Chulalongkorn University
Faculty of Engineering
Water Resources Engineering Department

DETERMINATION OF DEEP PERCOLATIONS via SOIL MOISTURE APPROACH IN SAIGON RIVER BASIN, VIETNAM

Presented by:
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Content

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I. INTRODUCTION

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As a critical factor of the groundwater balance, the groundwater recharge rate plays an essential role in determining sustainable yields for groundwater resources, especially in overexploited aquifers. Traditionally, due to the difficulty of measurement, groundwater recharge could be estimated based on lysimeter, unsaturated zone water balance, Darcy flux, water table fluctuation, tracer, and parameters optimization from groundwater modeling. However, soil profile somehow cannot be validated and lead land recharge incorrectly equated with the sustainable yield of an aquifer.

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II. STUDY AREA

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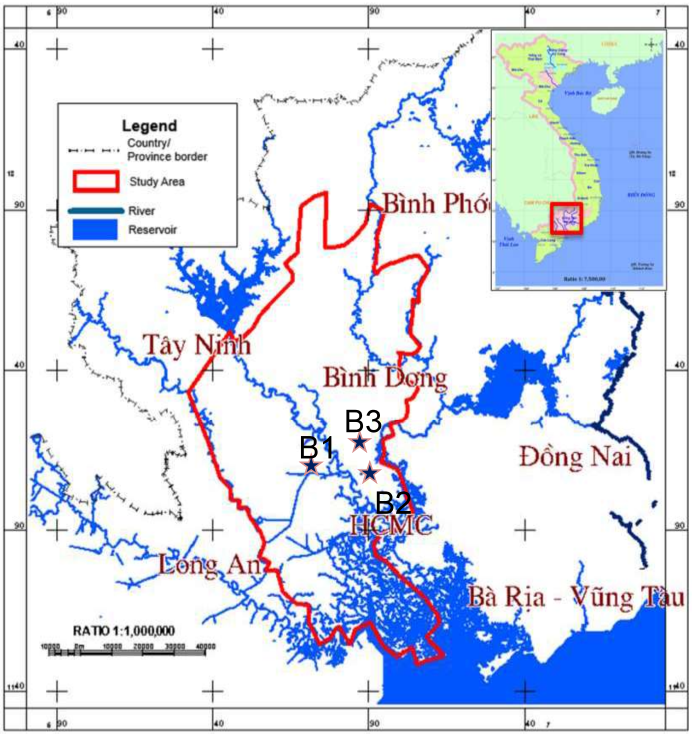
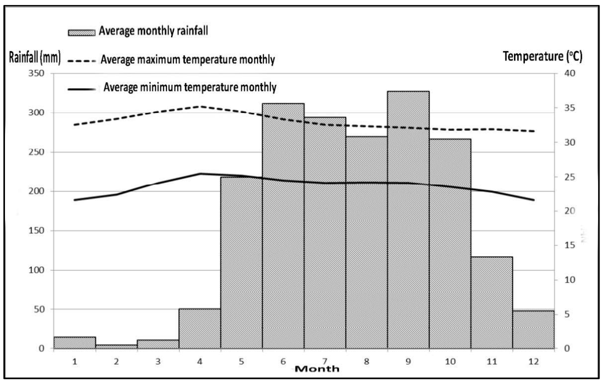




FIELD TEST
B1- Sand clay loam, B2- Sand clay, B3- Clay

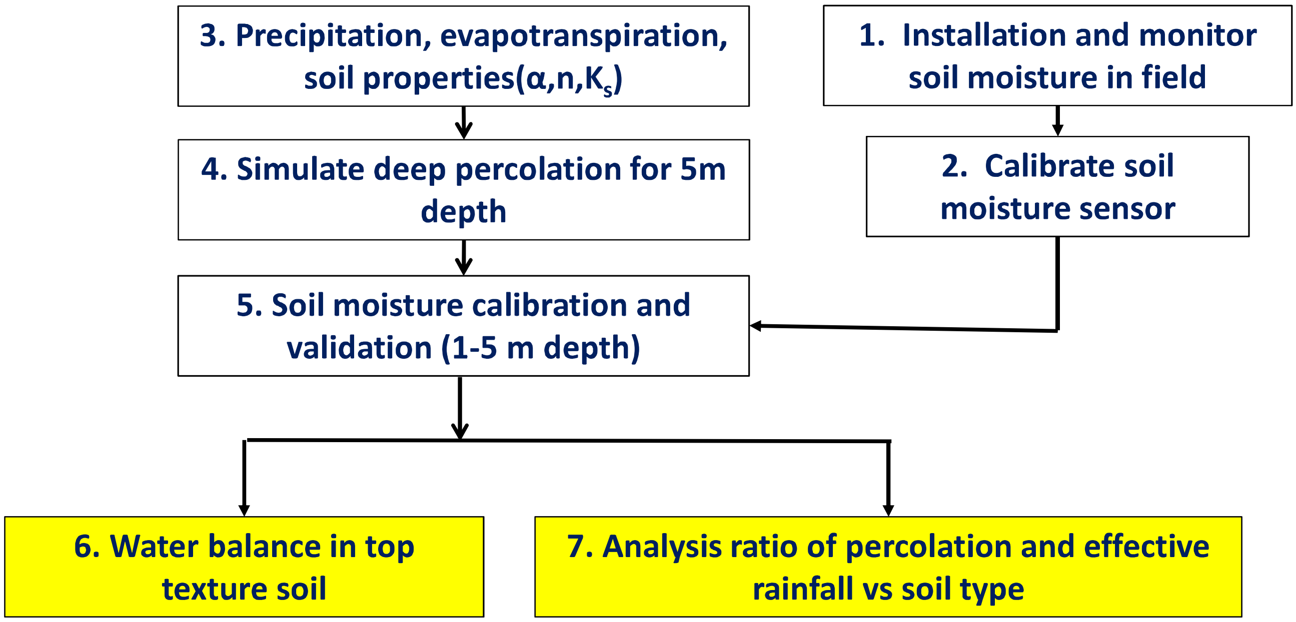
II. OBJECTIVE/STUDY AREA

The paper will focus on describing deep percolation flow using Richard's function (Hydrus 1D).

- First, the daily deep percolation of 3 soil types is simulated using the Hydrus 1D model. The water retention parameters are calibrated and verified by field experimental data in the study area of Saigon River Basin, Vietnam.
- Second, relationship effective rainfall and land recharge are analyzed to detect the deep percolation function for 3 soil types in the Saigon River basin, South East of Vietnam.
- Finally, the assessment water balance provides a better understanding of the deep percolation flow.

III. STUDY THEORIES AND PROCEDURES

Analysis groundwater and surface water interaction process



III. STUDY THEORIES AND PROCEDURES

Soil water balance equation

$$I - ET + P - RO - DP \pm \Delta SW = 0 \qquad (1)$$

where, I is irrigation (L),

ET is evapotranspiration (L),

P is precipitation,

RO is surface runoff (L),

DP is deep percolation (L),

and ΔSW is change is soil water content(L).

III. STUDY THEORIES AND PROCEDURES

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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)

$$\frac{\delta\theta}{\delta t} = \frac{\delta}{\delta x_i}\left[K\left(K_{ij}^{A}\frac{\delta h}{\delta x_j} + K_{iz}^{A}\right)\right] - S \qquad (2)$$

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 (root plant) [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 **K^A**
K is the unsaturated hydraulic conductivity function [LT^{-1}] given by

III. STUDY THEORIES AND PROCEDURES

$$K(h) = K_s S_e^{1/2}\left[1 - (1 - S_e^{1/m})^m\right]^2 \quad (3)$$

$$\theta(h) = \begin{cases} \theta_r + \frac{\theta_s - \theta_r}{[1-|\alpha h|^n]^m} & h < 0 \\ \theta_s & h \geq 0 \end{cases} \quad (4)$$

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} \quad (5)$$

$$m = 1 - 1/n, \quad n > 1 \quad (6)$$

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

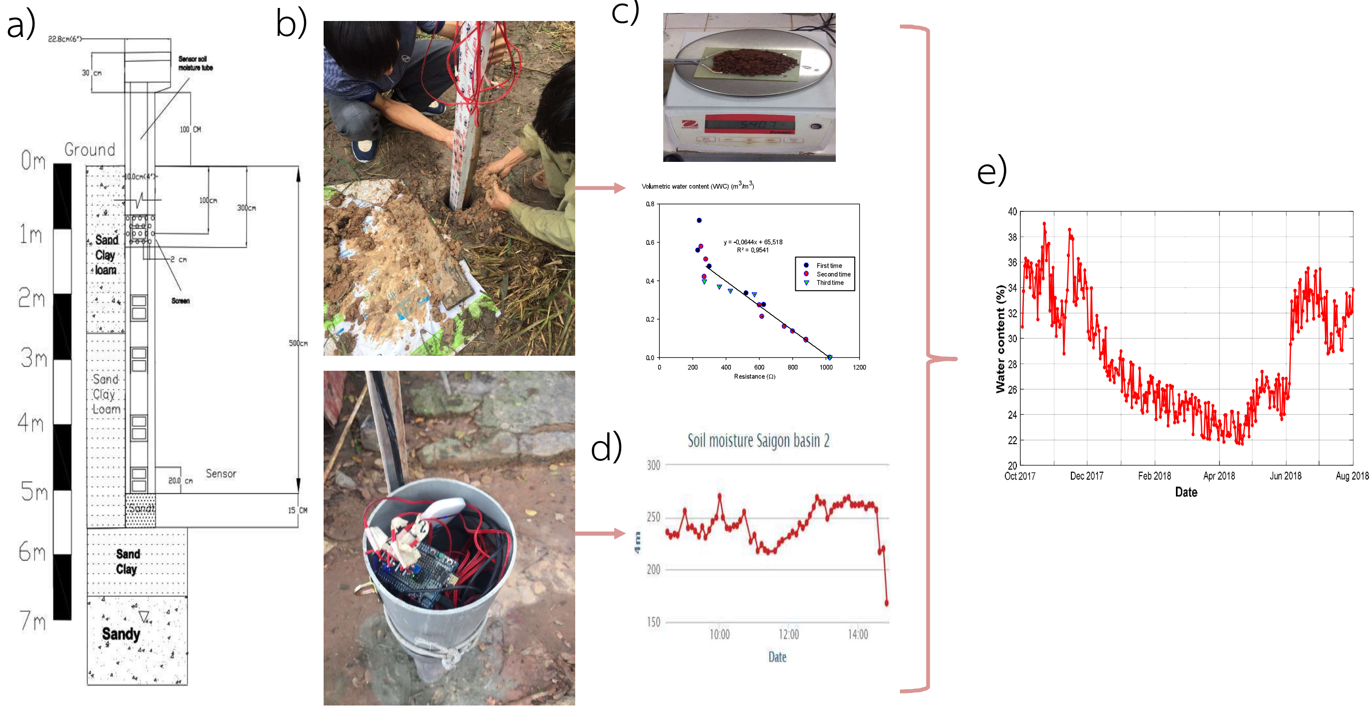
III. STUDY THEORIES AND PROCEDURES

The x-components of the percolation rate are computed for each node N according to (Simunek, Van Genuchten, and Sejna 2005)

$$q_N^{j+1} = -K_{N-\frac{1}{2}}^{j+1}\left(\frac{h_N^{j+1} - h_{N-1}^{j+1}}{\Delta x_{N-1}} + 1\right) - \frac{\Delta x_{N-1}}{2}\left(\frac{\theta_N^{j+1} - \theta_N^j}{\Delta t} + S_N^j\right) \quad (7)$$

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]
Δt is time calculation (d)
Δx is grid size
j is time step
N indicate the position node in the finite difference mesh

Field measurement set up



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III. STUDY THEORIES AND PROCEDURES
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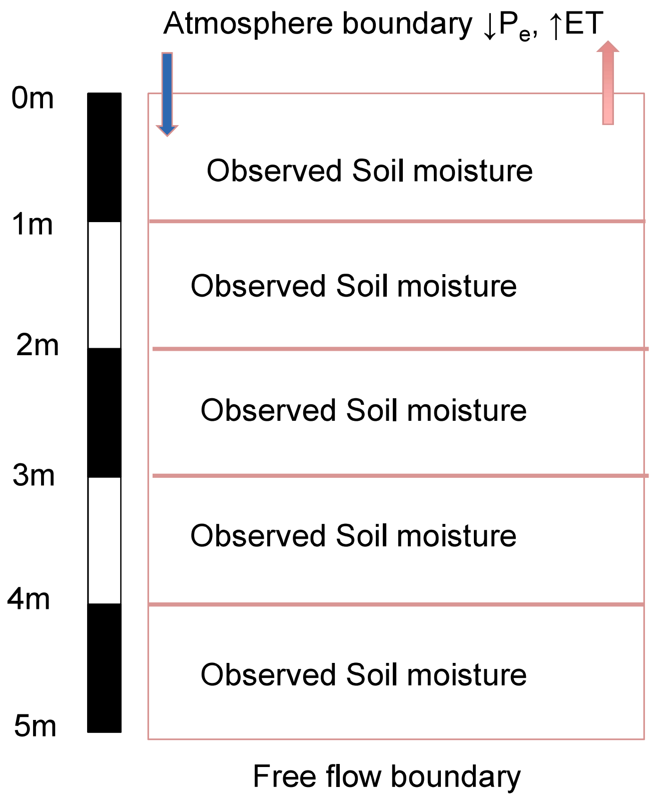
Boundary conditions for modeling



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IV. RESULTS

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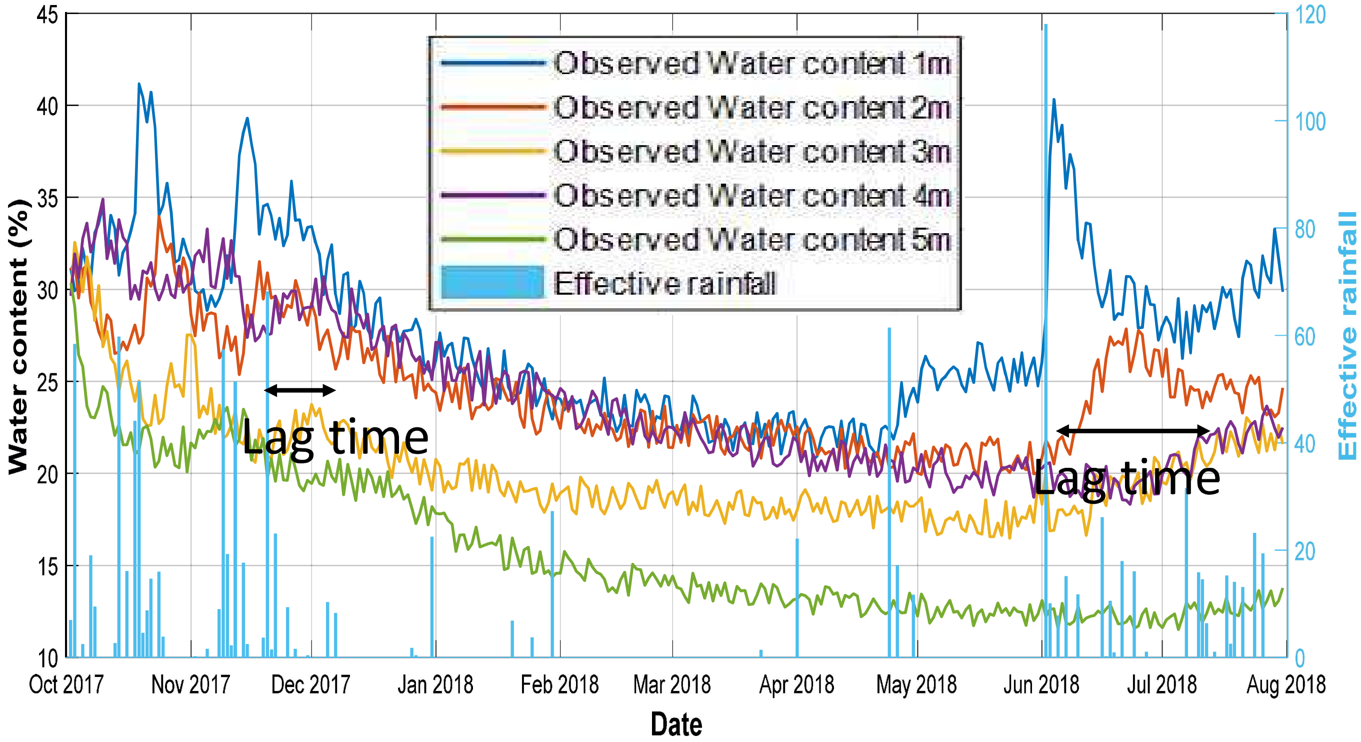
Field measurement data



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V. RESULTS

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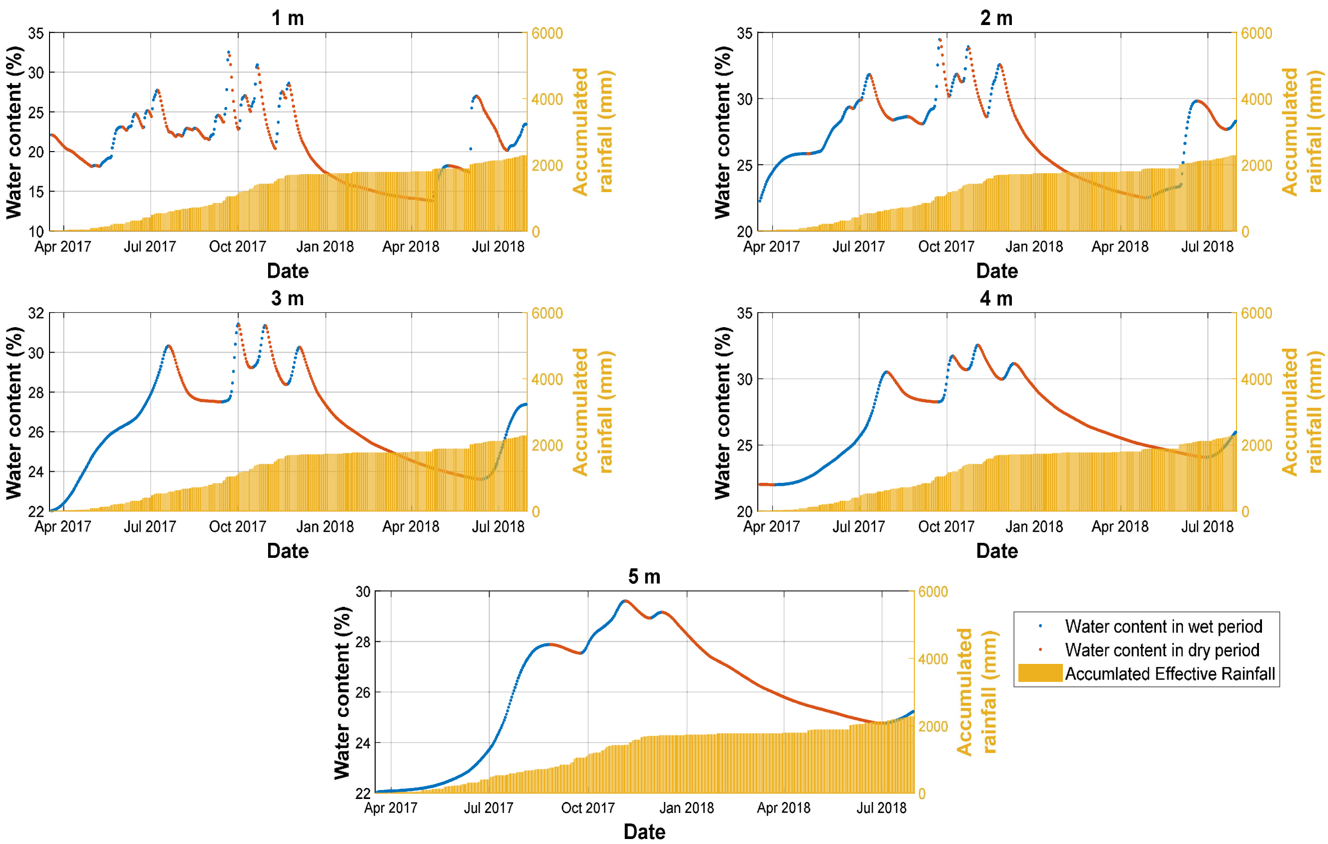

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V. RESULTS

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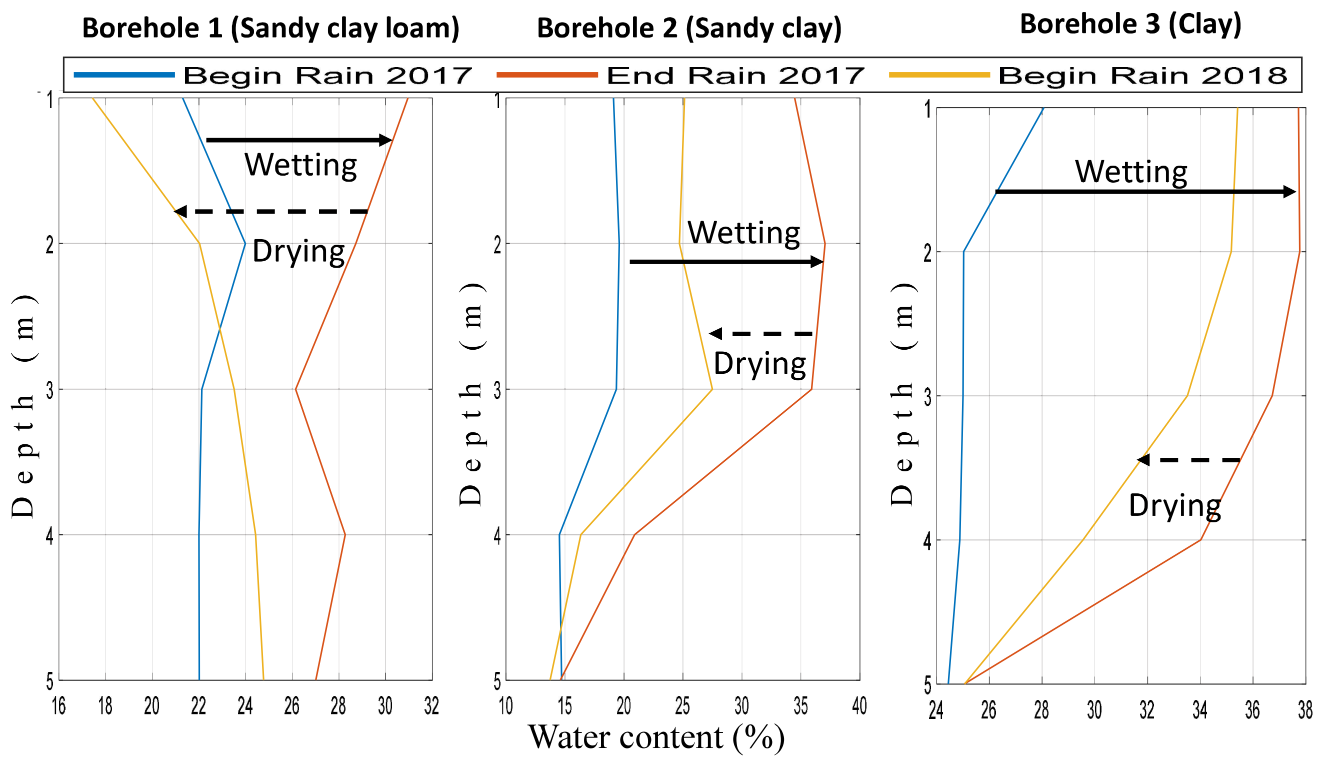
Soil moisture profile in 3 boreholes



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V. RESULTS

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Soil properties and calibrated soil parameters

Depth	Sand (%)	Silt (%)	Clay (%)	Soil type	θ_r	θ_s	α (1/mm)	n(-)	K (mm/day)
Borehole 1									
1m	71.4	14.6	13.9	Sandy loam	0.065	0.41	0.0075	1.89	361
2m	67.5	8.5	24	Sandy clay loam	0.061	0.38	0.0029	1.6	124.4
3m	65.5	6.5	28	Sandy clay loam	0.061	0.38	0.00277	1.64	120.3
4m	63.2	16.4	20.4	Sandy clay loam	0.06	0.39	0.0029	1.48	114
5m	64.1	12.8	23.1	Sandy clay loam	0.06	0.38	0.0015	1.7	120
Borehole 2									
1m	50.2	10.4	39.4	Sandy clay	0.1	0.38	0.0035	1.65	55.8
2m	53	9.6	37.4	Sandy clay	0.1	0.38	0.0032	1.62	51
3m	54.5	7.5	38	Sandy clay	0.1	0.38	0.0031	1.65	45
4m	56	5.7	38.3	Sandy clay	0.1	0.38	0.0027	2.2	60
5m	61.3	4.6	34.1	Sandy clay	0.1	0.38	0.00025	2.1	65
Borehole 3									
1m	17.2	3.4	79.4	Clay	0.068	0.39	0.0015	1.29	15.6
2m	16.7	7	76.3	Clay	0.068	0.39	0.0012	1.25	17.6
3m	10.8	2	87.4	Clay	0.068	0.39	0.0008	1.25	18.1
4m	23.6	5.4	71	Clay	0.068	0.385	0.0006	1.26	24
5m	23.5	4.5	73	Clay	0.068	0.385	0.0004	1.75	27

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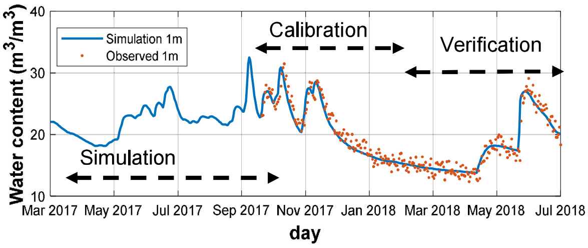
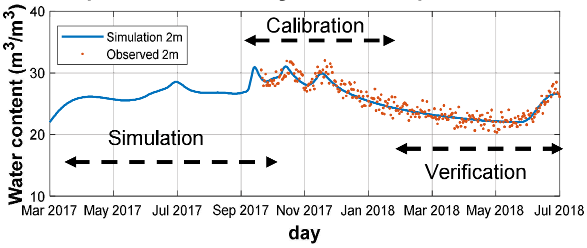
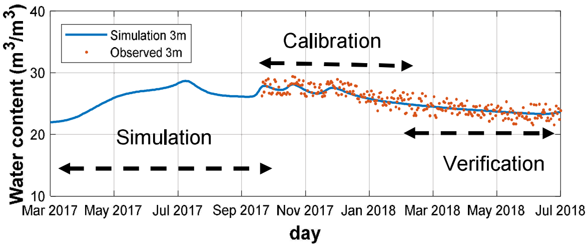
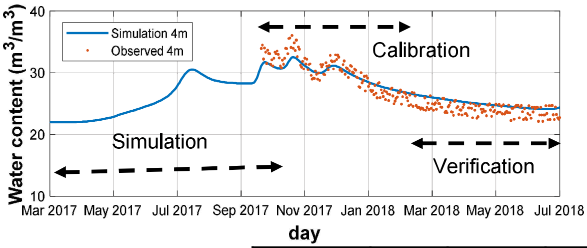
CALIBRATION & VERIFICATION

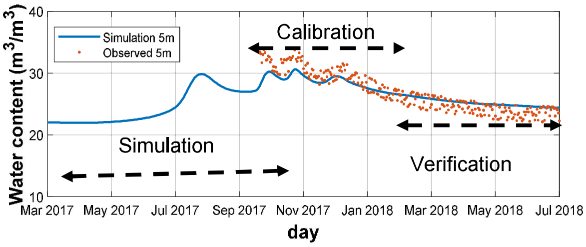
Soil moisture Borehole 1 (Sand clay loam)











	Sand clay	Sand Clay	Clay
Calibration			
RMSE	0.98	0.88	0.82
R^2	0.85	0.78	0.85
Verification			
RMSE	0.75	1.06	1
R^2	0.7	0.67	0.69

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V. RESULTS

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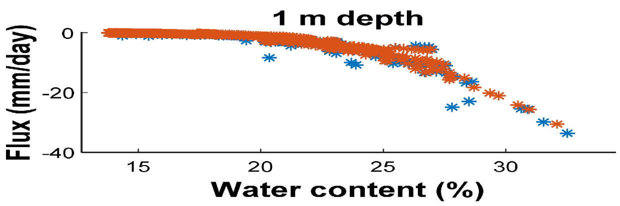
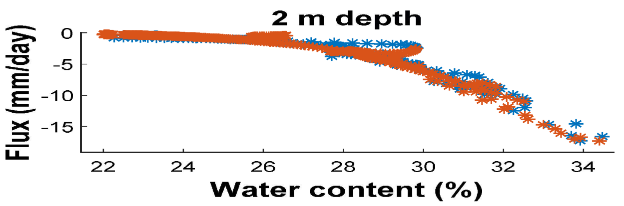
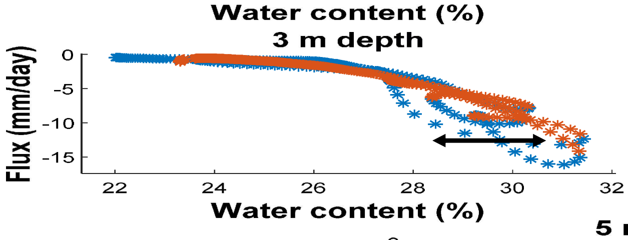
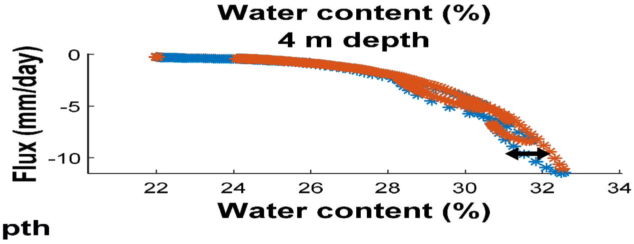
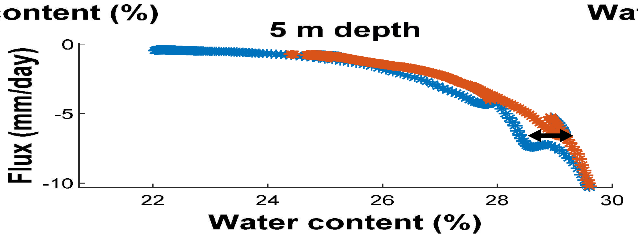
Flux vs water content of sand clay loam











* Wetting
* Drying

⇒ Flux in sand in top soil is higher than in the deeper soil

⇒ Flux is different between drying and wetting at 3 to 5 meter

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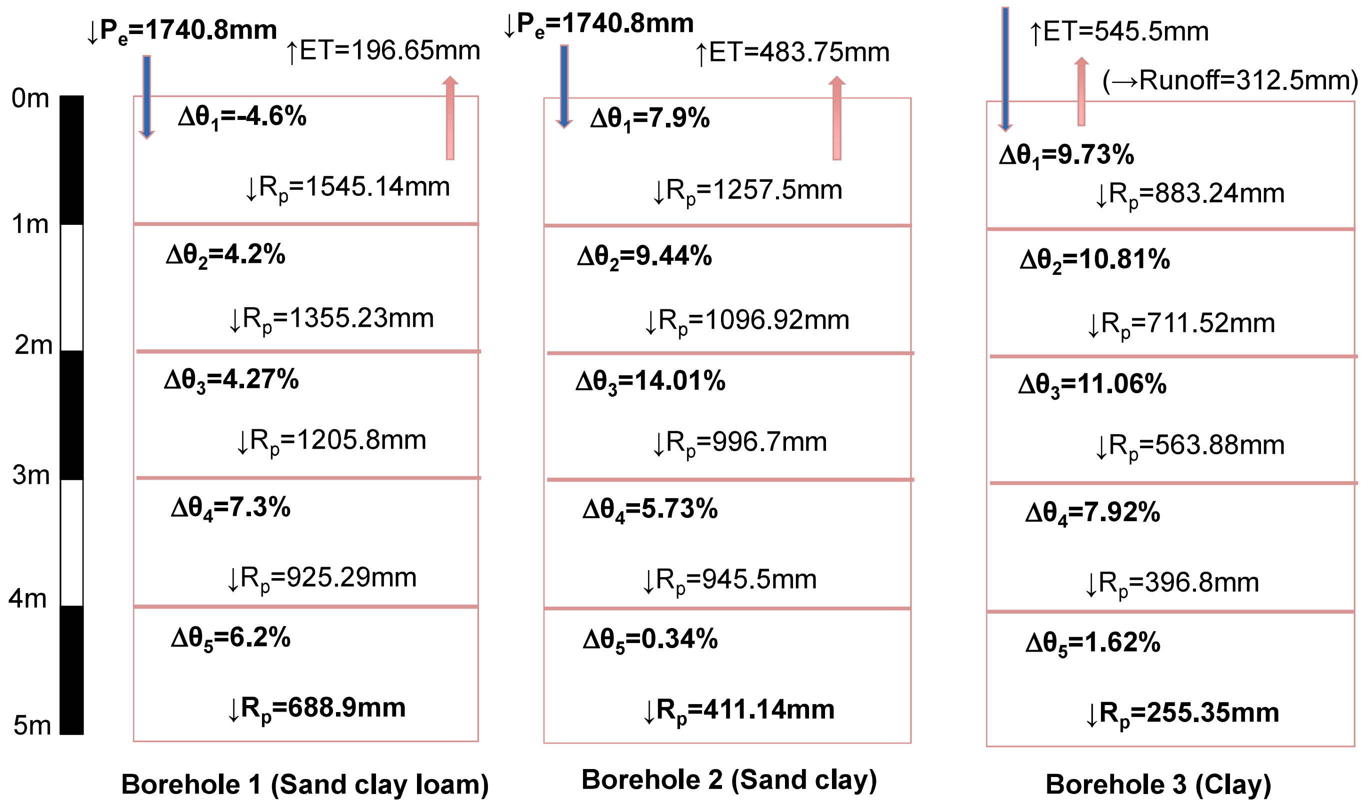
V. RESULTS

Land recharge and water balance in wet season



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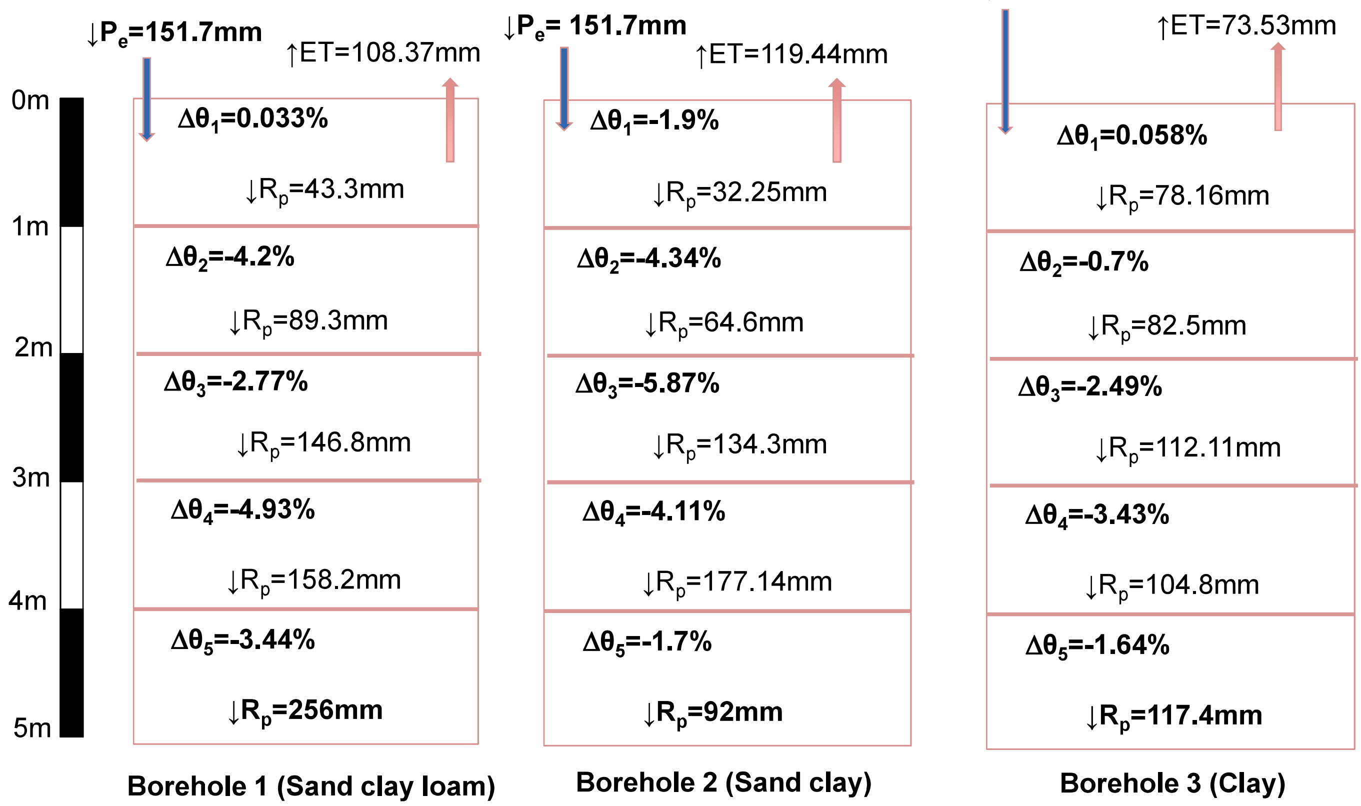
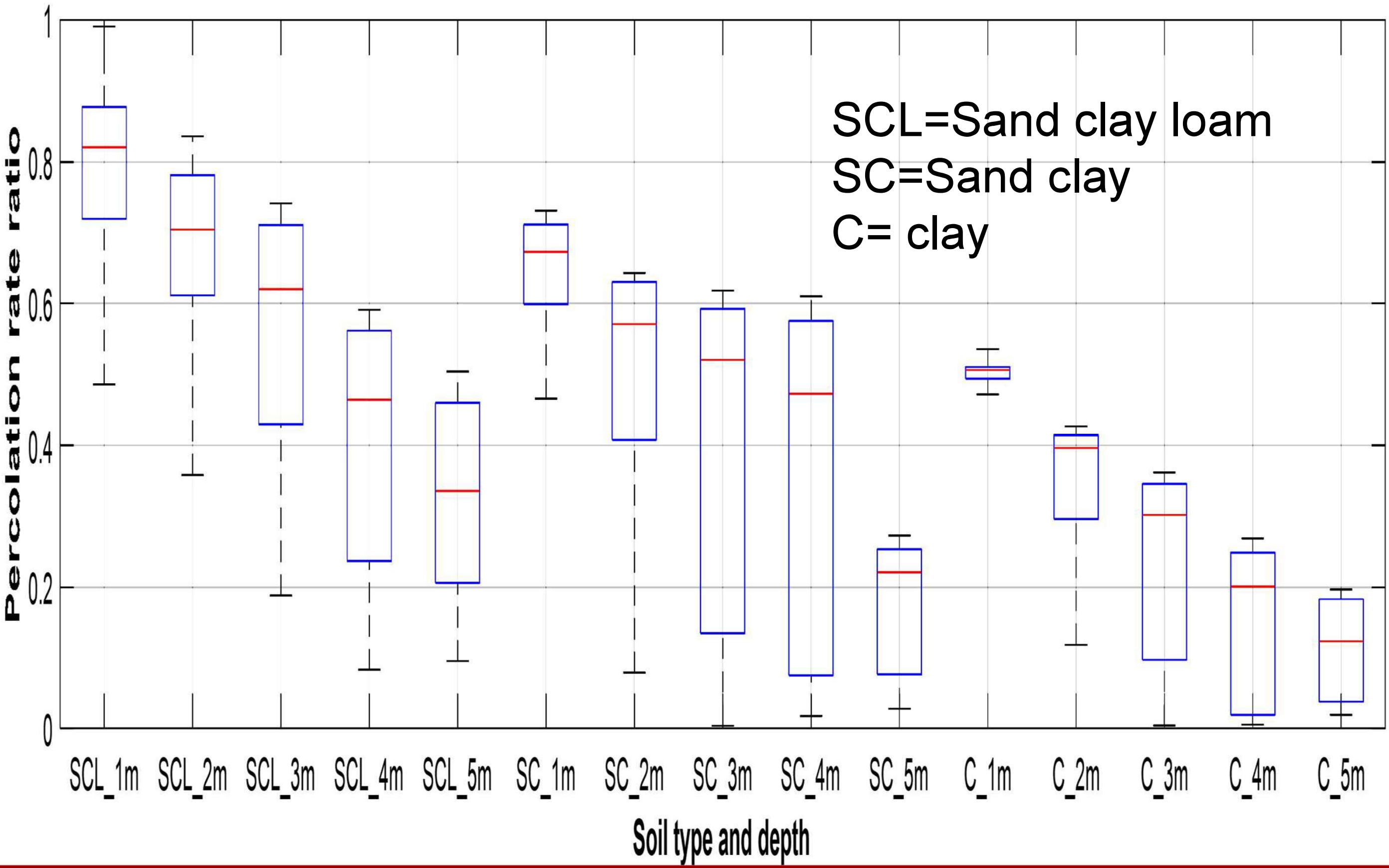
V. RESULTS

Land recharge and water balance in dry season



V. RESULTS



V. RESULTS

Percolation rate and Infiltration rate via soil type

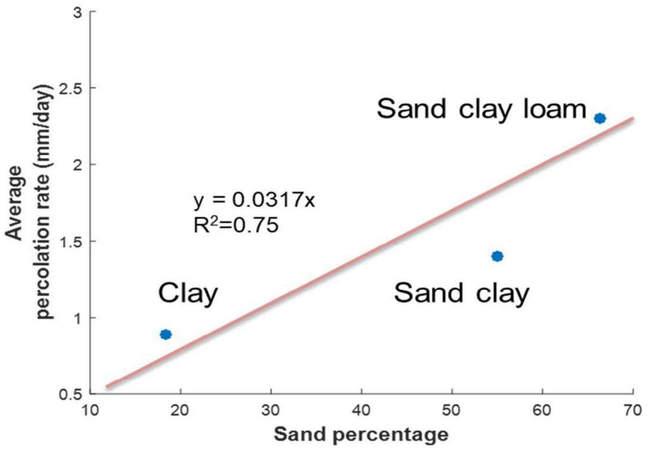
#	Sand (%)	Silt (%)	Clay (%)	Soil type	K_S (mm/day)	Average Deep Percolation rate at 5m depth (mm/day)	Infiltration rate saturated soil at 1 m depth (mm/day)
1	66.34	11.76	21.88	Sandy clay loam	167.94	2.3	866*,
2	55	7.56	37.44	Sandy clay	55.6	1.4	31.2*,
3	18.36	4.46	77.42	Clay	15.6	0.89	12*,

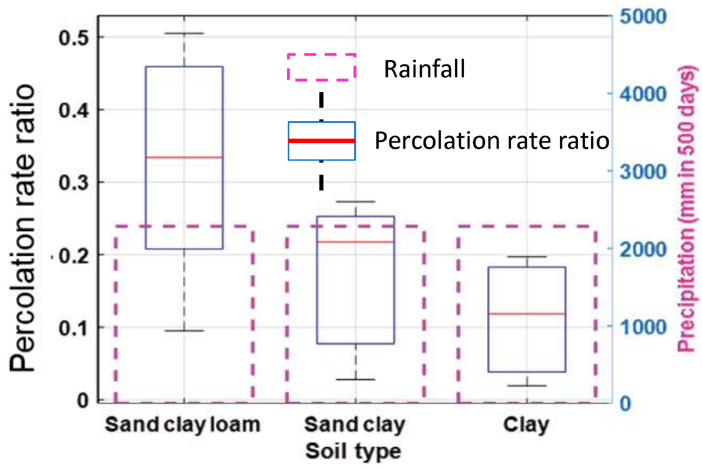
*Free, Browning et al. 1940

The infiltration rate of saturated soil is close to saturated hydraulic conductivity. While the average deep percolation rate are lower than infiltration rate of saturated soil. During practice in short time, infiltration rate was measured under constant water supply, which may cause high intensity water flow into cracker of soil sample. Therefore, the infiltration rate of saturated soil probably gives overestimated recharge to groundwater under nature precipitation.

VI. CONCLUSION

The percolation ratio is proportional with percentage of sand in soil. The water was captured in upper clay layer and reach difficultly to bottom layer. While the water pass through sand clay loam and sandy clay more than clay. Under high evaporation, rainfall in dry season cannot infiltrate into soil. Hence, the percolation rate in dry season at 5 meter is from water of upper soil which absorbed water during wet season.





VI. CONCLUSION

The percolation ratio of sand clay loam, sand clay, and clay are 0.33, 0.22, and 0.18, respectively . The experiments are in accordance with the results of previous study, which also pointed out land recharge is limited to 27.6% of rainfall. Moreover, the percolation rate of sand clay loam is closed with the rate of same soil type in Phitsanulok, Thailand (2.3 mm/day) (PWINT PHYU AYE, 2019).

These experiments presented an insights approach to estimate better deep percolation from effective rainfall via field soil moisture sensor. The approach gives better understanding mechanism of deep percolation. The approach has potential to help planning the water resources and disaster management more efficient in the consecutive drought years.

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Acknowledgment

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Q&A

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THANH YOU FOR YOUR ATTENTION

Review on land recharge estimation

Rainfall	Soil type	Location	Lag time	Percolation rate	Source
834mm/year	Silty clay	Hebei Plain, China	35 days	155mm/year (Ratio 19%)	(Lu, Jin et al. 2011)
600 to 700 mm/year	Sandy Loam	Moscow Artesian Basin		15 to 144 mm/year	(Grinevskiy and Pozdniakov 2013)
555-600mm/year	Silt loam, silty clay loam and clay loam	Rajasthan, India		6.86 cm, 3.76 cm and 1.16 cm/ year	(Khatal, Ali et al. 2018)

The timing of recharge for some models is calculated by lagging the recharge by the time proportional to the depth to the water table [Swancar and Lee, 2003]. A variation of this method ignores rainfall events below a 'threshold' and also assumes the recharge to be zero for events less than the daily evaporation [Lee, 1996].

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IV. CALIBRATION & VERIFICATION

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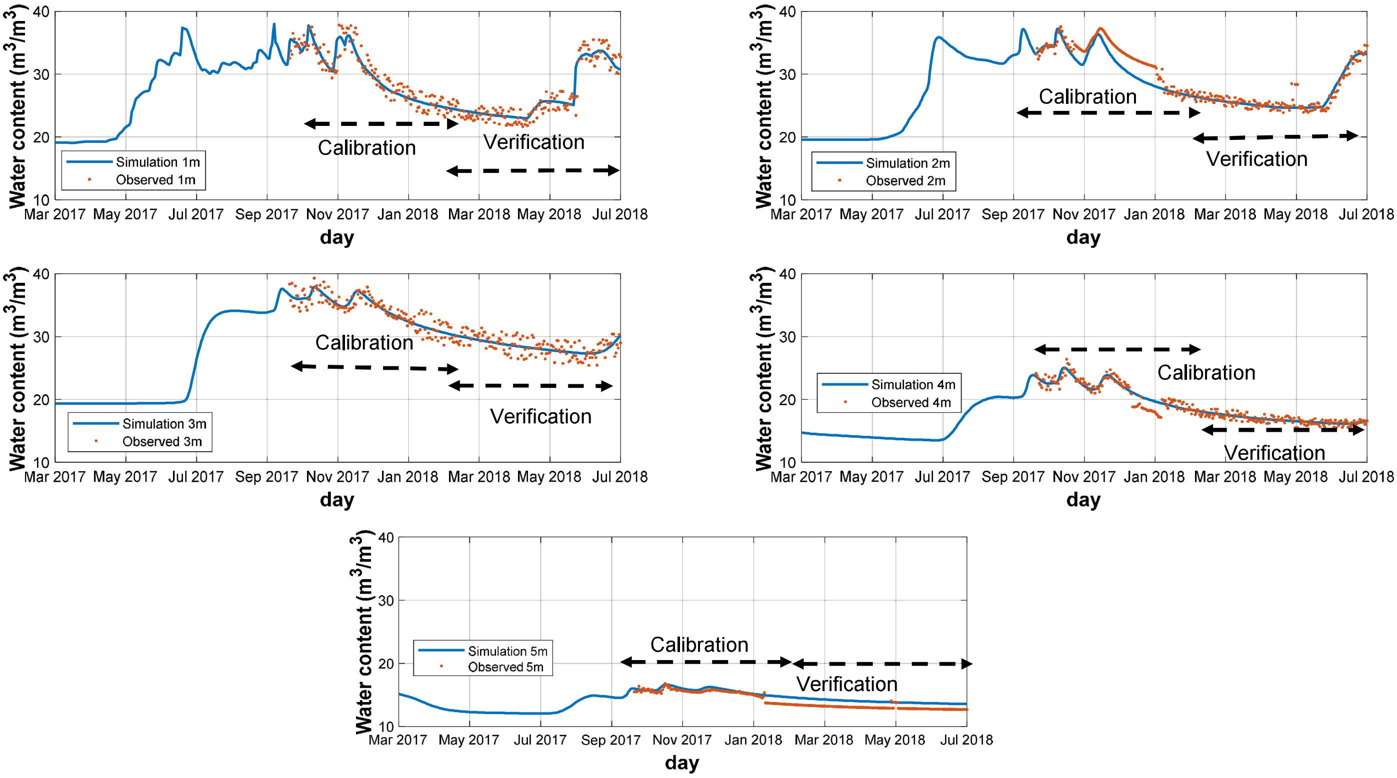
Soil moisture Borehole 2 (Sand clay)



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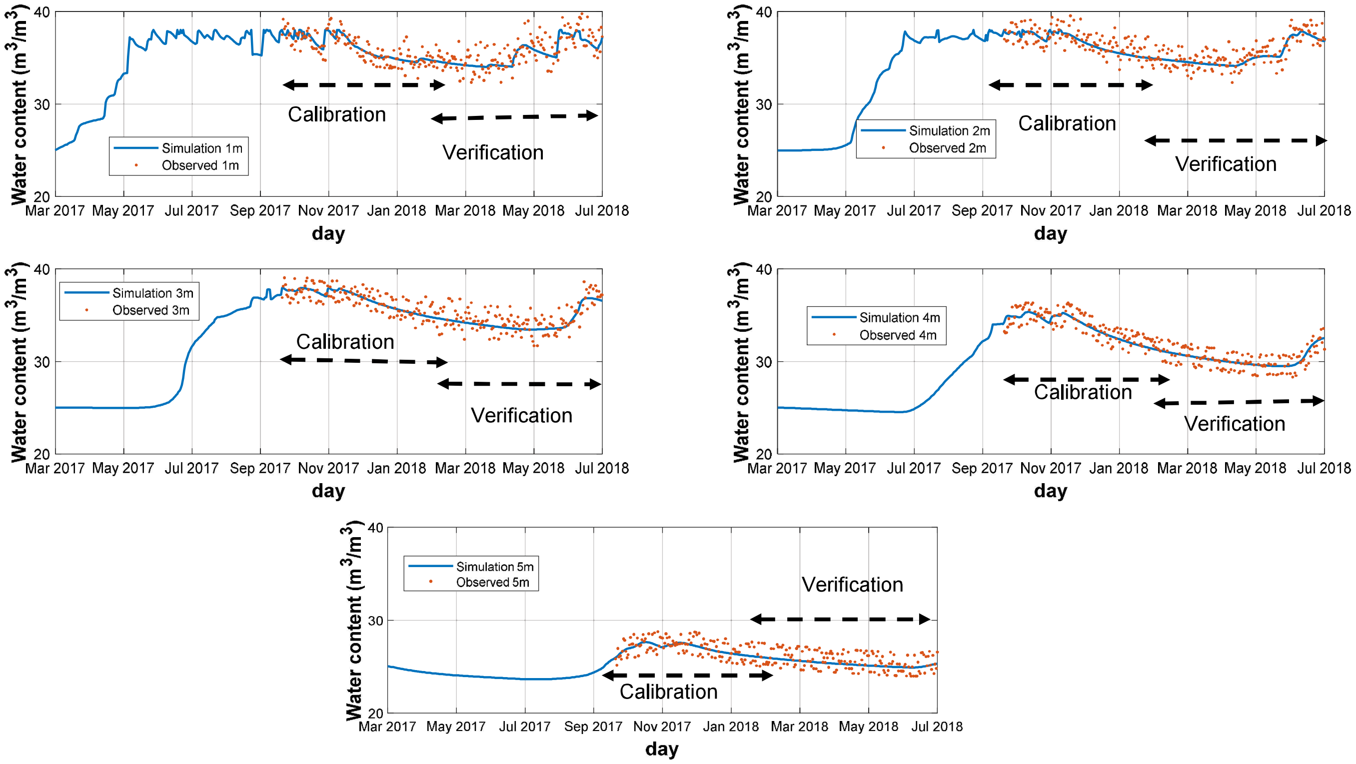
Soil moisture Borehole 3 (Clay)



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