Predicting Regional Soil Moisture Dynamics Using Machine Learning Techniques and A Dense Observational Network

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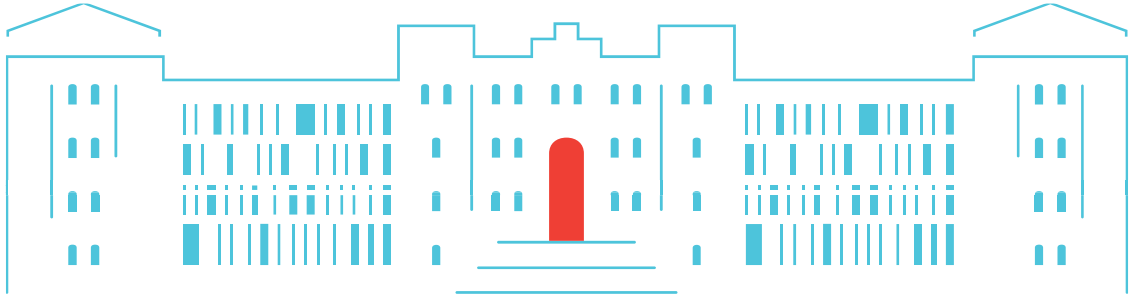

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Introduction & Objectives

- Soil moisture has a direct impact on ecosystem functioning, vegetation and crop production and plays a crucial role in all aspects of land-atmosphere interactions.
- The highly localized and complex nature of soil moisture present a major challenge to its accurate estimation.
- Notwithstanding recent advances in satellite-based monitoring, the temporal and spatial resolution and shallow observation impede their application to mechanistic modelling and to highly resolved applications.

Objectives

- We aim to develop a predictive tool capable of describing the relationship between soil moisture and a wide range of climatic and soil related parameters using AI-based approaches.

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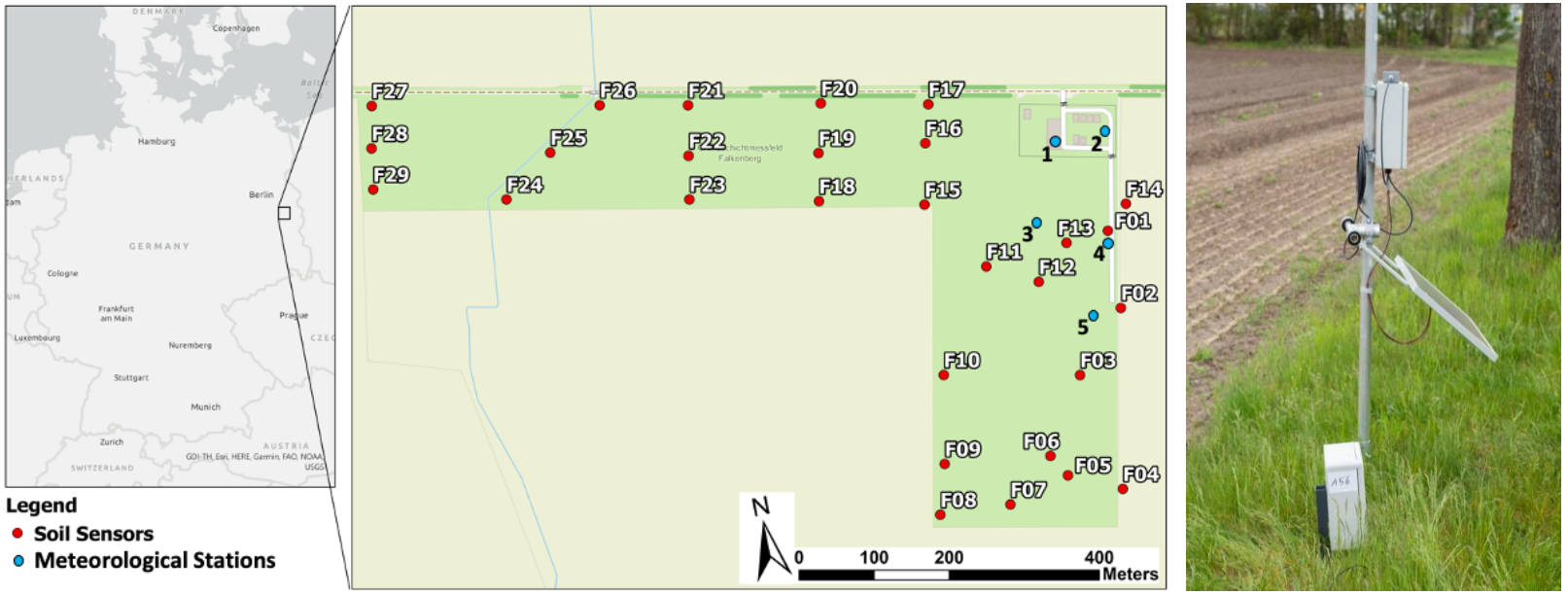
Field Measurement and Data Collection

- We conducted a detailed observational campaign covering about 20,000 m^2 in Falkenberg in Germany as a part of FESSTVaL campaign (https://fesstval.de/) using several sensors measuring a wide range of soil and climatic parameters
- Soil sensors recorded soil moisture, temperature and electrical conductivity with temporal resolution of 10 minutes.
- In five meteorological stations, various climatic parameters were recorded including near surface and air temperature[1], relative humidity[5], wind speed[3], precipitation[2], pressure[1], turbulent fluxes[4], solar and terrestrial waves[4].



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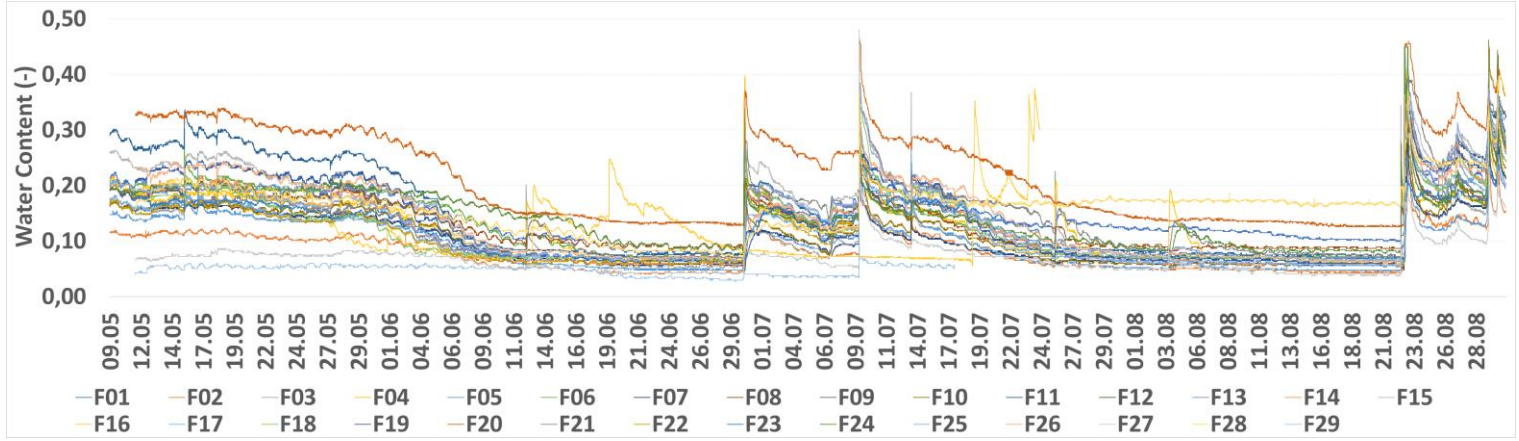
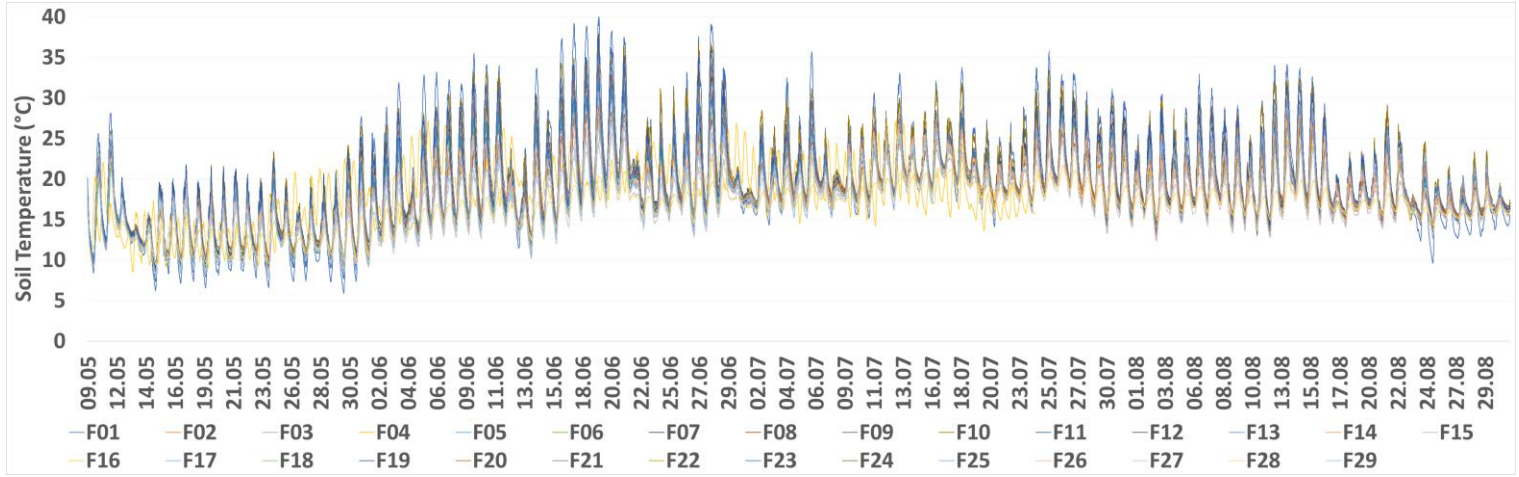
Typical measured soil data

- Typical examples of measured soil water content and temperature over time





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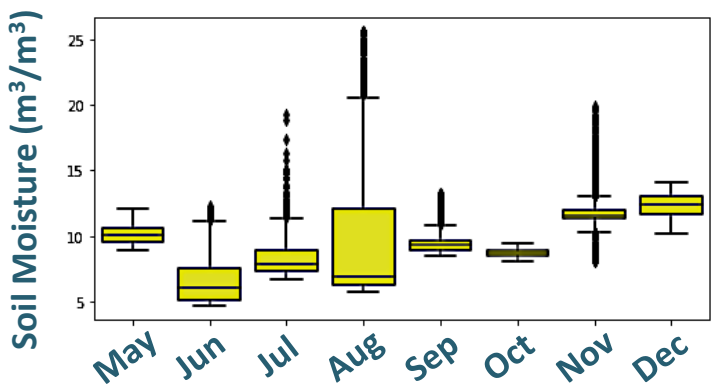
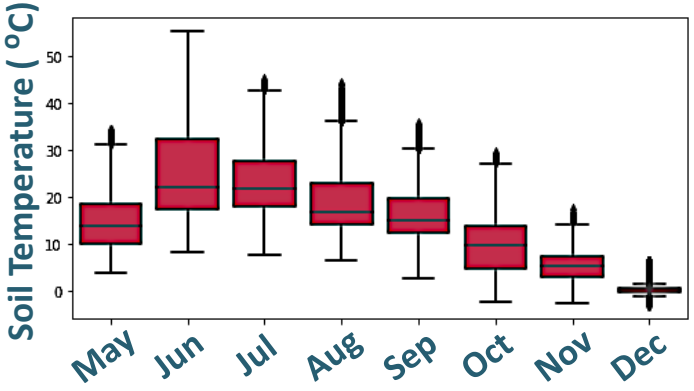
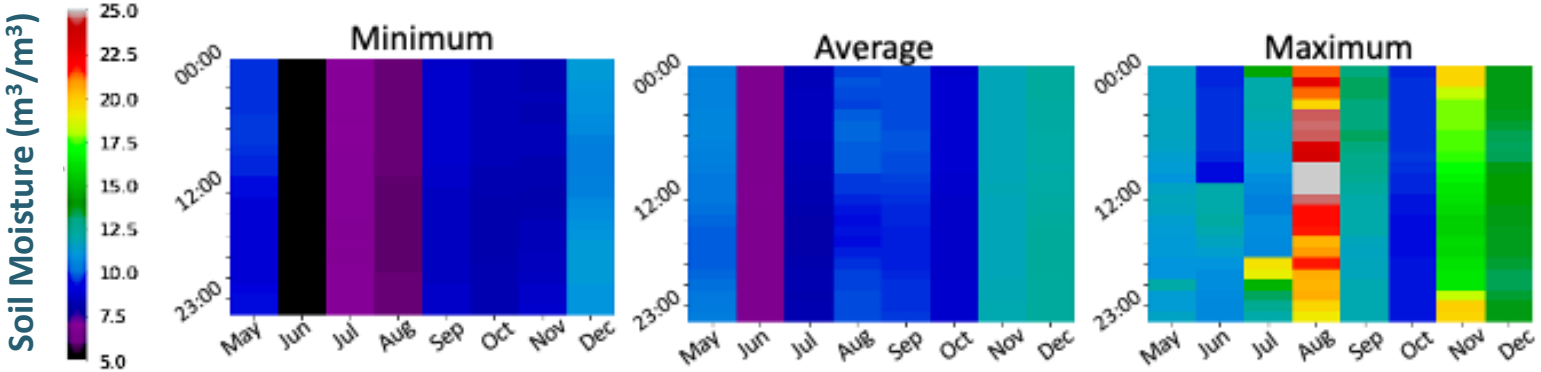
Data Analysis

- Soil moisture and temperature variations during 8 months of year 2021 were analyzed using Python statistical data visualization library, seaborn.





- Boxplots and heat maps are used to illustrate the statistical distribution of measured soil moisture & temperature and the variations of recorded soil moisture at different times of the day. (averaged over each month)



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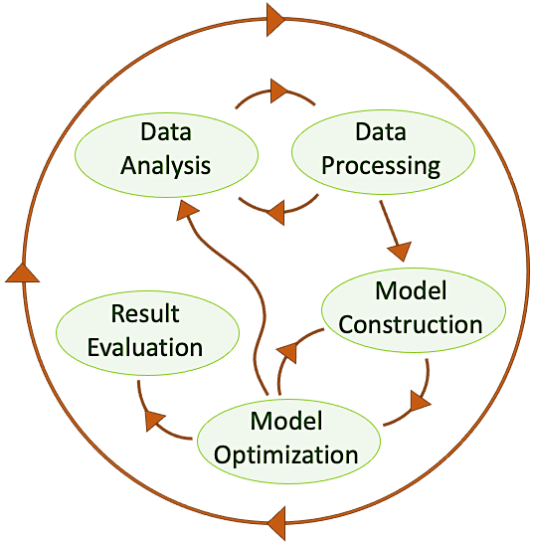
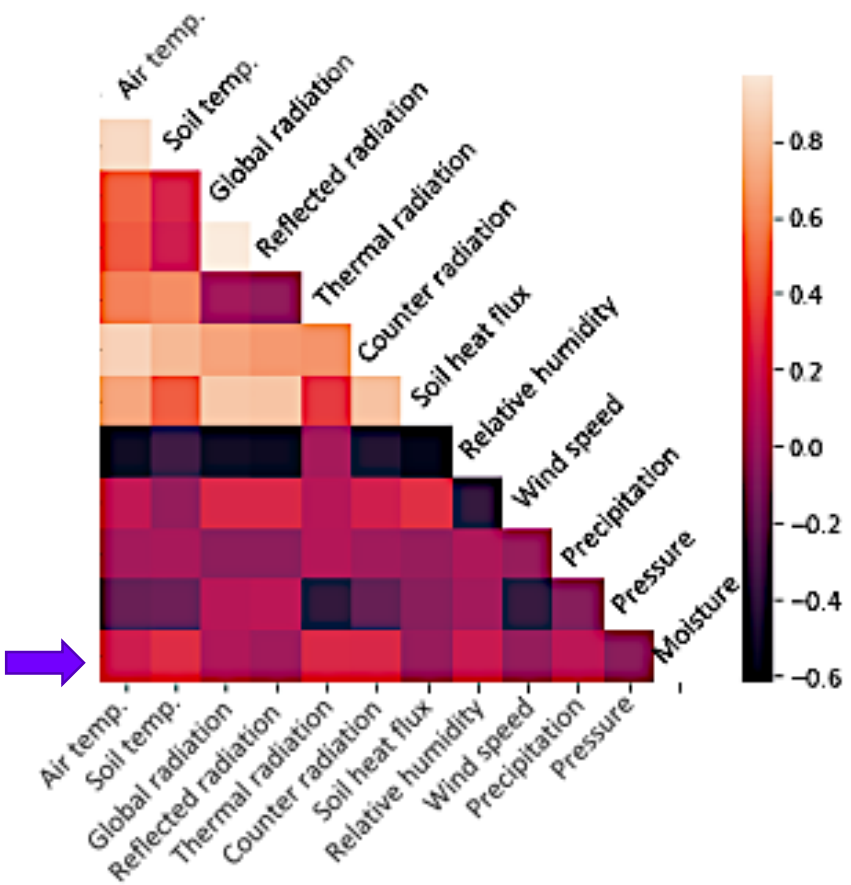
Model Development

- We used Pearson's coefficient to quantify relationships between the variables with +1 and -1 representing a positive and negative correlation respectively, and 0 representing no relationship
- Long short-term memory (LSTM) model was used in our analysis to capture the complex relationship between the soil moisture and predictors. Based on the computed Pearson's coefficients, 9 variables were selected to train models relating soil moisture (target value) to predictors.





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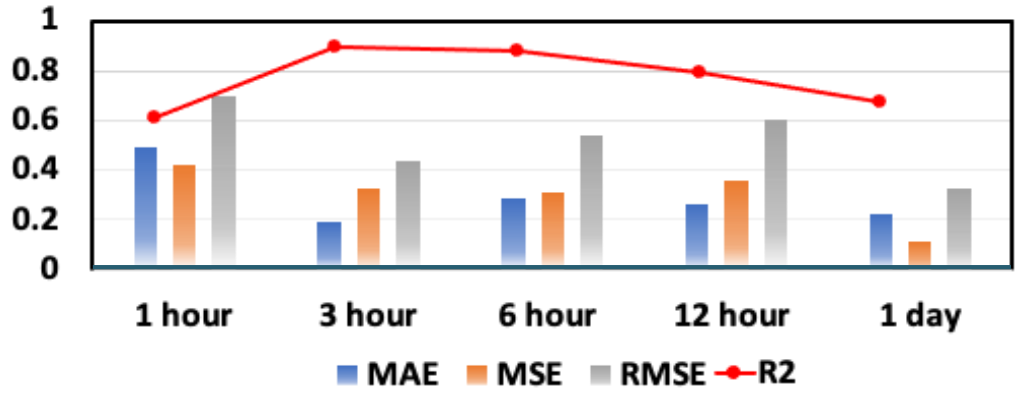
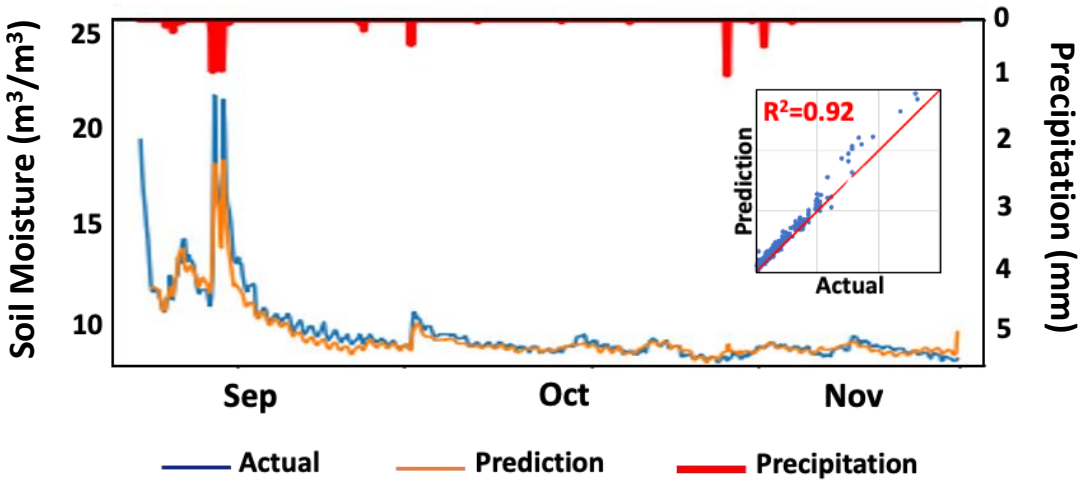
Results & Discussion

- Constructed LSTM model was optimized in terms of structure and computational complexity. Feed data density was a key element influencing computational complexity.
- Robust predictions could be obtained when data measured during one day with a time resolution of 3 hours were used to predict the soil moisture one step ahead.
- Various performance indicators were used to evaluate the performance of trained models. The effect of data density was evaluated via four indicators (Mean Absolute Error, Mean Squared Error, RMSE and R^2). Data density of 3 hours (with R^2 over 90%) was used for the subsequent model training and predictions.
- A typical example of predicted soil moisture dynamics (for one sensor) evaluated against the measured values is illustrated.





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Conclusions and Future work

- AI approaches offer a great potential to predict soil parameters and responses
- Predicting the measured soil moisture by all sensors.
- Developing a general AI-based framework to predict spatial and temporal variations of soil moisture under different climatic conditions.

Thank you!

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