumping Station Kleče

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Summary

Soil moisture conditions are an important interface between agriculture and the environment. The optimum soil moisture conditions for plant growing are around field capacity. Both significantly high or significantly low soil moisture contents have agronomic and environmental consequences, such as reduction in plant growth, decrease in the nitrogen uptake efficiency and more. Measurements of the soil moisture conditions in the lysimeter on the premises of the Water Pumping Plant Station Kleče in Ljubljana, Slovenia are currently not possible. Therefore soil water balance was calculated using a predictive model Soil Moisture Deficit simulator to estimate soil moisture conditions within the lysimeter. Observed period 2000 - 2007 showed increase in soil moisture deficit in several parts of the year. Annual amount of precipitation of the observed period was substantially lower than the average annual precipitation of the standard meteorological period 1961 - 1991.

Keywords: water balance, soil moisture, modeling

Introduction

Soil moisture conditions are an important interface between agriculture and the environment (SCHULTE et al. 2005), as they impact vegetation season length, plant growth rate, nutrient uptake, as well as cycling of the chemicals and the loss thereof from the soil to the environment. The optimum soil moisture conditions for plant growing are around field capacity and both significantly high or significantly low soil moisture content has agronomic and environmental consequences. Soil moisture content is an important part of the soil water balance. For determination of soil moisture content in the field soil moisture measurements are necessary. However, such measurements are expensive and sometimes not possible. In such cases, the use of computer model is extremely useful method for determination of soil moisture conditions. One disadvantage of such models is that they can have high data input demand i.e. SWAP (VAN DAM et al. 1997). SCHULTE et al. (2005) developed a hybrid model to predict soil moisture deficit (SMD) of the top layer (rooting zone) of grasslands on contrasting soil types in Ireland with the objective to formulate a predictive model with minimum requirements for input parameters in order to maximize its practical applicability.

Lysimeter station in Kleče, Ljubljana, which is situated on the premises of the main Water Pumping Station of Water and Waste Water Public Utility Supply of Ljubljana (*Figure 1*), was built in 1991 for water balance studies. Measurements of the soil moisture conditions in the lysimeter are currently not possible. In the paper we present the results of the SMD model simulation for Kleče soil with green cover.

Material and methods

Lysimeter station

Concrete container of the lysimeter is 2.0 m deep with 0.9 m radius, filled with autochthon soil, sand (pebbles of 2-4 cm diameter), gravel and drainage material in 50 cm layers respectively, total volume of the lysimeter is 5.09 m^3, and volume of pores is 1.45 m^3. At the bottom of the container outflow drain pipe leads into adjacent collecting shaft. Outflow is measured with tipping bucket inside the adjacent bunker (*Figure 1*).

Daily measurements of rain, air humidity, average air temperature and lysimeter outflow are measured. Recordings of the measurements are available since 2000. Mean annual precipitation in the study area for 1971 - 2000 period is 1435 mm (EAS, 2008), measured at Ljubljana (299 m a.s.l., N 46°3'57'', E 14°31'2''), with average annual T of 10.2 °C.

Soil moisture deficit (SMD) calculator Model

Model distinguishes three different hydrological classes of soil, well drained, moderately drained and poorly drained soils, which can be determined by observation of their hydrological status during winter (SCHULTE et al. 2005). SMD is defined as the necessary water amount (mm), deriving from either precipitation or irrigation, to replenish soil water content to field capacity and can be calculated as soil water mass balance, which proved to be a very useful tool in environmental studies for assessment of soil water deficit (BERGANT and KAJFEŽ-BOGATAJ 1998). SMD is calculated from cumulative balance of precipitation (P), evapotranspiration (ET) and drainage (SCHULTE et al. 2005):

$$SMD_t = SMD_{t-1} - P + ET_t + Drain$$

Where SMD_t and SMD_{t-1} are soil moisture deficits on day *t* and day *t*-1 respectively (mm), P I the daily precipitation (mm/day), ET_t the daily actual evapotranspiration (mm/day), calculated according to FAO Penman-Monteith equation (ALLEN et al. 1998). Drainage rate (mm/day) is described

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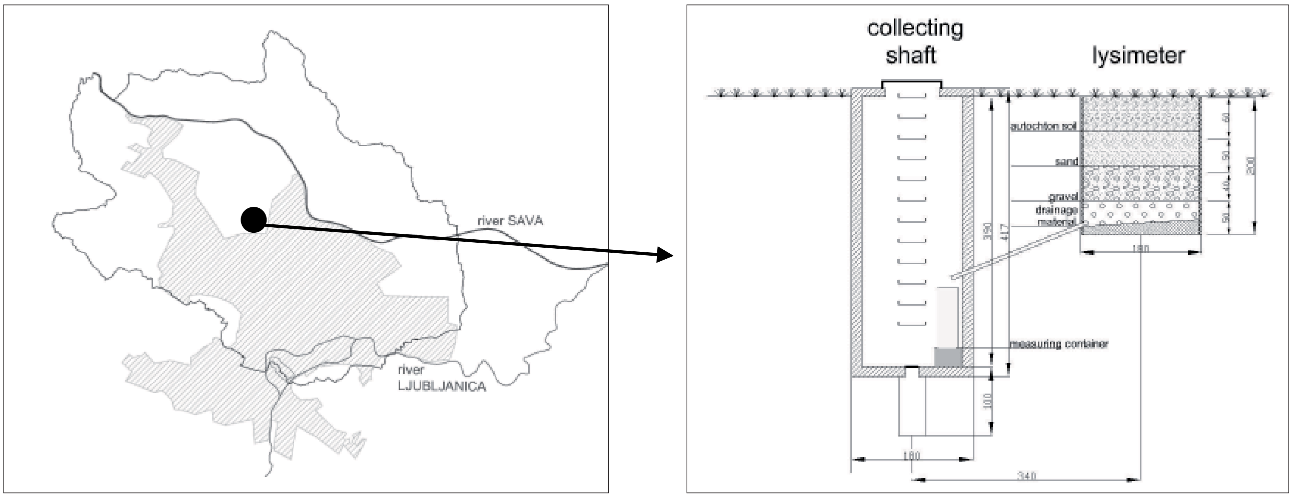

Figure 1: **City of Ljubljana, Slovenia with the location of lysimeter station in Kleče (black dot) and lysimeter cross section.**

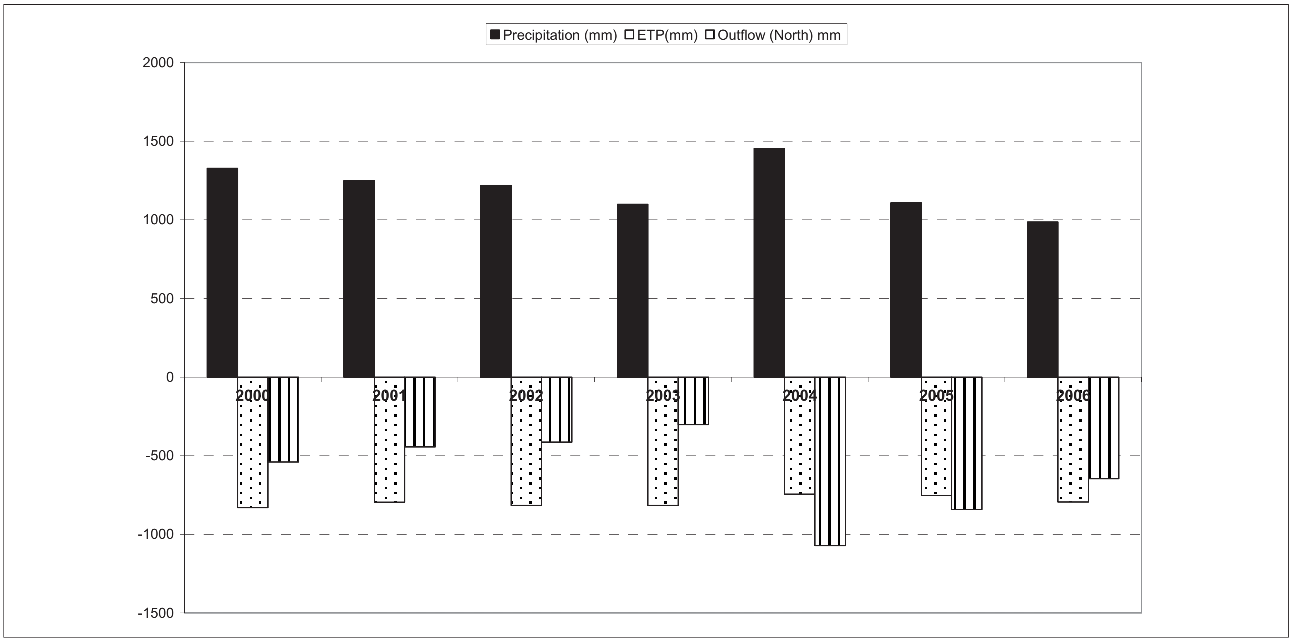

Figure 2: **Annual precipitation (mm), evapotranspiration (mm) and outflow (mm) for lysimeter station in Kleče, Ljubljana, Slovenia between 2000 and 2006.**

as a linear function of *SMD*, when *SMD* ≤ 0 (SCHULTE et al. 2005).

As *SMD* simulator employs no soil profile description, beyond hydrological nature of the soil and vague notion that it calculates *SMD* of the root zone, *SMD* is difficult to determine. SMD value cannot be directly correlated to soil water status. One possibility is compare measured soil water status with soil water retention characteristics or pedotransfer function, i.e. Van Genuchten's model (VAN GENUCHTEN et al. 1991).

Results

Water Balance

During the standard meteorological period 1961 - 1990 the average air temperature (T_{avg}) in Ljubljana was 9.8 °C (T_{max} 14.8 °C, T_{min} 5.5 °C) and the average annual precipitation 1393 mm. For the observed period 2000 - 2006 the measured parameters on the Lysimeter station in Kleče show higher T_{avg} (T_{avg} 10.7 °C), higher extreme minimal and maximal T values (T_{max} 16.3 °C, T_{min} 7.0 °C), with lower annual precipitation amount, 1206 mm. The driest years was year 2003 (1091 mm) (*Figure 2*).

Soil moisture deficit (SMD) simulation results

We compared lysimeter outflow (in mm, *Figure 3*) and *SMD* simulation results (in mm, *Figure 4*) for the year 2006.

Outflow (mm) occurred from March till beginning of May 2006, then again at the beginning of June and mid August - October 2006. Finally, there was outflow at the end of the year in December 2006 (*Figure 3*).

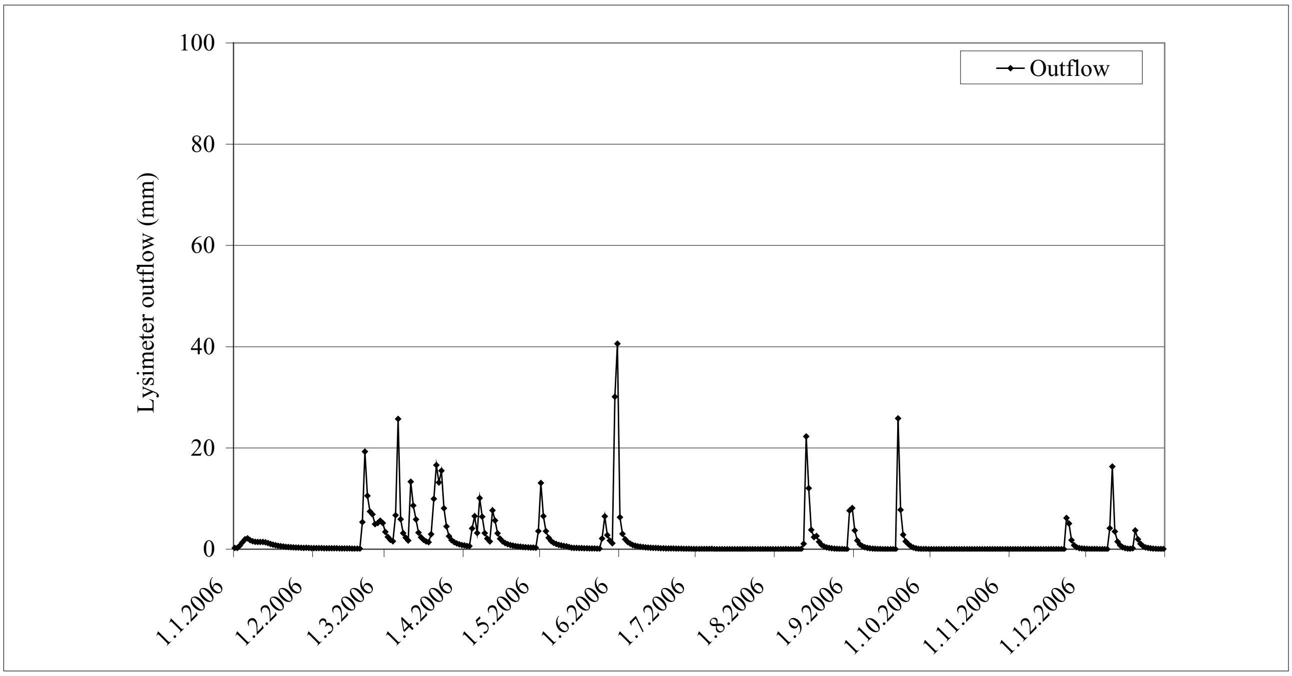

Figure 3: **Daily outflow (mm) from lysimeter in year 2006 in Kleče, Ljubljana, Slovenia.**

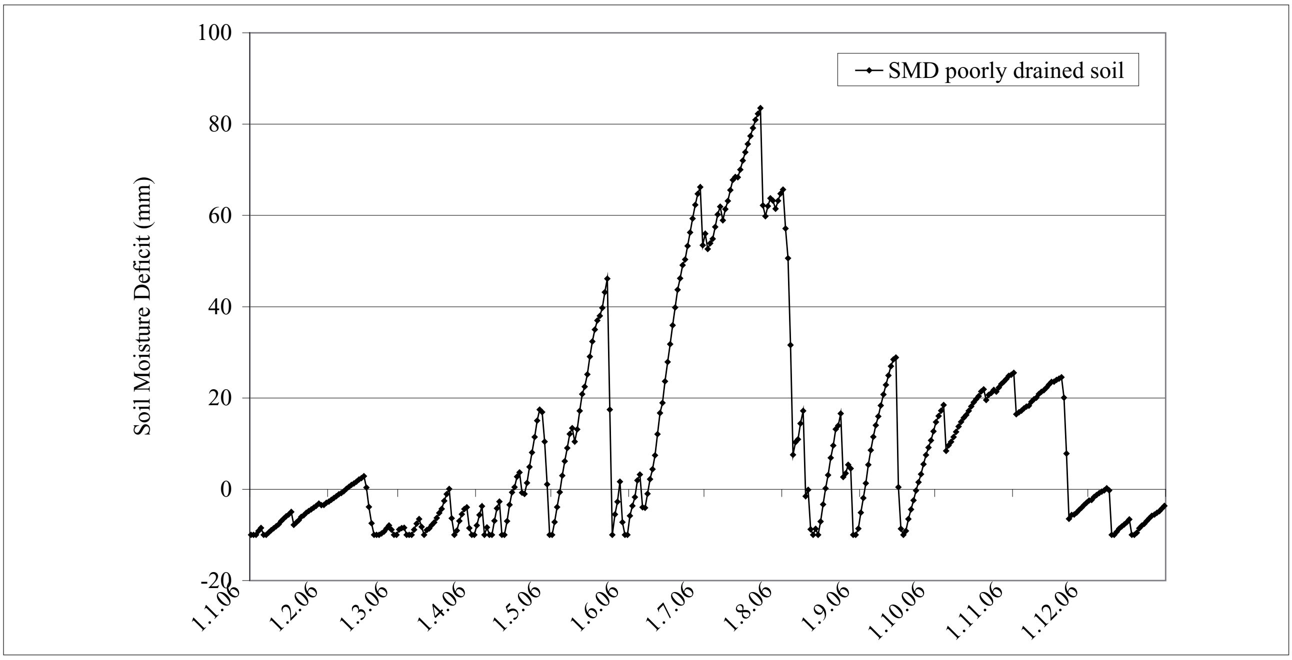

Figure 4: **Daily Soil moisture deficit (mm) in lysimeter in Kleče, Ljubljana, Slovenia, calculated with SMD simulator for year 2006.**

Simulation results show same dynamic as outflow occurrence (*Figure 4*), with sever SMD in June and July 2006. However, since there is no input for soil profile description, use of SMD values for actual soil moisture conditions is problematic.

Conclusions

The SMD model is simple and easy to use, with daily meteorological data of precipitation, T_{min} and T_{max} as input. The interface is easy to user friendly and easy to understand. That makes SMD simulator a very useful for clarification of soil water conditions, and assessment of the severity of the SMD. For year 2006 model simulated drainage and outflow showed good accordance, which suggests suitability of the model for calculation of SMD within the lysimeter. For further nitrate leaching studies, the model should be carefully calibrated and validated against measured data.

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