Chulalongkorn University
Faculty of Engineering
Water Resources Engineering Department

Deep Percolation Characteristics via Field Moisture Sensor Measurements in Rice Experimental Field, Phitsanulok, Thailand

Nittaya Kangboonma
Chulalongkorn University

Bangkok, Jan 24, 2019

Straightforward Overview

I. Introduction

II. Objectives and study area conditions

III. Study Procedures and Theories used

IV. Field investigations

V. Results

VI. Conclusions

CHULA ΣNGINEERING
Foundation toward Innovation

I. INTRODUCTION

In recent several years, surface water trends to be deficit in some areas. The insufficient surface water resources lead to increase groundwater abstraction especially in dry season. In this last ten years, the tendency of groundwater level declined in the Lower Yom and Nan River due to groundwater use mainly for irrigation use. Groundwater recharge mechanism knowledge is essential to understand groundwater movement especially in the area where groundwater use is excessive.

Deep percolation from irrigation water plays a key role in irrigation demand and groundwater supply by replenishing shallow aquifers at the local and regional scales. Percolation is accounted by vertical flow during the experiment

CHULA ΣNGINEERING
Foundation toward Innovation

I. INTRODUCTION

In the study, the soil moisture sensor module is used to detect the moisture of the soil or judge if there is water around the sensor. If more water is presented in the soil, the sensor would output resistance of soil which could covert to soil moisture. The motivation of soil moisture sensor is adapted from low-cost soil moisture profile probe [6]. Percolation identified water content in the soil flows below root zone efficiently [7]. The advantage of percolation is to induce recharge to groundwater and dilute chemicals in the soil. Hillel [8] concluded that percolation rate relied on both soil property and water content. Soil properties, affected to percolation, are porosity, void distribution, and void shape while flow properties, affected to percolation, are density and viscosity.

II Objectives

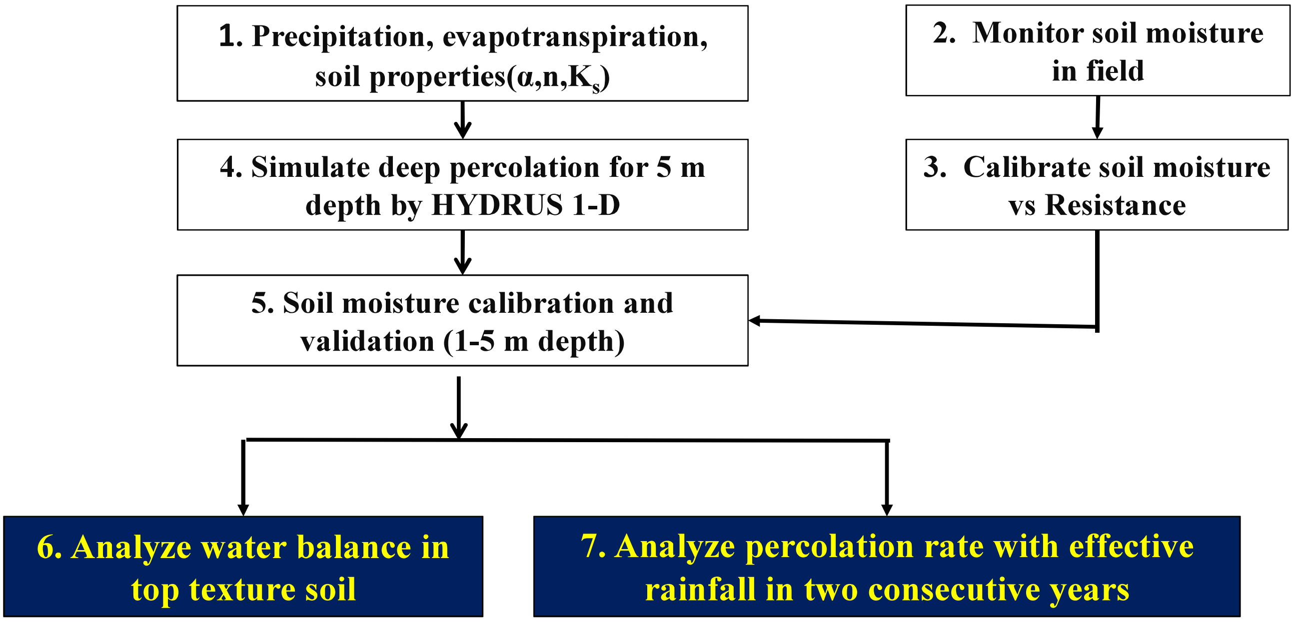
- This investigation aims to understand deep percolation mechanism (soil moisture change, water balance, percolation rate) from rainfall utilizing field soil moisture monitoring approach. Henceforth, the deeper percolation procedure and results will be useful for further determining groundwater yields and groundwater recharge in the consecutive drought years.

The study area

- Phitsnulok Province (north of center plain),
- A main irrigation area,
- Does not enough surface water in dry season.
- Conjunctive groundwater use.

III. Study Procedures and theories

Analysis groundwater and surface water interaction process



III. Study procedures and Theories

The governing flow equation for the uniform Darcian flow of water in a porous medium is adopted by the following modified form of the Richards' equation: (Simunek, Van Genuchten, and Sejna 2005)

$$\frac{\delta\theta}{\delta t} = \frac{\delta}{\delta x_i}\left[K\left(K_{ij}^{A}\frac{\delta h}{\delta x_j} + K_{iz}^{A}\right)\right] - S \qquad (1)$$

θ is the volumetric water content, (L^3L^{-3})
K is the hydraulic conductivity (LT^{-1}),
h is the pressures head (L)
S is a sink term [T^{-1}]
x_i (i-1,2) are the spatial coordinates [L],
t is the time (T) and
z is the vertical ordinate (L)
K^A_{ij} are components of a dimensionless anisotropy tensor $\mathbf{K^A}$
K is the unsaturated hydraulic conductivity function [LT^{-1}] given by

III. STUDY Procedures and THEORIES

$$K(h) = K_s S_e^{1/2}\left[1-(1-S_e^{1/m})^m\right]^2 \qquad (2)$$

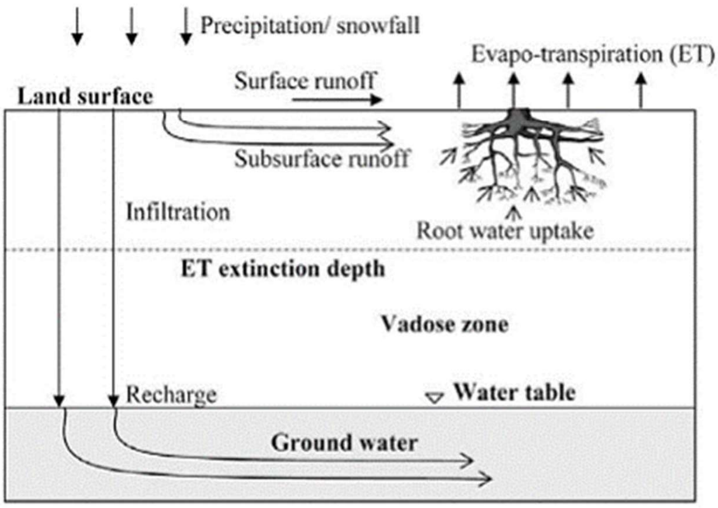
$$\theta(h) = \begin{cases} \theta_r + \frac{\theta_s-\theta_r}{[1-|\alpha h|^n]^m} & h < 0 \\ \theta_s & h \geq 0 \end{cases} \qquad (3)$$

$$S_e = \frac{\theta-\theta_r}{\theta_s-\theta_r} \qquad (4)$$

$$m=1-1/n, \quad n>1 \qquad (5)$$

S_e is the effective water content
θ_r denote the residual water content
θ_s denote the saturated water content
K_s is the saturated hydraulic conductivity
α is the inverse of the air-entry value (or bubbling pressure)
n is a pore-size distribution index

III. STUDY Procedures and Theories used



A schematic showing the processes affecting subsurface hydrology (Source : Twarakaviet al., 2008)

Field Investigation

Percolation

- **Purpose**

  to determine land recharge rate and land recharge coefficient via soil moisture sensor

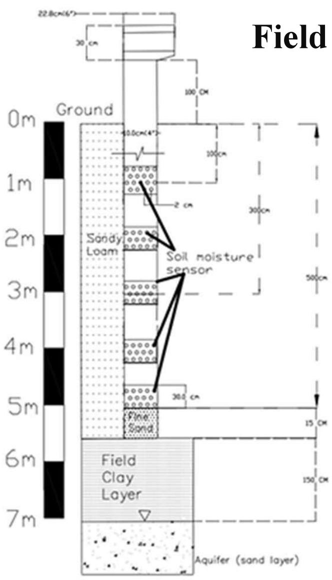
- **Location**

  The experiment site was located in the Rice Water Use Experimental Station 2 of Royal Irrigation Department in Phitsanulok Province

- **Study period**

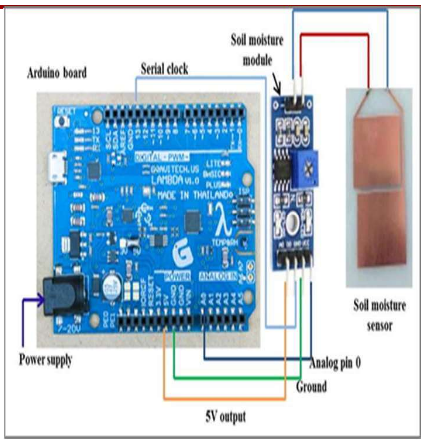
  Daily (**350** days, July 2017-June 2018) measured soil moisture data in the field at 1-5 m depths

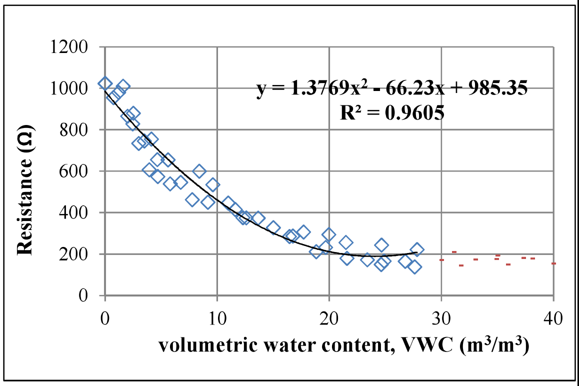
Field equipment installation



Field Data analysis

- **Sandy Loam (0-4 m)**
- **Sandy Clay(5 m)**

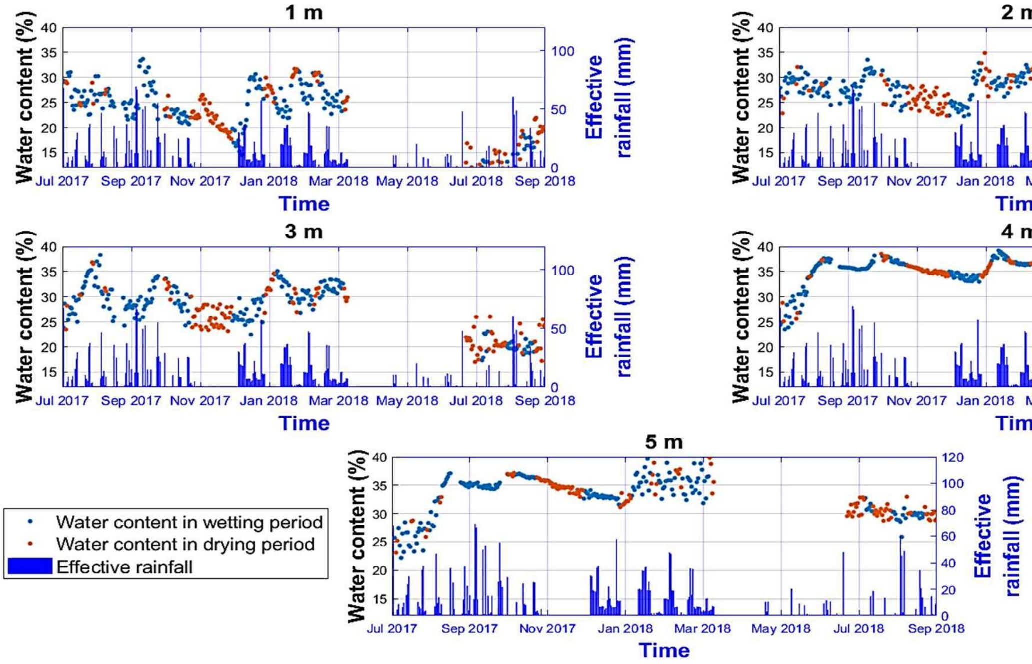




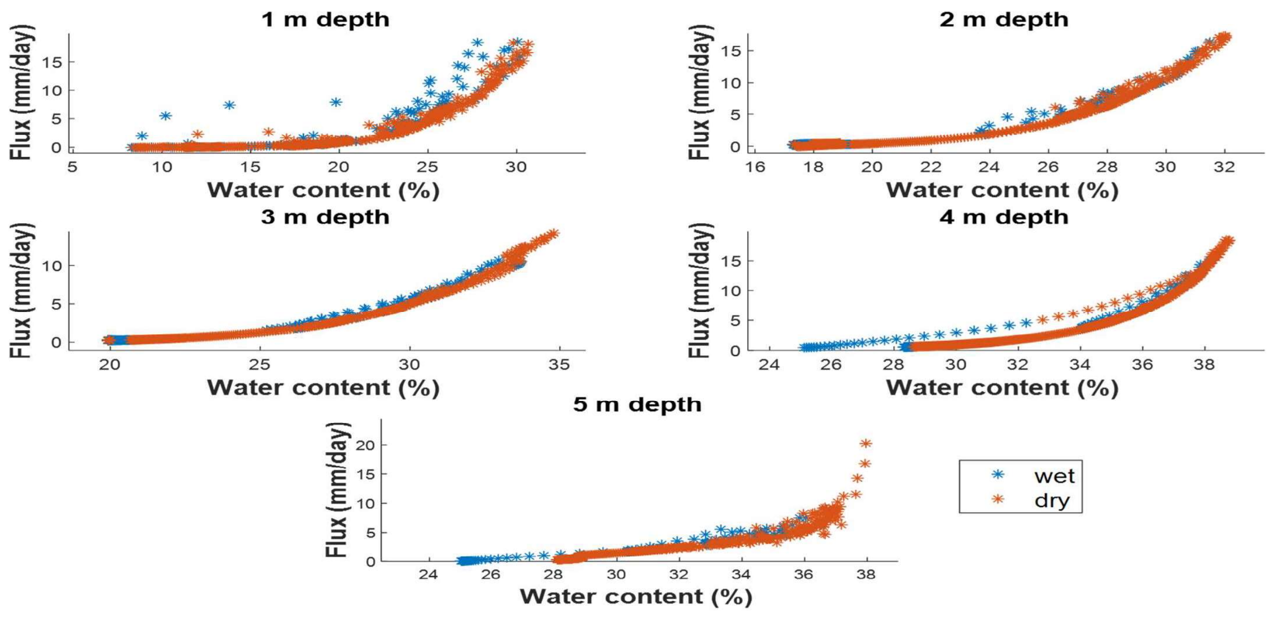
Source : Pwint phy aye, 2017

- Daily measurement (**350** days) soil moisture 1-5 m. depth
- For HYDRUS-1D simulation
- Inputs from field data
  - Rainfall
  - Evaporation
  - Transpiration
  - Groundwater level

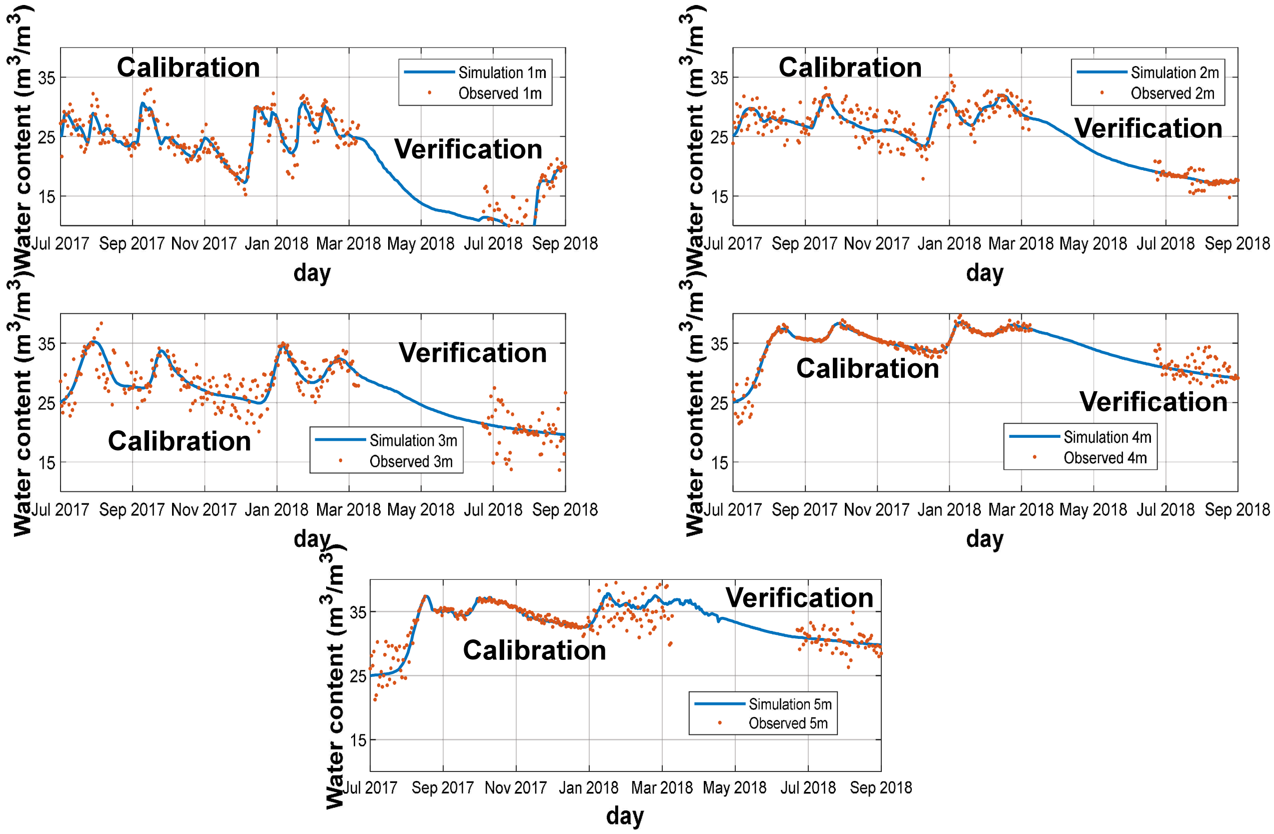
Results : Field measurement data



Relationship of flux and water content in the field test



CHULA ΣNGINEERING
Foundation toward Innovation

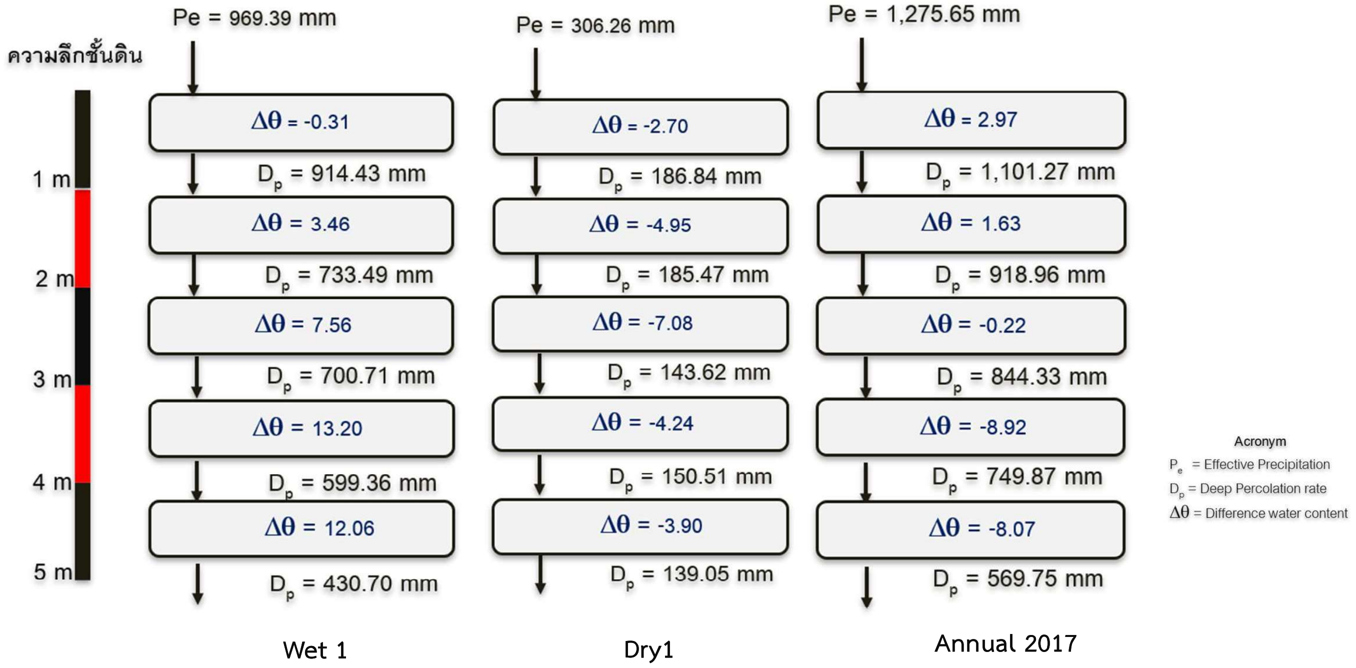


CHULA ΣNGINEERING
Foundation toward Innovation

Soil retention parameters after calibration

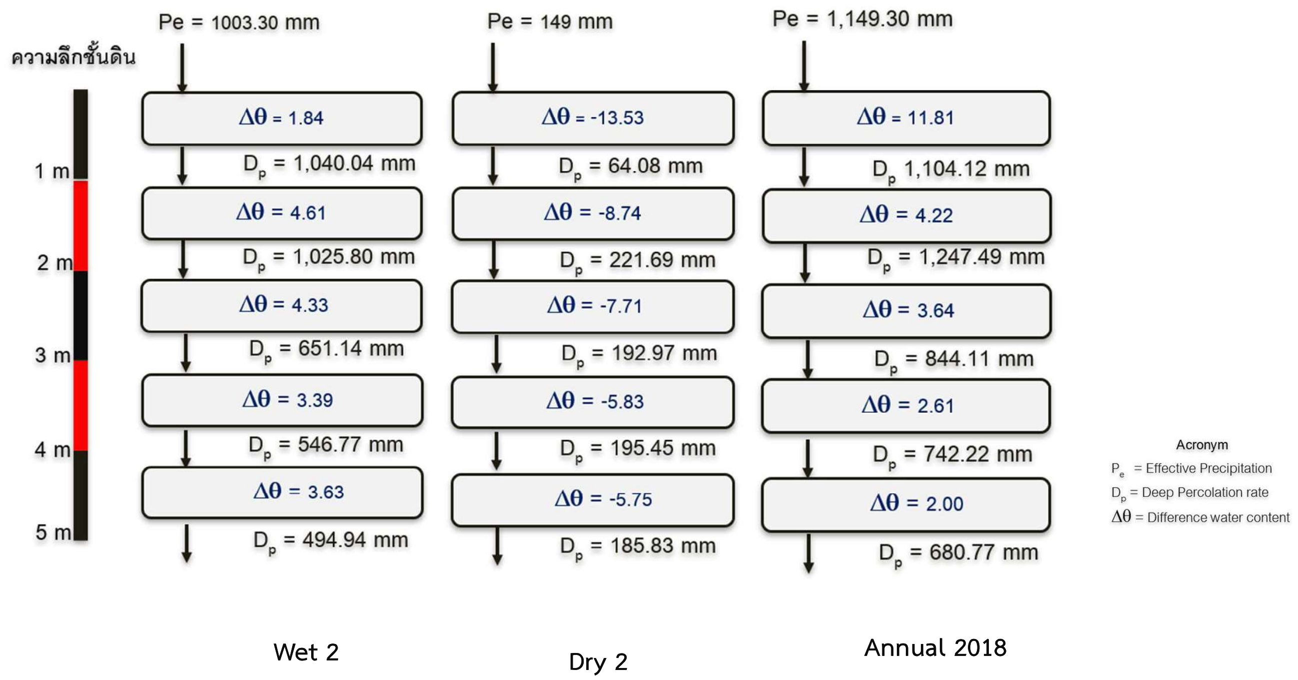
Soil Depth (m)	Soil type	θr	θs	α	η	Ks
1	Sandy Loam	0.065	0.41	0.0075	1.89	170
2	Sandy Loam	0.065	0.41	0.0065	1.75	150
3	Sandy Loam	0.065	0.41	0.0045	1.65	90
4	Sandy Loam	0.065	0.41	0.0027	1.47	30
5	Sandy Clay	0.100	0.38	0.0021	1.35	25

Water balance and water content change in 2017

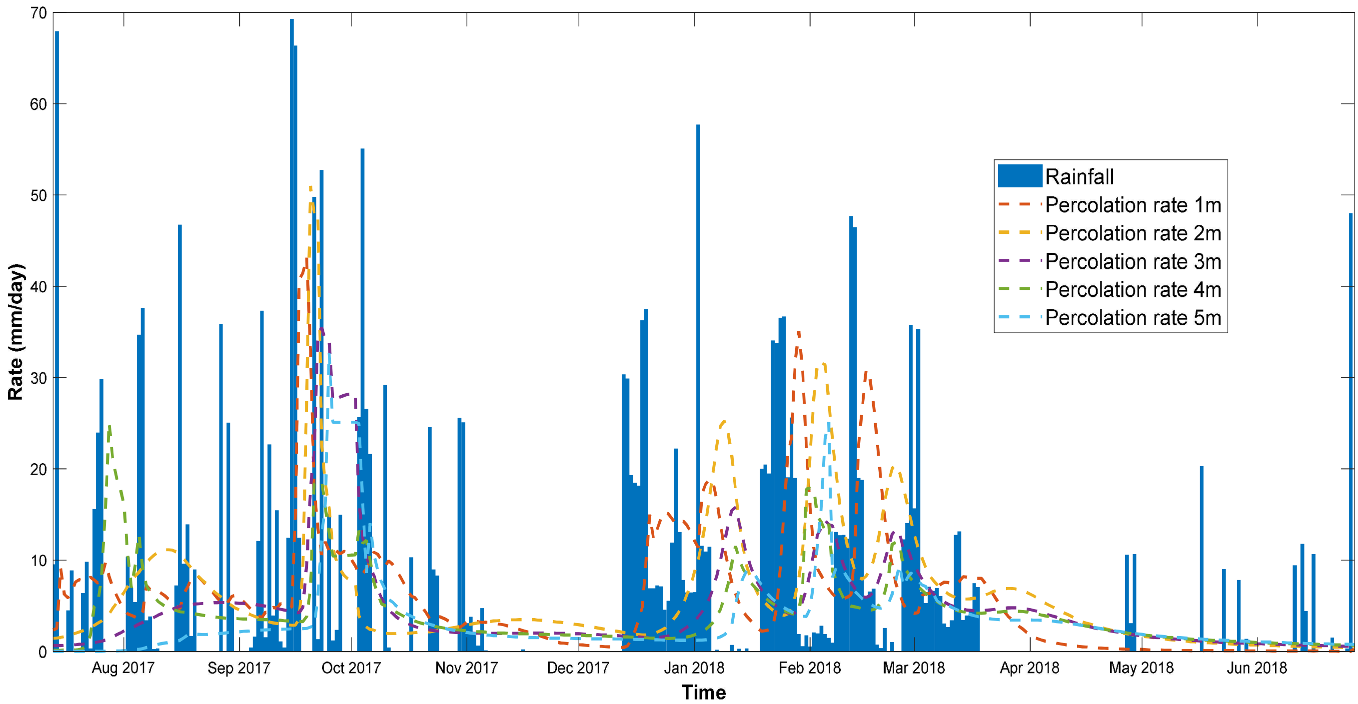


CHULA ENGINEERING
Foundation toward Innovation

Water balance and water content change in 2018



Percolation rate and Effective rainfall



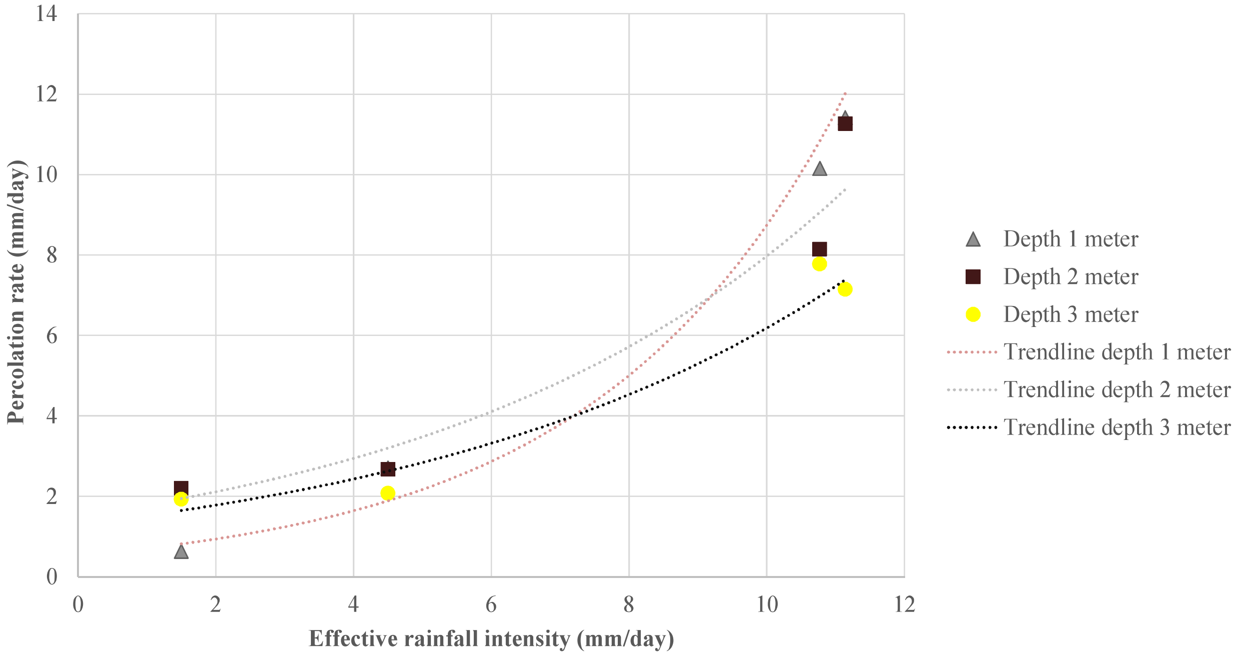
CHULA ΣNGINEERING
Foundation toward Innovation

Percolation rates at each soil depth and each period

Soil depth	Average percolation flux rate (mm /day)					
	Wet 1	Dry 1	Wet 2	Dry 2	Mean	
	July 13 – Oct 10, 2017 (90 days)	Oct 11- Dec 18, 2017 (69 days)	Dec 19, 2017 – Mar 19 , 2018 (91 days)	Mar 20 – June 27 2018 (100 days)	Wet (mm/day)	Dry (mm/day)
1 m	10.16	2.71	11.42	0.64	**10.79**	**1.48**
2 m	8.15	2.68	11.27	2.21	**9.71**	**2.40**
3 m	7.78	2.08	7.15	1.93	**7.46**	**1.99**
Effective rainfall	969.39	306.26	1003.3	149	**10.96**	**3.00**

CHULA ΣNGINEERING
Foundation toward Innovation

The relationship percolation rate and Effective rainfall intensity



CHULA ΣNGINEERING
Foundation toward Innovation

VI Conclusions

- The developed soil moisture sensor system gave reliable values of soil moisture under natural condition. The field monitored data with the application of HYDRUS 1-D model can estimate percolation rate and analyze water balance in each soil depth in more details.

- The percolation fluxes were compared with effective rainfall to find the percolation rate ratio in study area. The percolation rate ratios decrease from top to bottom depth. The highest ratio is sandy loam. The second ratio is sandy clay. The percolation flux of sand clay loam from top to bottom is 10.79 to 7.47 in wet period.

- The average rate of percolation to effective rainfall in each period is 0.43-0.49.
- The percolation rate is also affected from rainfall pattern and intensity, i.e., more intensified rainfall, more water content and more percolation, i.e., rainfall intensity of 2-11 mm/day induce percolation rate of 7-11 mm/day.
- The results from the model help to understand the deep percolation characteristics, the relationship of deep percolation rate with soil moisture content, effects of rainfall pattern and rainfall intensity.
- It also helped to estimate groundwater recharge and groundwater potentials in areas where the groundwater is used to mitigate the drought period.

Acknowlegements

- This paper could not be accomplished without the support from Royal Irrigation Department and the Water Resources System Research Unit of Faculty of Engineering, Chulalongkorn University. The authors also thank to the staff at Rice Experimental Field of RID for field data collection

References

1. Steenhuis, T.S., et al., *Preferential movement of pesticides and tracers in agricultural soils.* Journal of Irrigation and Drainage Engineering, 1990. **116**(1): p. 50-66.
2. Jaber, F.H., S. Shukla, and S. Srivastava, *Recharge, upflux and water table response for shallow water table conditions in southwest Florida.* Hydrological Processes: An International Journal, 2006. **20**(9): p. 1895-1907.
3. Koontanakulvong, S. and P. Siriputtichaikul. *Groundwater Modeling In the North Part of the Lower Central Plain, Thailand*. in *International Conference On Water and Environment, Bhopal, India, Vol. Ground Water Pollution*. 2003.
4. Wu, J. and R. Zhang, *Analysis of Rainfall-Infi l tration Recharge to Groundwater*, in *Proceedings of Fourteenth Annual American Geophysical Union: Hydrology Days* 1994, Hydrology days: Colorado State University.
5. Slavich, P., G. Petterson, and D. Griffin, *The effect of gypsum on deep drainage from clay soil used for rice.* Australian sodic soils: distribution, properties and management. CSIRO, Melbourne, 1995: p. 205-210.
6. Kojima, Y., et al., *Low-cost soil moisture profile probe using thin-film capacitors and a capacitive touch sensor.* Sensors, 2016. **16**(8): p. 1292.
7. Sharma, V. and S. Irmak, *Soil-water dynamics, evapotranspiration, and crop coefficients of cover-crop mixtures in seed maize cover-crop rotation fields. II: Grass-reference and alfalfa-reference single (normal) and basal crop coefficients.* Journal of Irrigation and Drainage Engineering, 2017. **143**(9): p. 04017033.
8. Hillel, D., *Fundamentals of soil physics*. 2013: Academic press.

9. Kantasinee Chaengpui, W.S.-a., Sujin Charoonsak & S. P. P. Srima, *Study on Consumptive Use of Dragon Fruit (2nd year)*, in *In Irrigated Agriculture Newsletter*. 2015, Royal Irrigation Department: Royal Irrigation Department.
10. Long, T.T., S. Koontanakulvong, and P.P. Aye, *Examination of land recharges using soil moisture approach: Case study in Thailand.* Internet Journal of Society for Social Management Systems 2017. vol 11(issue1): p. 10.
11. Lee, T.J. and R.A. Pielke, *Estimating the soil surface specific humidity.* Journal of Applied Meteorology, 1992. **31**(5): p. 480-484.
12. Simunek, J., M.T. Van Genuchten, and M. Sejna, *The HYDRUS-1D software package for simulating the one-dimensional movement of water, heat, and multiple solutes in variably-saturated media.* University of California-Riverside Research Reports, 2005. **3**: p. 1-240.
13. Schaap, M.G., F.J. Leij, and M.T. Van Genuchten, *Rosetta: A computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions.* Journal of hydrology, 2001. **251**(3-4): p. 163-176.
14. Grinevskiy, S.O. and S.P. Pozdniakov, *The use of Hydrus-1D for groundwater recharge estimation in boreal environments.* HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems, 2013. **107**: p. 1-13.
15. King, J., *Comparison of alternative estimators of deep percolation in full and deficit irrigation*. 2015, Colorado State University. Libraries: Colorado State University
16. Long, T.T. and S. Koontanakulvong. *Determination of deep percolations via soil moisture approach in Saigon River Basin, Vietnam*. in *THA2019*. 2019. Thailand: Chulalongkorn University.
17. Laphimsing, A., *Relationships among groundwater levels, rainfall, runoff and water uses in lower Yom and Nan River Basins*. 2016, Master Thesis, Water Resources Engineering Department, Chulalongkorn University. p. 255.

THANK YOU

FOR YOUR ATTENTION

ANY QUESTIONS ?