Evaporation over saturated bare soil: the role of soil texture

Wanxin Li[1,2], Wenke Wang[1,2], Philip Brunner[3], Zhoufeng Wang[1,2], Zhi Li[4], Yike Wang[1,2], Yanying Lu[1,2] and Harrie-Jan Hendricks Franssen[5]

1 Key Laboratory of Subsurface Hydrology and Ecological Effects in Arid Region, Chang'an University, Ministry of Education, P. R. China
2 School of water and environment, Chang'an University, P. R. China
3 Center for Hydrogeology and Geothermics, (CHYN), Université de Neuchâtel, Switzerland
4 Xi'an Research Institute of China Coal Technology & Engineering Group Corp.
5 Agrosphere (IBG-3), Forschungszentrum Jülich GmbH, Jülich, Germany

Introduction and Objectives

Calculating actual bare soil evaporation (E_a) on the basis of potential bare soil evaporation (PE) is a widely followed approach in many disciplines including hydrogeology, hydrology and agricultural sciences. This approach considers that PE is independent from soil properties, and only E_a is affected by soil properties. A unique experiment was set-up to measure diurnal and seasonal PE for fine (PE_{fine}), coarse (PE_{coarse}) and gravel (PE_{gravel}) sands.

Materials and Methods

The experiment was conducted at the "Semi-arid Groundwater and Environment Experimental Site", located at Chang'an University, Xi'an, China. Lysimeter observation columns are buried and aligned with the ground surface, and all have the same area (1m^2) and height (70cm). Columns are filled with homogeneous fine sand, coarse sand and gravel sand respectively. Direct measurements of potential evaporation for saturated sands (Figure 1A) were made by the "Automatic Water Replenishing Markov Bottle" (Figure 1C) based on the principle of mass balance. A drop of the water level in the Markov bottle of 88.7cm coincides with an evaporation rate in the lysimeter column of 1cm. Besides PE rate, meteorological variables, ground heat flux and soil temperature were captured at a high temporal resolution (10 min) for more than 15 consecutive months.

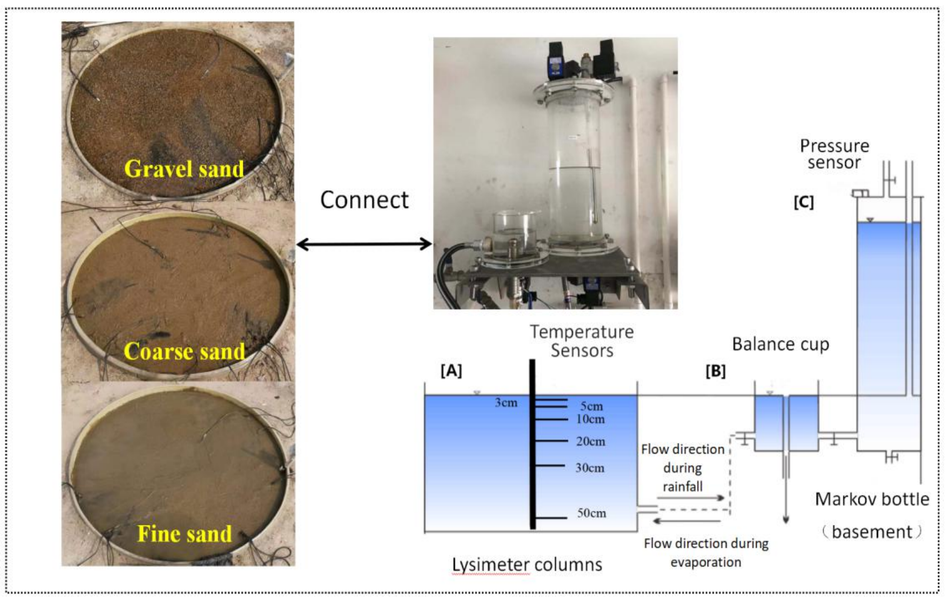

Figure 1: Setup of the PE measurement device: Lysimeter column(A), Balance cup (B), The Automatic Water Replenishing Markov Bottle (C)

Results

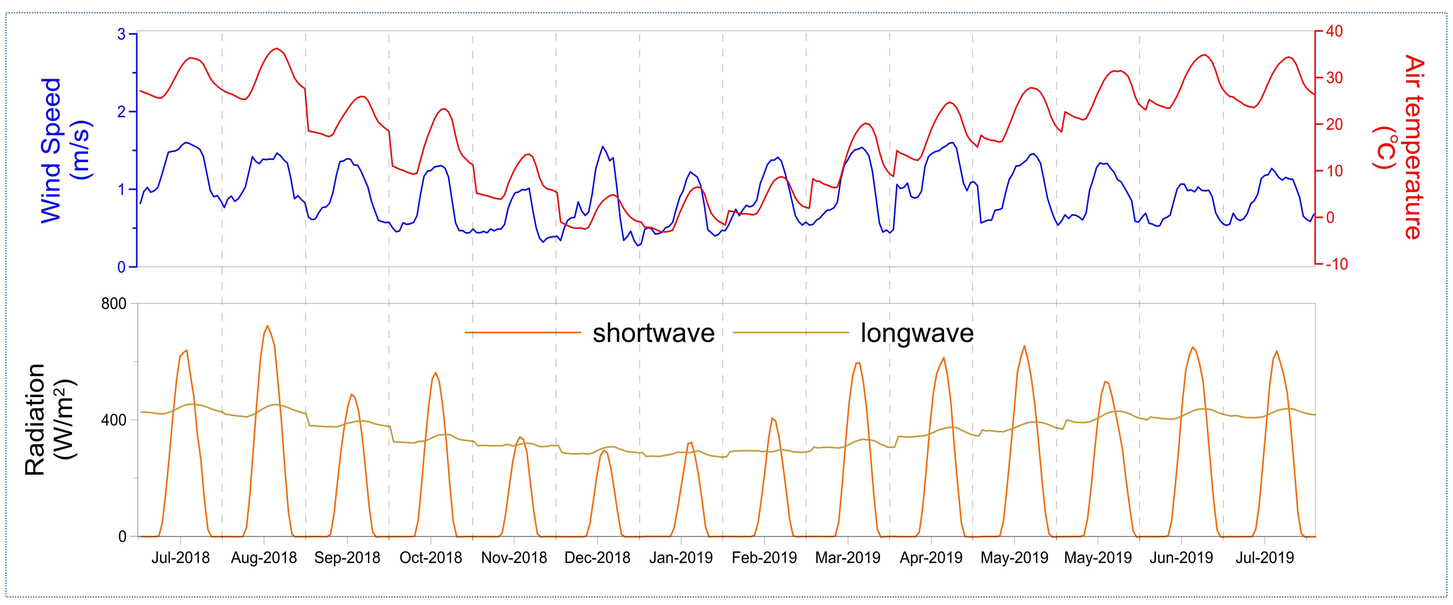

Figure 2: Monthly average diurnal cycles of meteorological variables

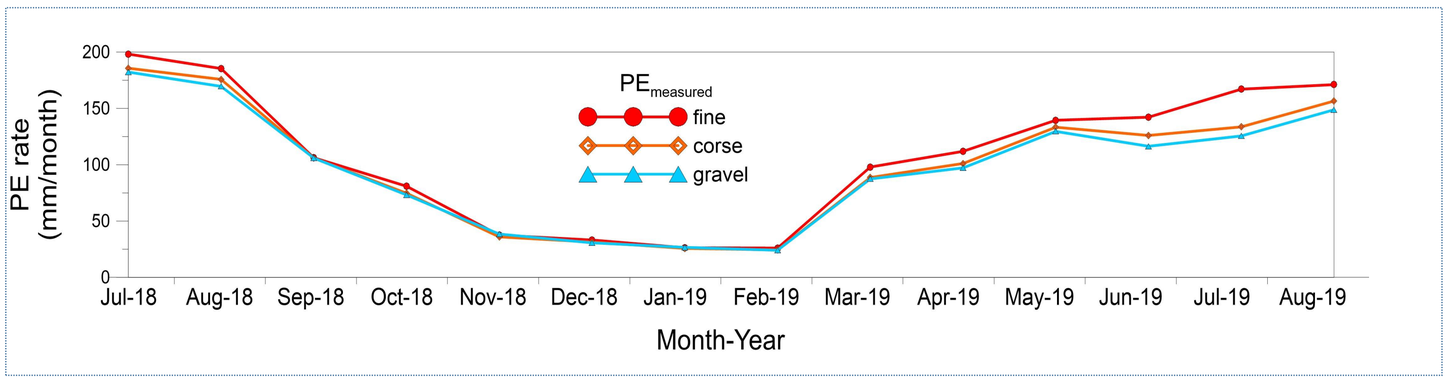

Figure 3: Monthly PE values for fine, coarse and gravel sands

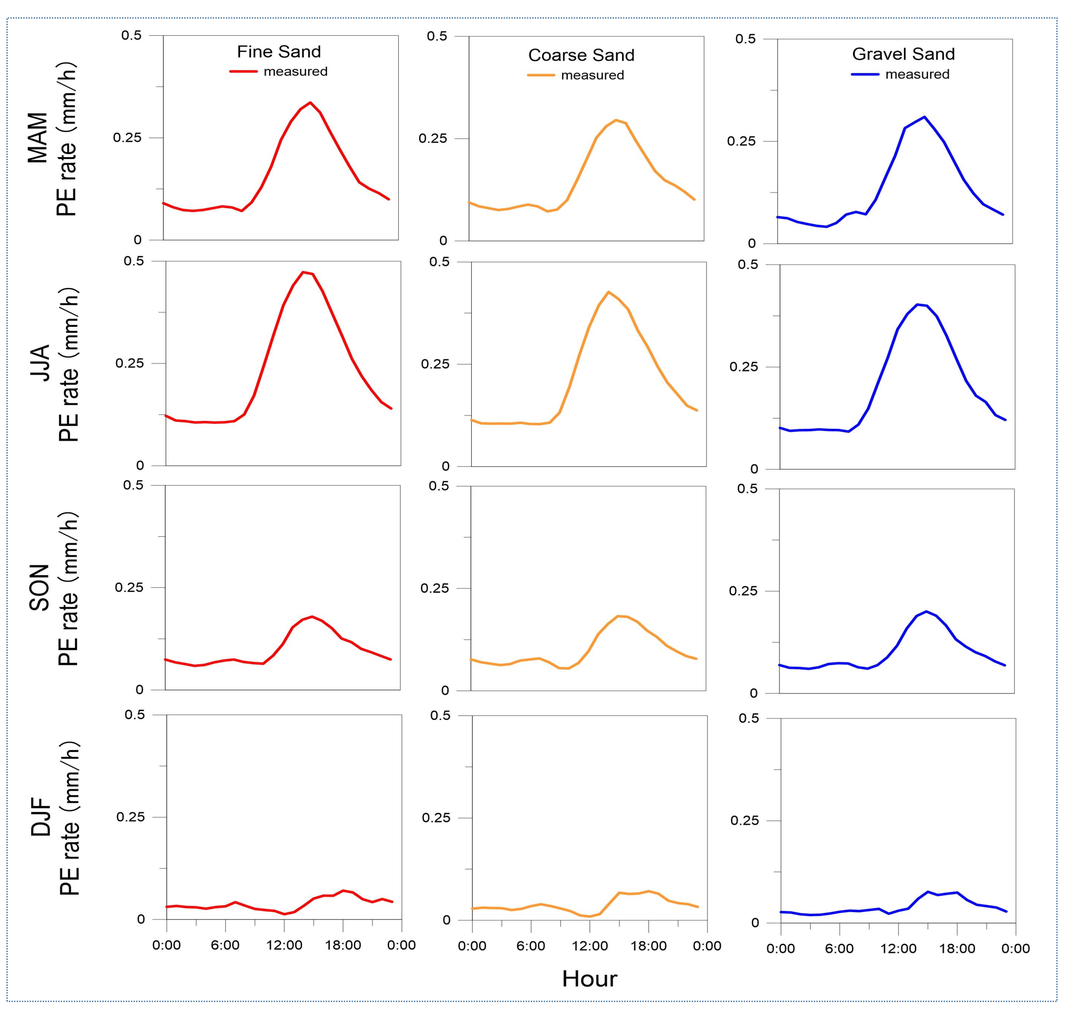

Figure 4: Measured seasonal average diurnal PE curves of fine, coarse and gravel sands

- The evaporation rates over saturated bare soils showed clear differences between gravel, coarse sand and fine sand, with higher PE for fine sand, smaller PE for coarse sand and smallest PE for gravel, especially during spring and summer. In autumn and winter, the measured PE rates over different surfaces showed only minor differences (Figure 3).
- The measurement data also revealed that during spring and summer night-time PE was considerable with ~1.0 mm per night (Figure 4).
- These results can be quantitatively explained with detailed calculations of the energy balance method. Considering the different porosities for gravel, coarse sand and fine sand, as well as the thermal conductivities of the phases which constitute the porous media. Gravel sand consumed more heat flux resulting in less energy for evaporation.

Conclusion and outlooks

Potential evaporation differs among soil textures, which is caused by differences in the ground heat flux. Differences are larger when the evaporative demand is higher. The Community Land Model (CLM) will be used to calculate latent heat flux from different saturated bare soils in future.

Acknowledgements

This study was financially supported by the The National Nature Science Foundation of China (Nos.U1603243, 41230314) and Chang'an University Short-Term Study Abroad Program for Postgraduate Students (300104190103).