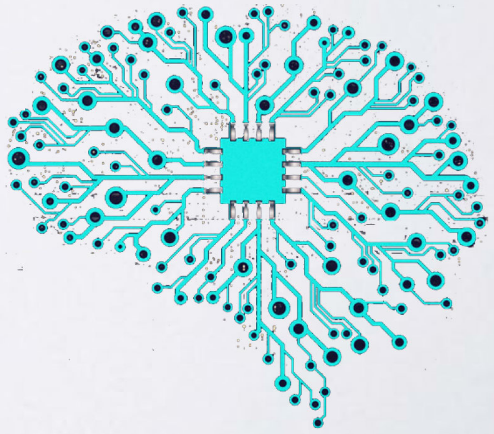
Journal of Zhejiang University-SCIENCE A

Cite this as: Zhi-liang Cheng, Wan-huan Zhou, Zhi Ding, Yong-xing Guo, 2020. Estimation of spatiotemporal response of rooted soil using a machine learning approach. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 21(6):462-477. https://doi.org/10.1631/jzus.A1900555

Estimation of spatiotemporal response of rooted soil using a machine learning approach

Key words:

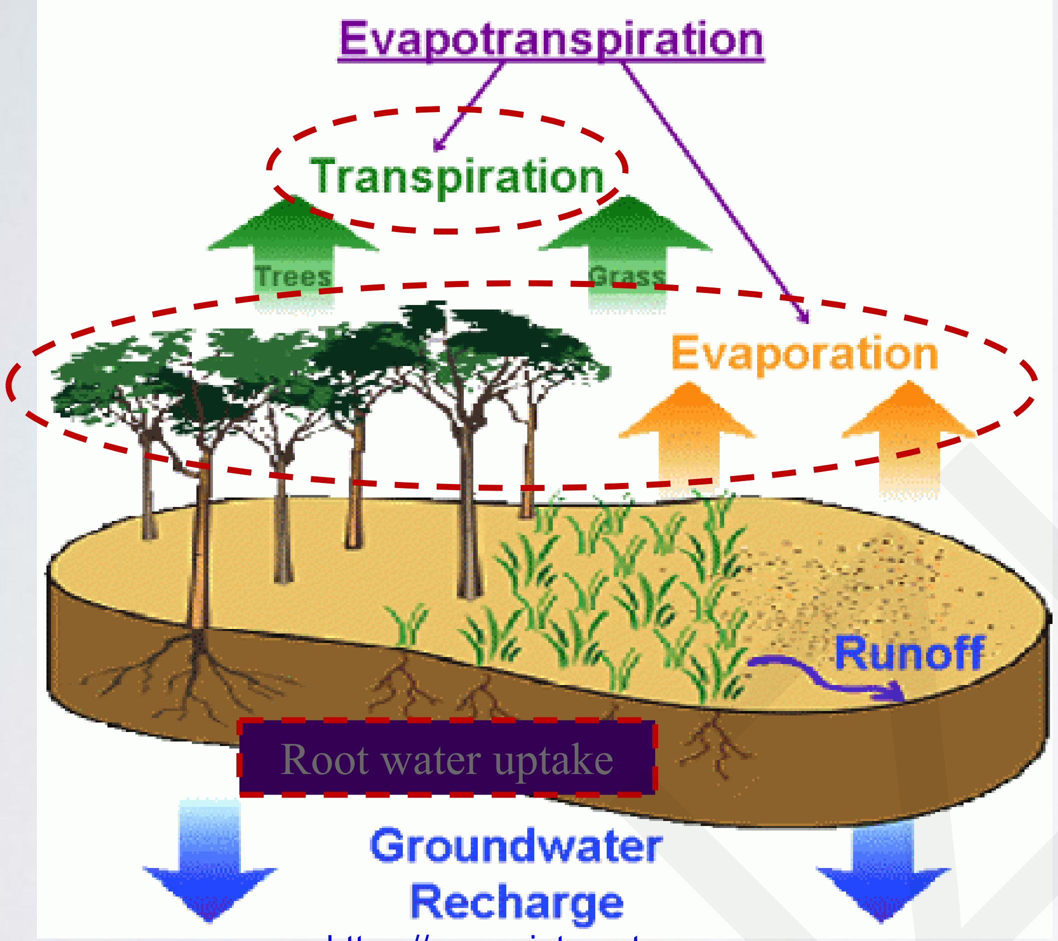
Genetic programming, Simplified statistical model, Spatiotemporal variations, Soil suction



Soil vegetation atmosphere interaction

Vegetation parameters

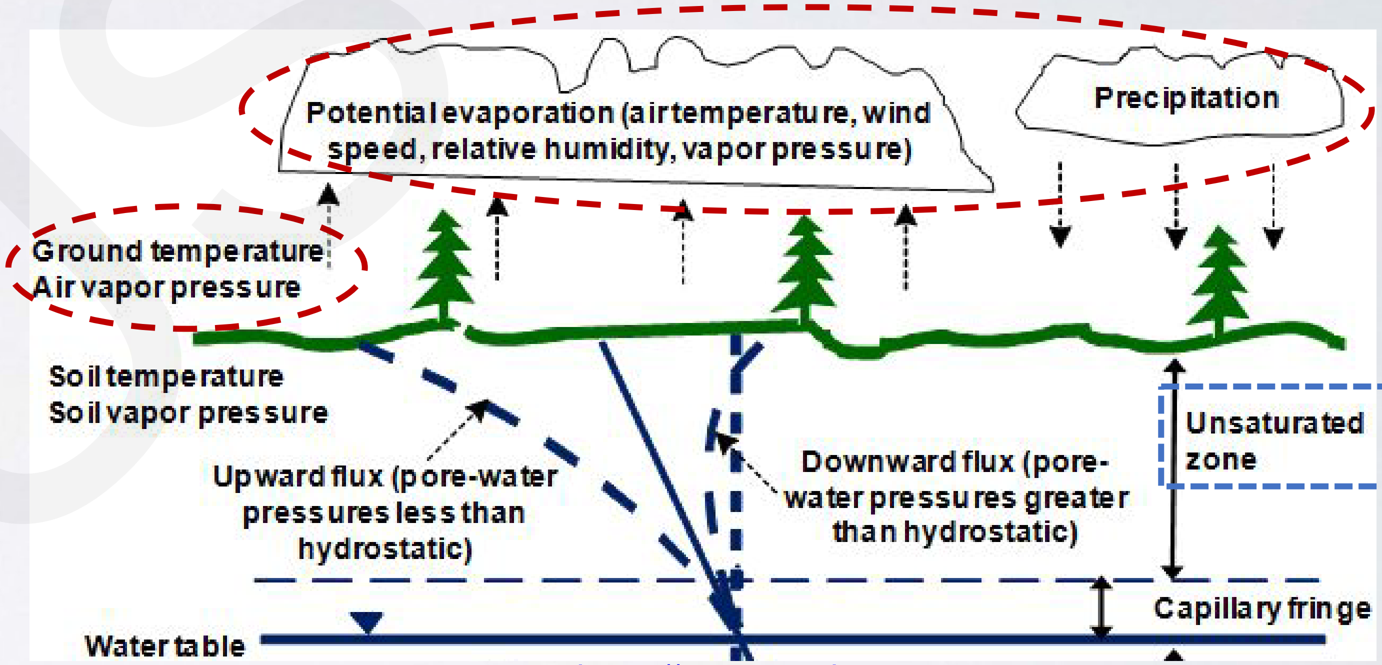
Canopy, Leaf area index, Root area index



https://www.pinterest.com

Meteorological parameters

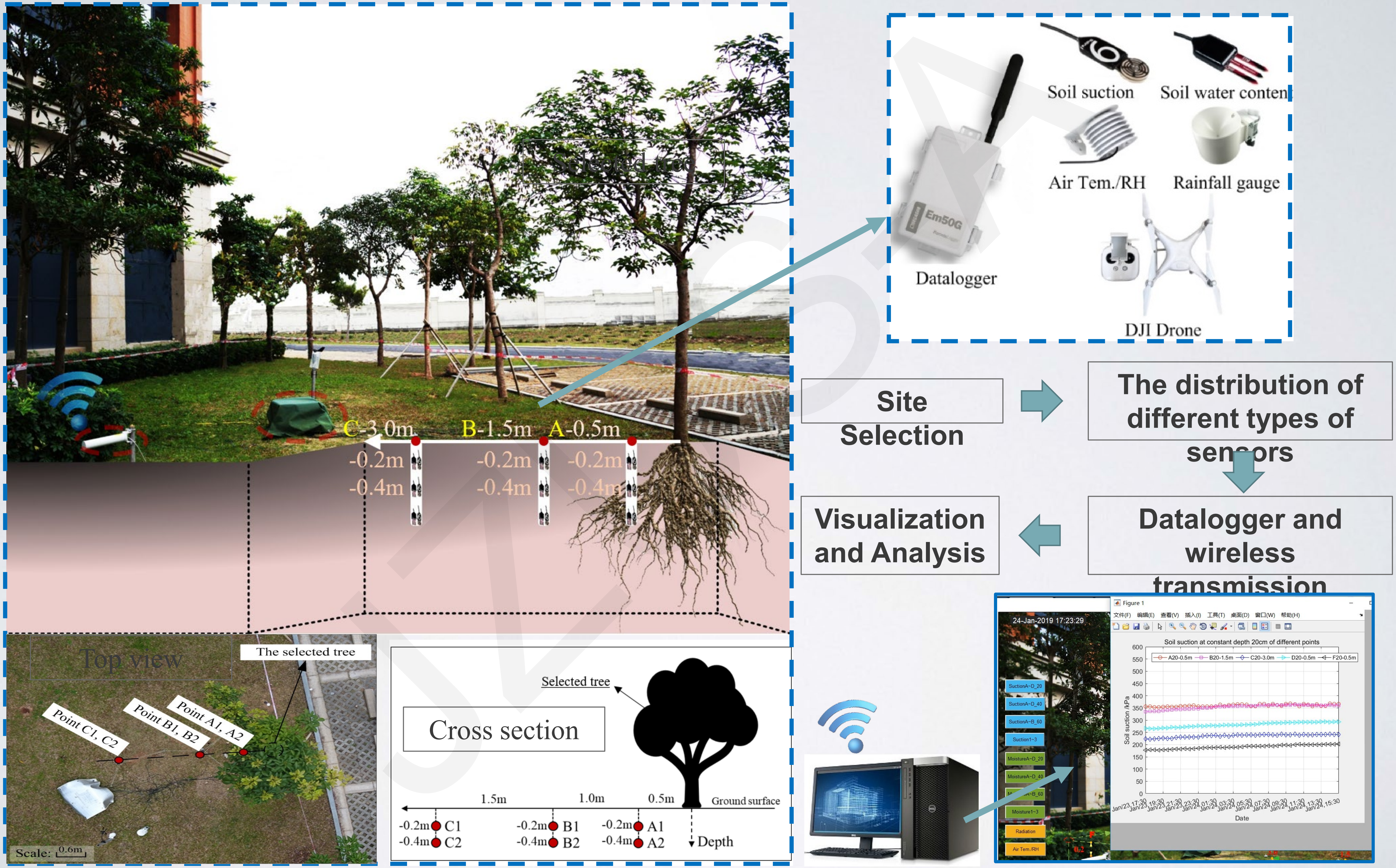
Temperature, Relative humidity, Rainfall, Solar radiation, Wind speed/direction



https://eps.ntu.edu.sg

Vegetation and meteorological parameters can cause great effects on variations of soil suction in soil-vegetation-atmosphere continuum. (Zhou et al. 2019)

Data collection by a field monitoring test

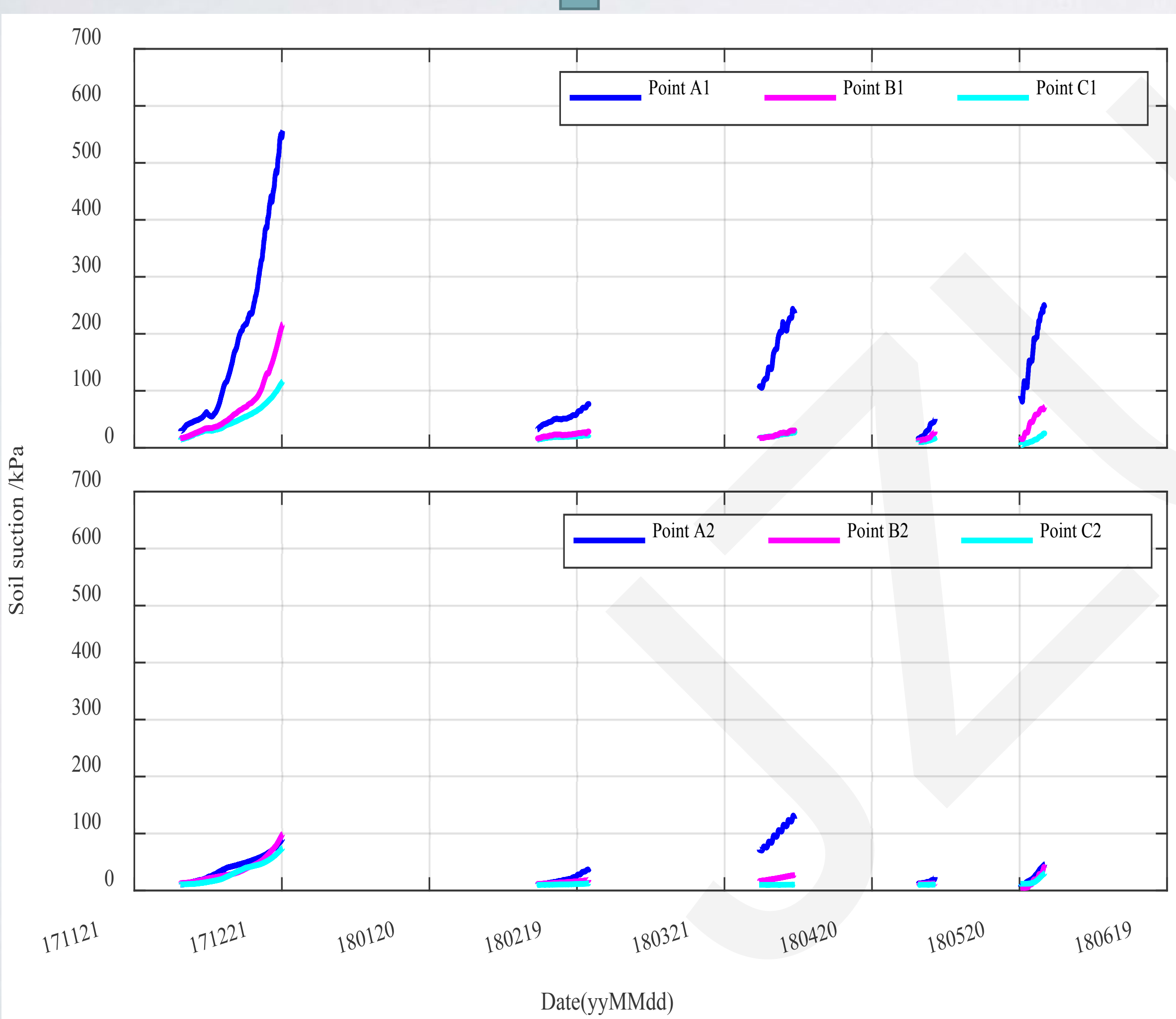


Model development using genetic programming

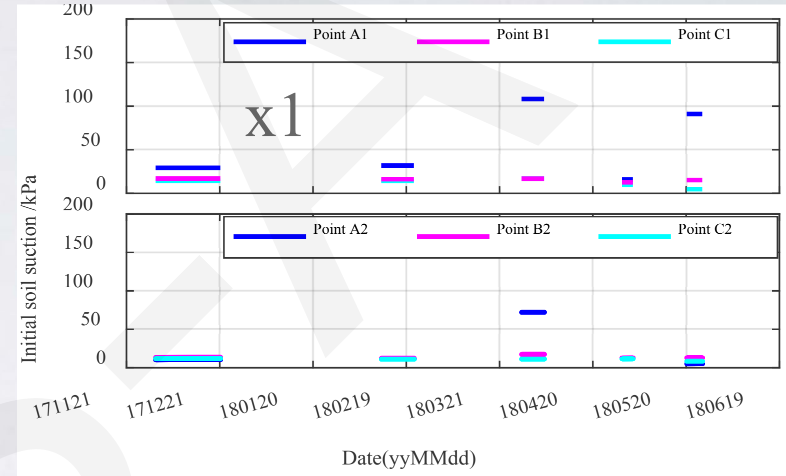
A simplified GP statistical model

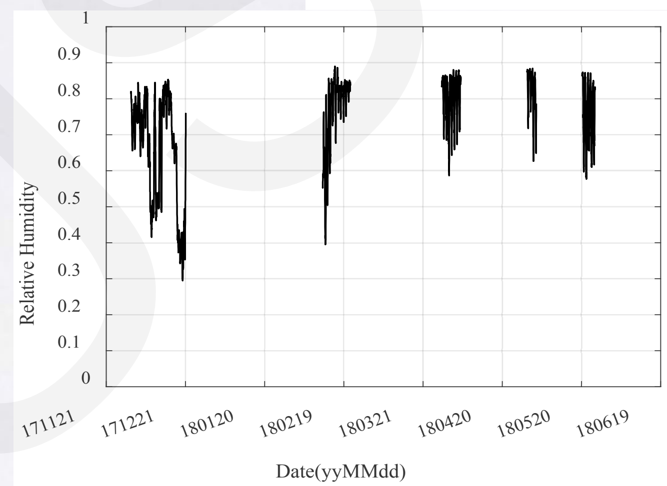
$$y = (2.90e\text{-}6 * x_1 * (x_3 + 61.13) * (x_3/x_4 + 290.32/x_2))/x_5 + 9.15$$

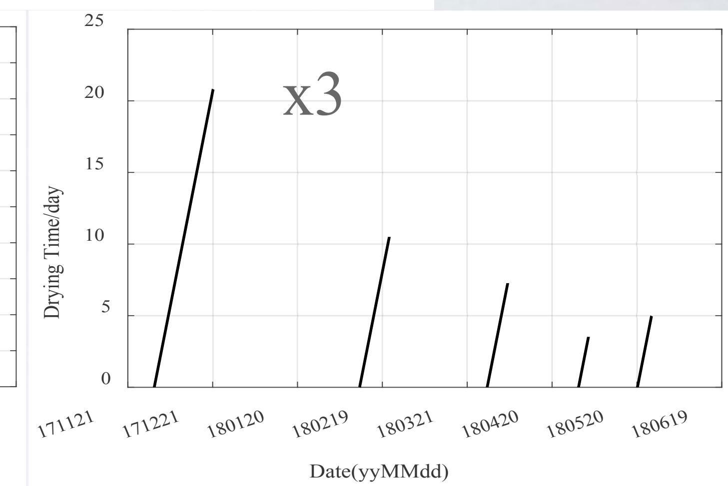
Output setting

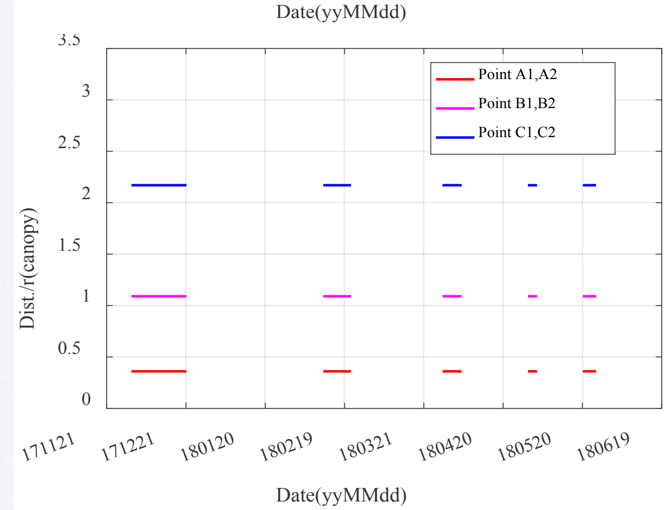


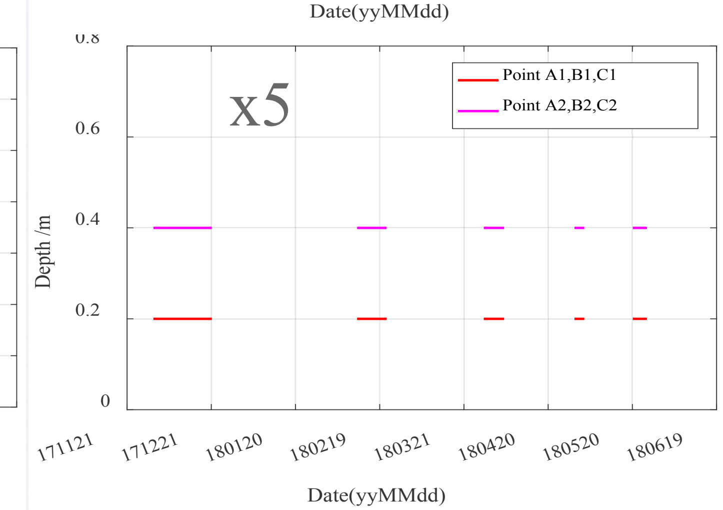
Input setting











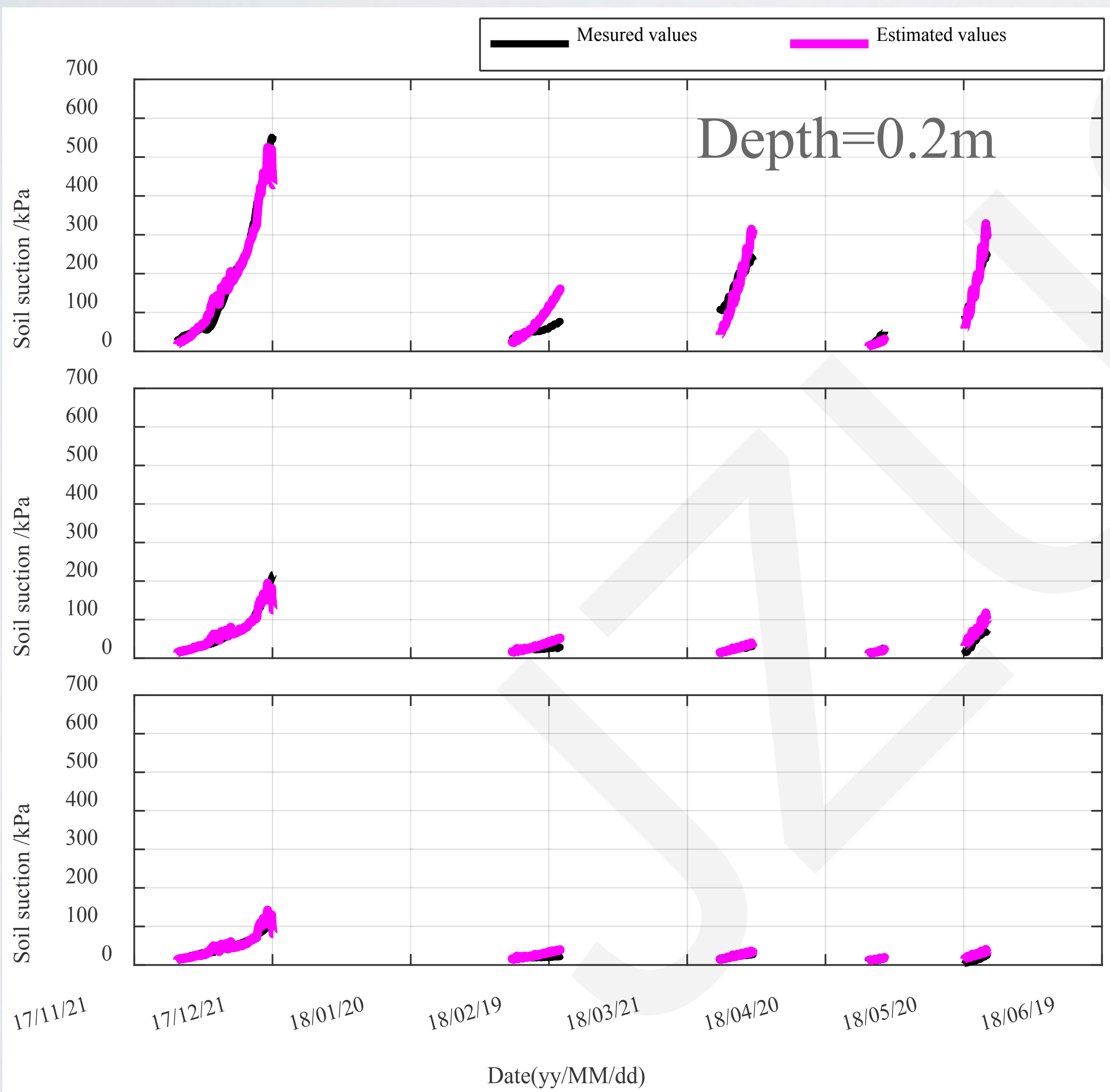
Performance evaluation of the GP model

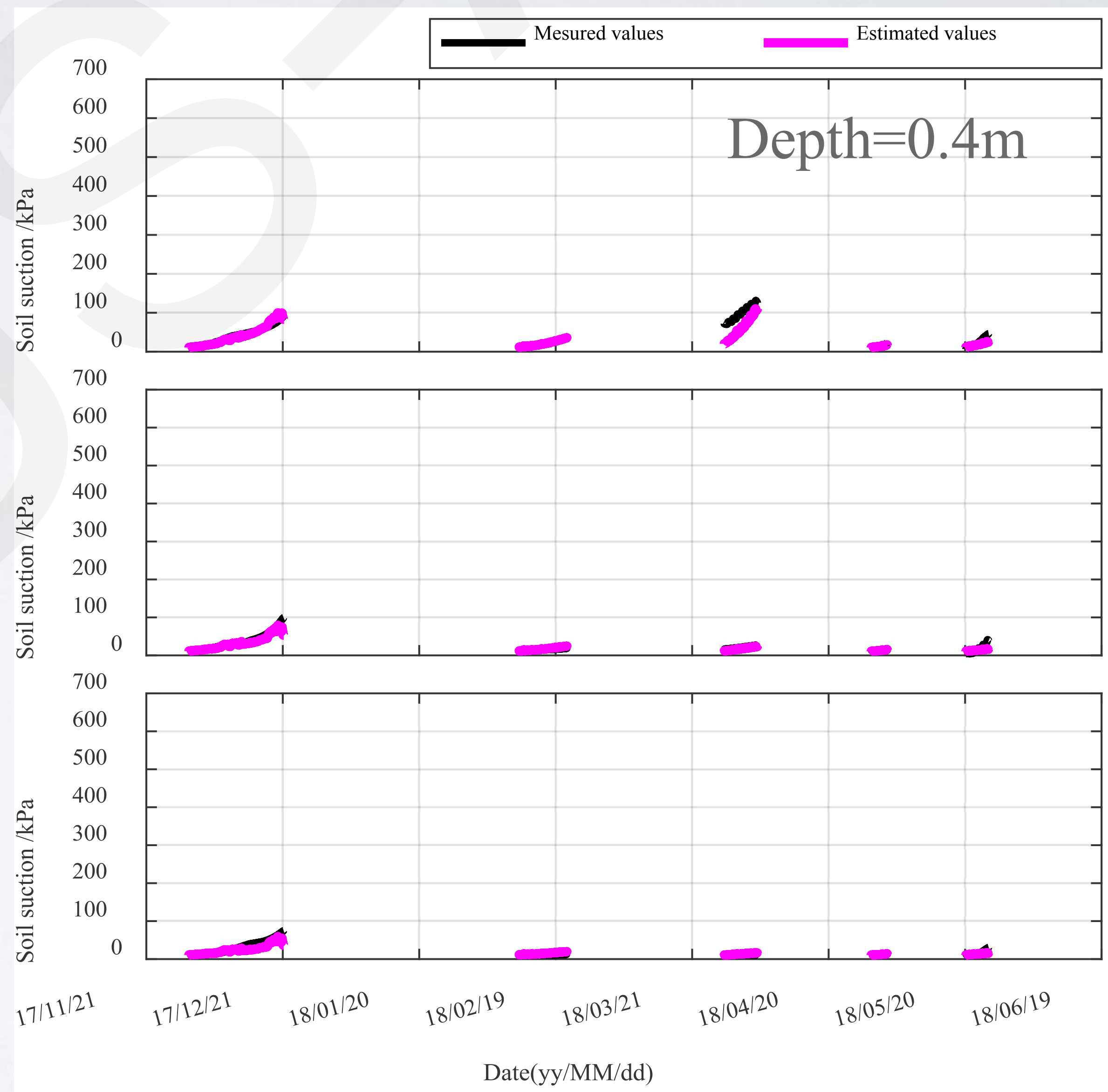
$$R^2 = \left[\frac{\sum_{i=1}^{n}(A_i - \overline{A_i})(P_i - \overline{P_i})}{\sqrt{\sum_{i=1}^{n}(A_i - \overline{A_i})^2 \sum_{i=1}^{n}(P_i - \overline{P_i})^2}} \right]^2$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} \left| P_i - A_i \right|^2}{N}} \times 100$$

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{A_i - P_i}{A_i} \right| \times 100$$

Training data	Testing data
R^2=0.9451	R^2=0.9459
RMSE=17.1824	RMSE=13.8306
MAPE=20.5974	MAPE=37.7543

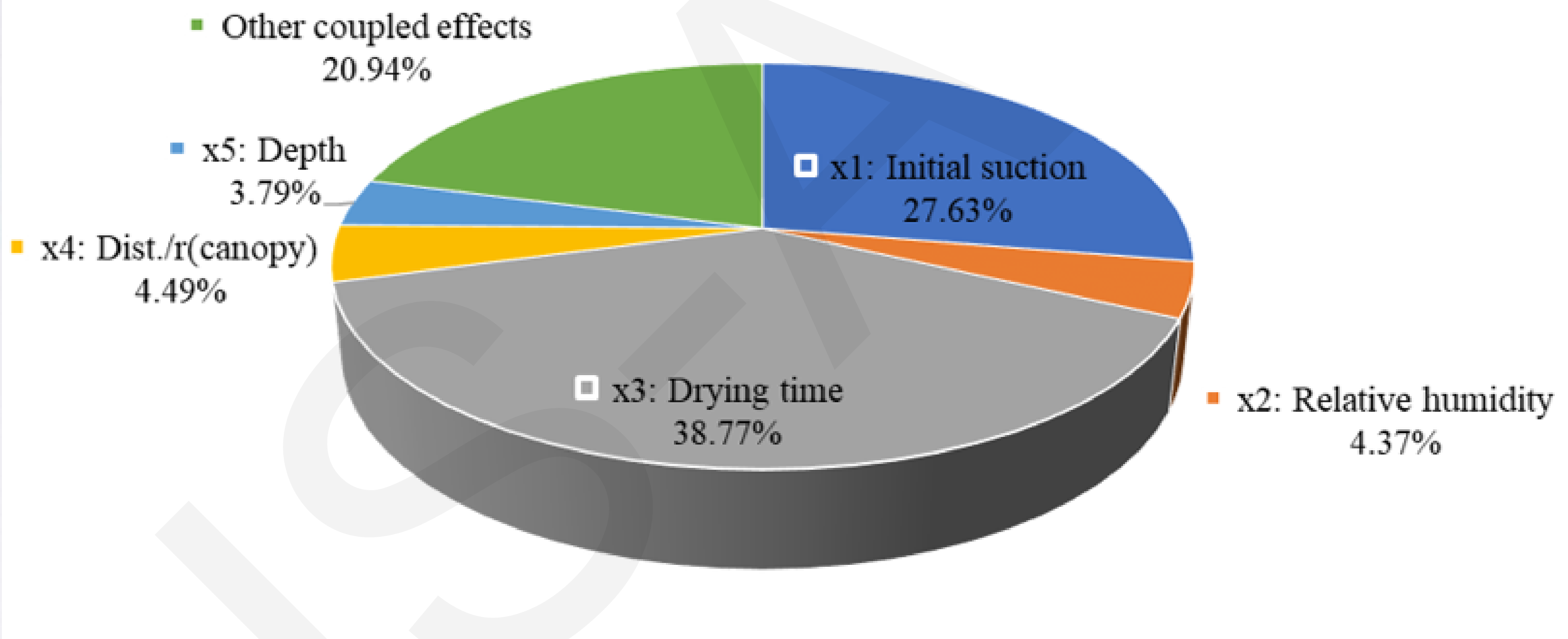




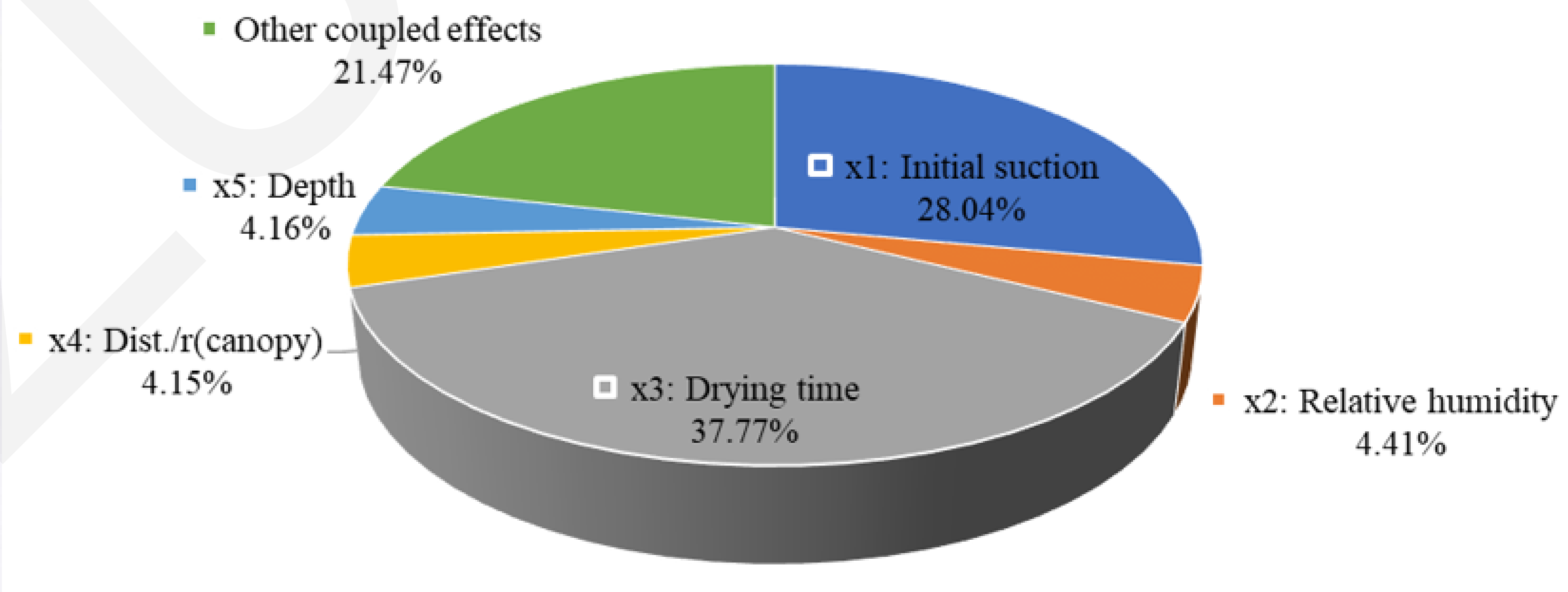
Variance-based global sensitivity analysis

The variance-based global sensitivity analysis with two methods (FAST and Sobol' sensitivity) was performed to analyze the contribution of each input variable to the total variance of the output variable.

Analysis results confirmed that the drying time as the most important input, and the initial suction is the second most influential variable for estimation and prediction of the soil suction in drying cycles based on the obtained simplified GP model.

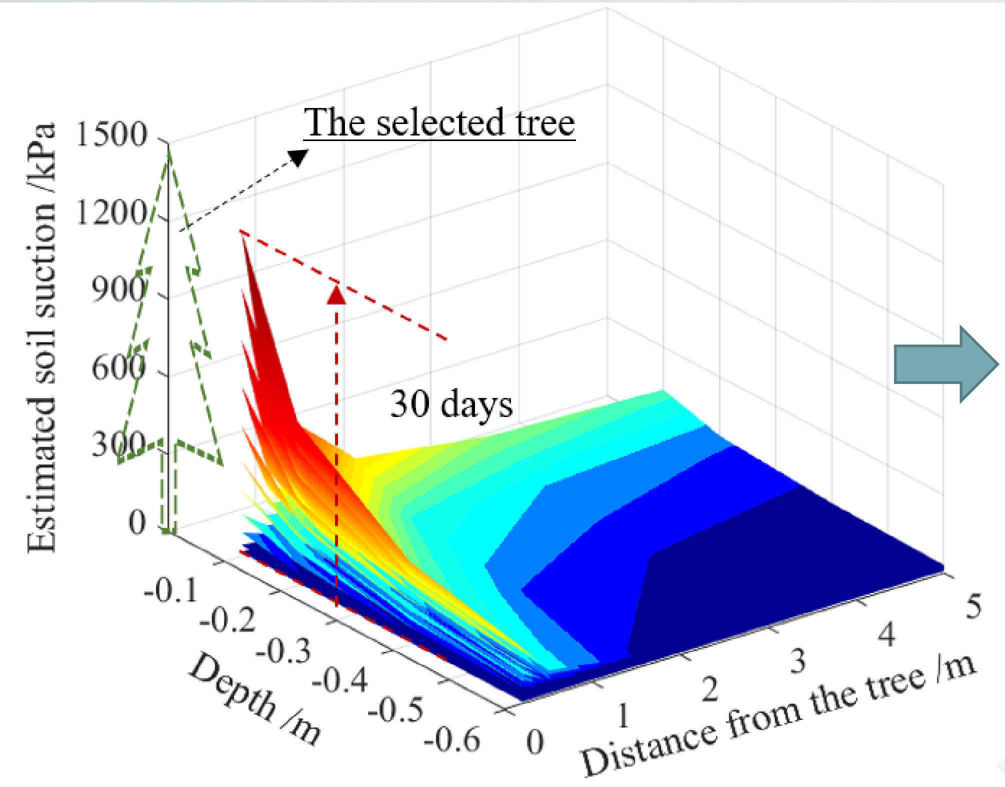


(a) FAST method



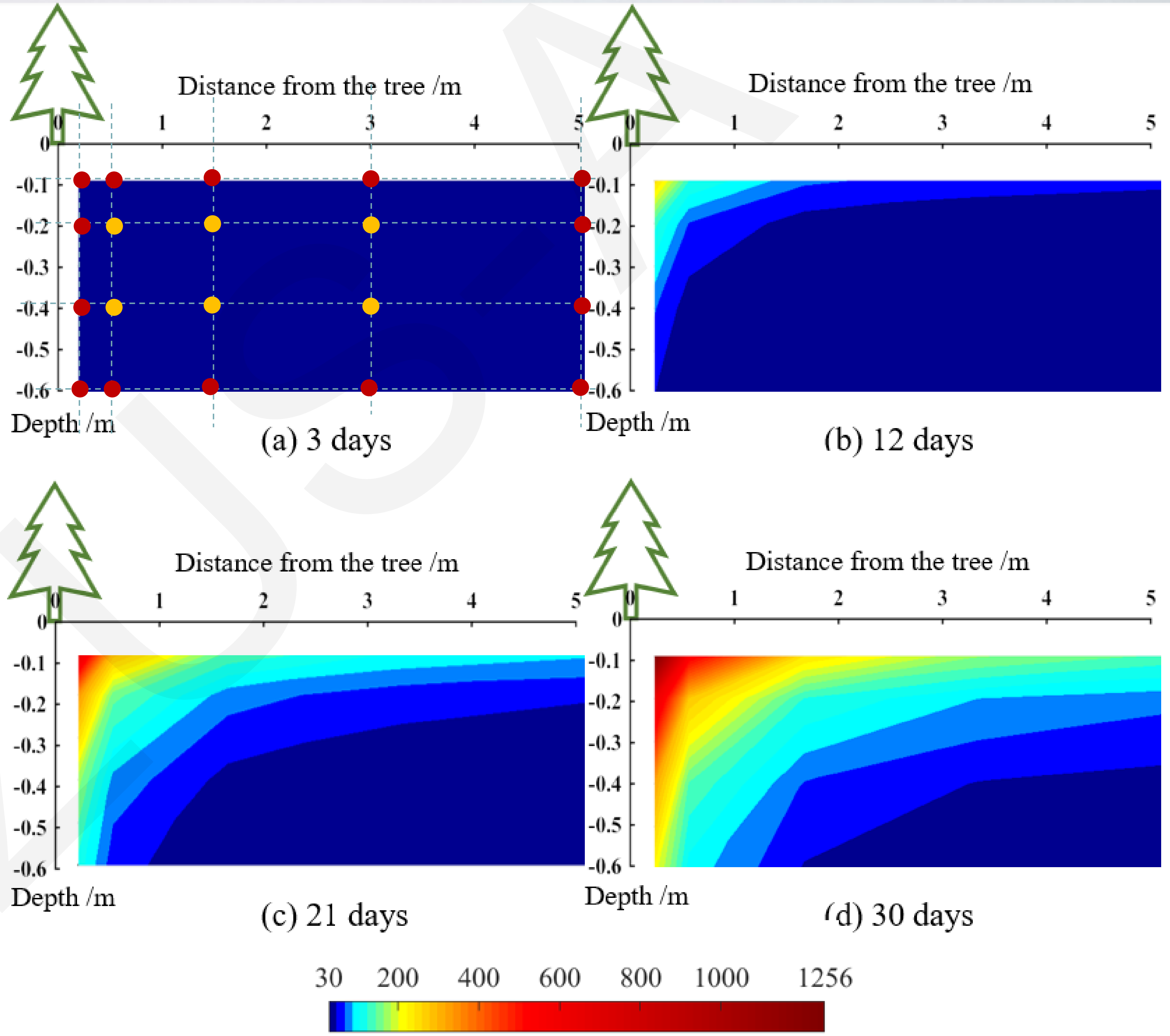
(b) Sobol' sensitivity method

Temporospatial prediction of soil suction variations



Assumed settings of input variable

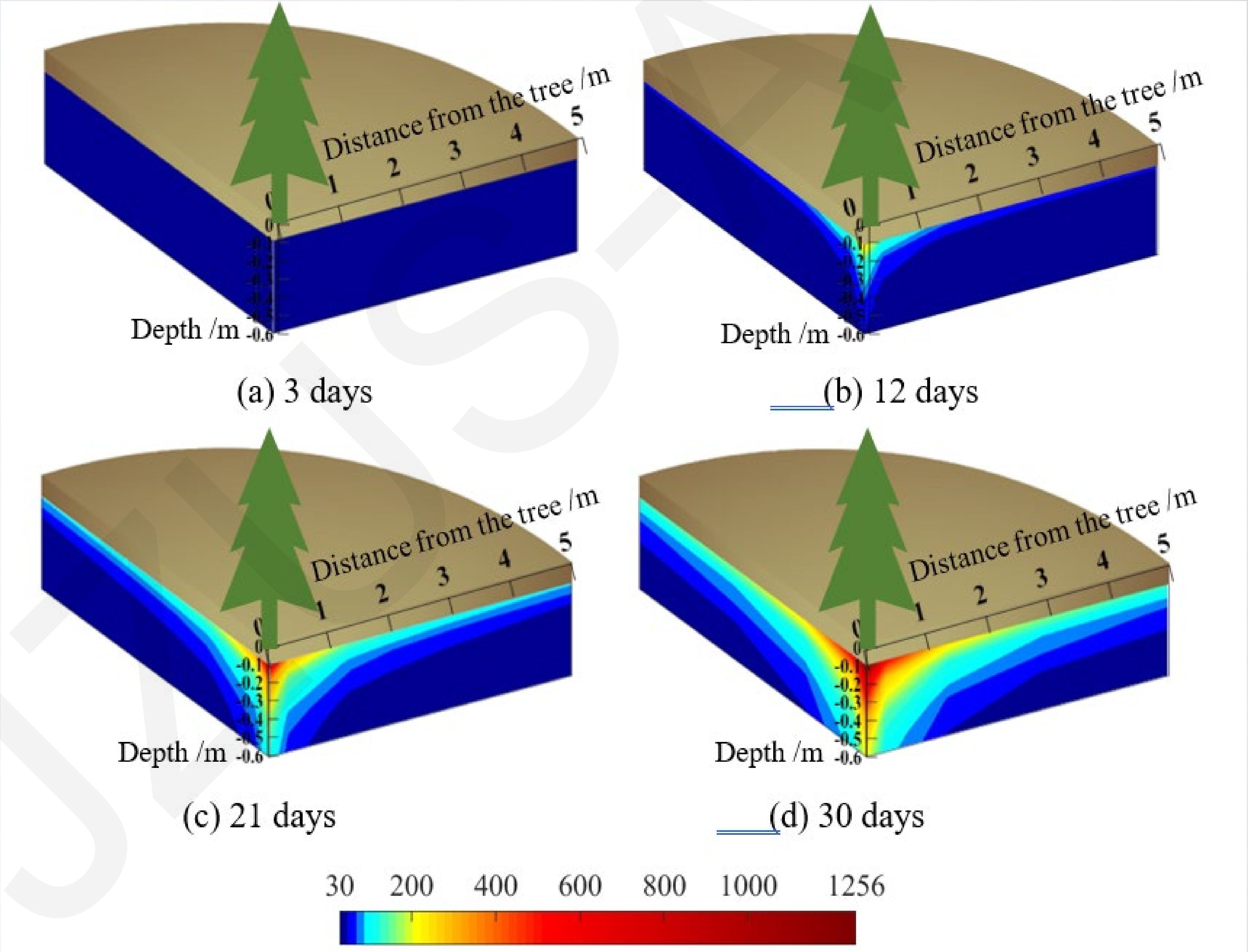
Input variables	x_1 /kPa	x_2	x_3 /day	x_4	x_5 /m
Assumed values	10	0.822~0.791	0~30	0.14, 0.36, 1.09, 2.17, 3.62	0.1, 0.2, 0.4, 0.6



The obtained simplified GP model: $y = (2.90e\text{-}6 * x_1 * (x_3 + 61.13) * (x_3/x_4 + 290.32/x_2))/x_5 + 9.15$

Temporospatial prediction of soil suction variations

If it is assumed that the effect of tree on soil suction at same distances in horizontal direction of 360 degrees is same and the soil physical properties at a certain site around the tree is same, the spatial distribution of soil suction around a tree vicinity can be obtained.



Perspectives and Research Priorities

Research Priorities:

- **Model development using genetic programming for estimation of field-monitored soil suction variations considering the effects of atmosphere and vegetation factors.**
- **The global sensitivity analysis method for importance of each input on output.**
- **Temporospatial prediction of soil suction variations using the proposed GP model.**

This study is an initial step in encouraging the implementation of machine learning approach for efficient safety and risk assessment of geotechnical and green infrastructure by estimation and prediction of several significant soil property parameters (e.g., soil suction and soil water content). The developed GP computational model for describing and predicting the spatiotemporal variations of soil suction indicates a potential to be used as a helpful tool for an assessment of soil parameter variations in a rooted soil.

Relevant literature:

Zhi-Liang Cheng, Wan-Huan Zhou, Ankit Garg. (2020) Genetic programming model for estimating soil suction in shallow soil layers in the vicinity of a tree. Engineering Geology, 268, 105506.