Czech University of Life Sciences Prague
Faculty of Environmental Sciences

DIPLOMA THESIS

Prediction System for Soil Water Pressure Head

Arij Chmeis

Department of Water Resources and Environmental Modeling

Supervisor of the diploma thesis:	doc. Ing. Michal Kuráž, Ph.D.
Study programme:	Landscape Engineering
Field of study:	Environmental Modeling

Prague, 2021

Appendix A

A.1 Additional Work

A preliminary simulation run was conducted, where the role of root water uptake (RWU) was not considered. The influence of this term was then studied by introducing it into the model using the method explained in Chapter **??**. The approach imposes uptake reductions in the drier area of the root zone using a dimensionless function $\alpha(h)$ that decreases the actual extraction rate according to soil water potential. Figures A.1 and A.2 illustrate the predicted pressure head and soil temperature calculated by the model during this preliminary run. The influence of assuming no water uptake is evident in the general overestimation of the soil water content indicated by the pressure head value. In addition to h, soil temperature values were also overestimated by the model during this run. This clearly signals the underestimation of the evaporation rate, which can also be seen in Figure A.3, comparing the model-predicted E while neglecting, and then including the root water uptake term.

In order to incorporate a representation of RWU in the model, evaluation of the stress reduction function $\alpha(h)$ was required. Initially, standard values of h_0-h_3 and S_{max} that were calculated in Hydrus-1D for grapevines, were used as the shape-limiting pressure heads and the maximum plant transpiration parameters. After comparing the simulated plots of pressure head and soil temperature with the observations, the value of the maximum transpiration parameter was decreased by one order of magnitude. The last change to this term was assigning S_{max} to equal half of its original value. The introductory values and the changes committed after (for the layers containing root zones) are given in Table A.1.

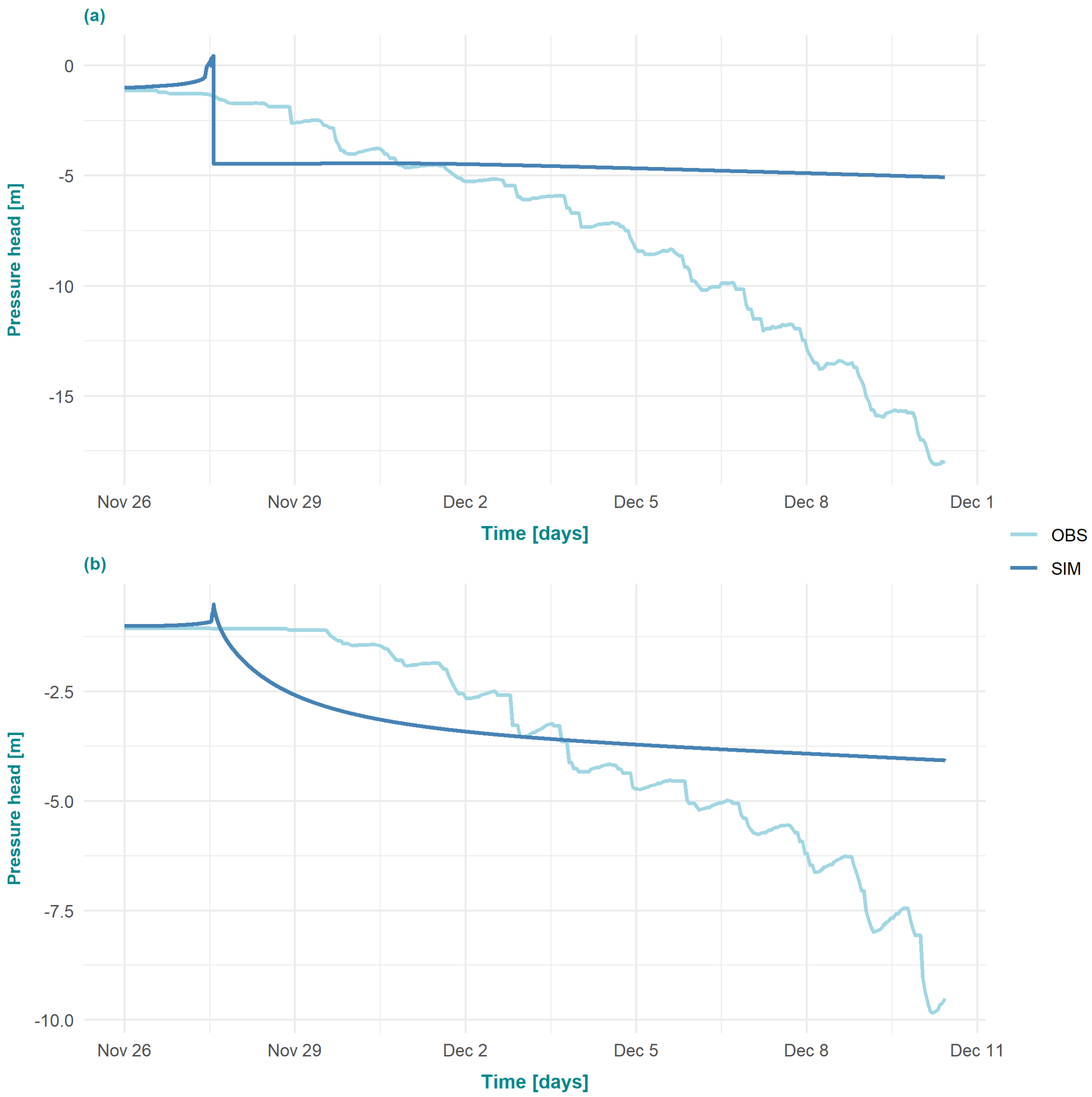

Figure A.1: Simulated versus observed pressure head at depths (a) 0.35 m and (b) 0.8 m during the preliminary simulation disregarding the role of root water uptake (26 Nov. 2020 - 10 Dec. 2020).

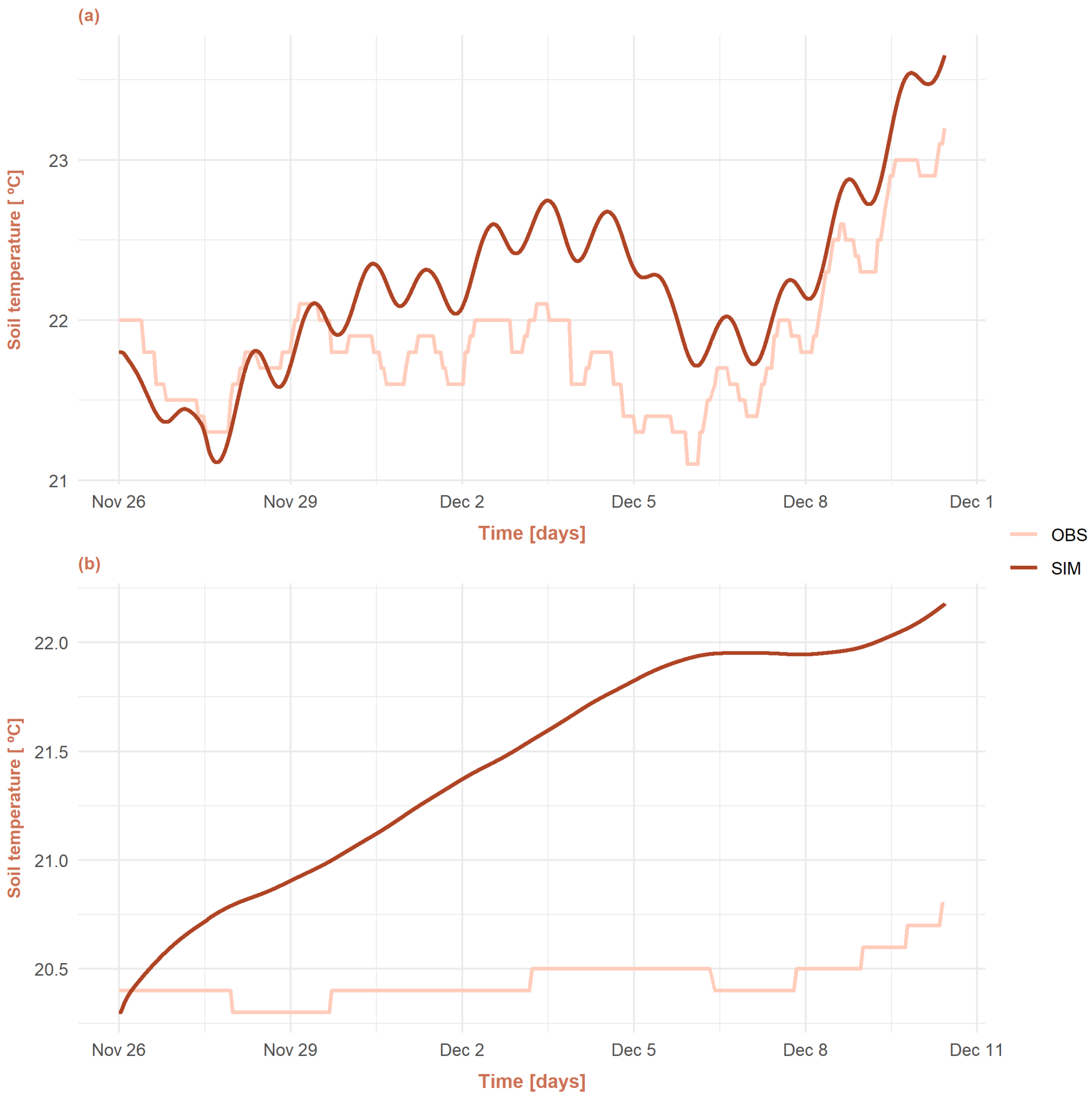

Figure A.2: Simulated versus observed soil temperature at depths (a) 0.35 m and (b) 0.8 m during the preliminary simulation disregarding the role of root water uptake (26 Nov. 2020 - 10 Dec. 2020).

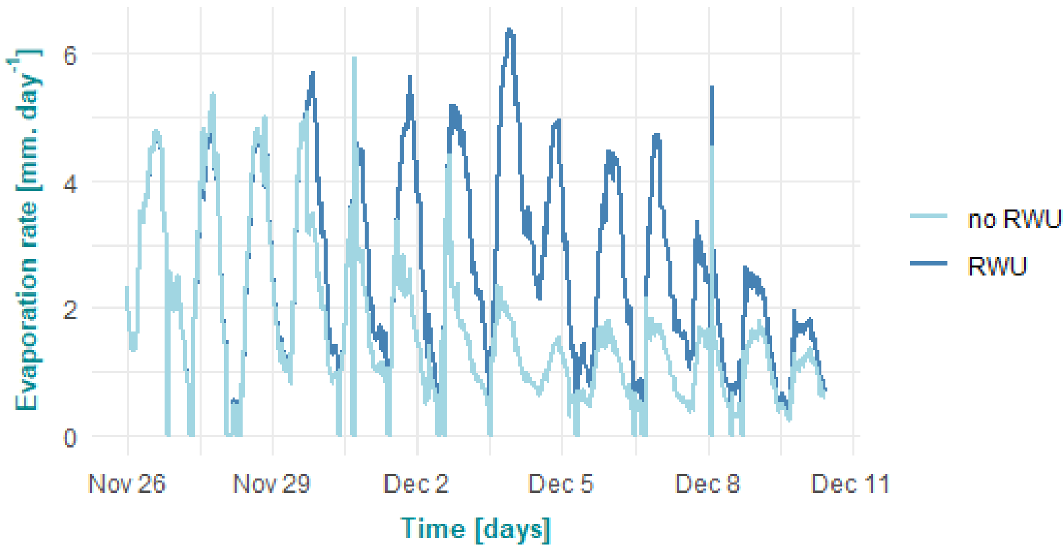

Figure A.3: Evaporation rate estimating with and without the effect of root water uptake (26 Nov. 2020 - 10 Dec.2020)

Table A.1: Root water uptake parameters for layers 4 and 5. Note that roots are not present in the rest of the layers.

Simulation Setup	**Parameter**	**Symbol**	**Value**	**Unit**
Preliminary	Specific critical matric potential	h_0	-0.1	[m]
	Specific critical matric potential	h_1	-0.25	[m]
	Specific critical matric potential	h_2	-1	[m]
	Specific critical matric potential	h_3	-18	[m]
	Maximal plant transpiration	S_{max}	5.55e-7	[$m^3.s^{-1}$]
First	Maximal plant transpiration	S_{max}	5.55e-8	[$m^3.s^{-1}$]
Second	Maximal plant transpiration	S_{max}	2.00e-7	[$m^3.s^{-1}$]

Appendix B

B.1 Supplementary Concepts

B.1.1 Net longwave radiation

Net longwave radiation is described in Chapter **??** as:

$$R_{nl} = \varepsilon_s R_{ld} \downarrow + R_{lu} \uparrow, \tag{1}$$

where $R_{ld} \downarrow$ [W.m^{-2}] is the incoming longwave radiation to the soil, $R_{lu} \uparrow$ [W.m^{-2}] is the outgoing longwave radiation emitted to the atmosphere, and ε_s [-] is the emissivity of the soil surface, defined by equation **??**. Monteith and Unsworth (2013) described the outgoing thermal longwave radiation emitted to the atmosphere from the surface (including vegetation and soil) as:

$$R_{lu\uparrow} = \varepsilon_s \sigma T_s^4, \tag{2}$$

where T_s [K] is the top soil temperature. The Stefan-Boltzman law can be used to describe the incoming thermal longwave radiation emitted by the atmosphere and received at the soil surface in the following formula:

$$R_{ld\downarrow} = \varepsilon_s \varepsilon_a \sigma T_a^4, \tag{3}$$

where T_a [K] is the air temperature, $\sigma = 5.67 \times 10^{-8}$ [W.m^{-2}.K^{-4}] is the Stefan-Boltzman constant, and ε_a is the atmospheric emissivity, which is expressed as:

$$\varepsilon_a = 0.70 + 5.95 \times 10^{-5} e_a \exp\left(\frac{1500}{T_a}\right), \tag{4}$$

where e_a [kPa] refers to the atmospheric vapor pressure, given as

$$e_a = 0.611 H_r \exp\left(\frac{17.27(T_a - 273.15)}{T_a - 35.85}\right). \tag{5}$$

Monteith and Unsworth (2013) also derived the incoming longwave radiation on a partially-cloudy sky from the average temperature difference between the clouds and the atmosphere of England as:

$$R_{lu\downarrow} = [(1 - 0.84c)\varepsilon_a + 0.84c]\sigma T_a^4, \tag{6}$$

where c [-] is a fraction of cloudiness factor.

B.1.2 Evaporation Modelling approaches

Modelling approaches to evaporation vary vastly in complexity. We recognize three main groups of models in this respect: One phase concept, one-and-a-half phase concept and two phase concept.

One phase approach

This is the classical Richard's equation approach, where only liquid water flow is considered, while vapor transport is neglected and the flow is assumed to be isothermal. In this case, the upper boundary condition is set to be potential evaporation in wet soils that later on changes to pressure head once a drying threshold is reached (Vanderborght et al., 2017).

One + 1/2 phase approach (isothermal)

Considering multiple-day simulations leads to the idea that diurnal temporal changes could cancel each other out. That indicates that temperature gradient-driven fluxes can be neglected, and so an isothermal flow, in this scheme, is once again assumed. However, an additional component is introduced to account for the vapor transport. A new assumption is made in the form of equilibrium between the vapor and the liquid phases pressures, which translates to those pressures being represented by h at the same time (Milly, 1984).

One + 1/2 phase approach (non-isothermal)

This approach couples Richard's equation and the heat equation together, meaning it involves fluxes that are dependant on pressure head and temperature-dependant fluxes. While the gas phase flow is not considered in this model, the diffusive transport of components in this phase is indeed accounted for. Vanderborght et al. (2017) explains the number of assumptions involved in this formula.

First, the effect of dry air concentration on the water component is not considered in either phase. Second, the molar volume gradients and the pressure in the gaseous phase are respectively negligible and time-constant. Third, the liquid phase's mass density is assumed to be constant. And lastly, the advective fluxes of the gas phase (in comparison with diffusive fluxes) can be neglected.

Two phase approach

Finally, in order to develop a complete definition of water and vapor transport, a non-isothermal two-phase flow two-component transport must be fully described. This means that parameters accounting for the two phases of liquid and gas, each having component transport of water and air must be presented. In this case two separate equations are required (i.e double the number of boundary and initial conditions) making this approach computationally expensive.

Appendix C

C.1 Codes

A Github repository was created to provide access to codes used and created in this thesis at `https://github.com/a-chmeis/Pressure-Head-Prediction-System`. The following codes are available:

- DRUtES configutaion files for the implemented evaporation model
- Input automation scripts created in IDLE (Python 3.8) for the construction of input to the DRUtES configuration file *ebalance.in*
- Observation automation scripts created in IDLE (Python 3.8) for the generation of observation records from API links
- The simulation analysis scripts for plotting the results in RStudio