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Catchment scale prediction of soil moisture trends from Cosmic Ray Neutron Rover Surveys using machine learning

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Soil moisture is a critical hydrological component for determining hydrological state conditions and a crucial variable in controlling land-atmosphere interaction including evapotranspiration, infiltration and groundwater recharge.

At the catchment scale, spatial- temporal variations of soil moisture distribution are highly variable due to the influence of various factors such as soil heterogeneity, climate conditions, vegetation and geomorphology. Among the various existing soil moisture monitoring techniques, the application of vehicle-mounted Cosmic Ray Sensors (CRNS) allows monitoring soil moisture noninvasively by surveying larger regions within a reasonable time. However, measured data and their corresponding footprints are often allocated along the existing road network leaving inaccessible parts of a catchment unobserved and surveying larger areas in short intervals is often hindered by limited manpower.

In this study, data from more than 200 000 CRNS rover readings measured over different regions of Germany within the last 4 years have been employed to characterize the trends of soil moisture distribution in the 209 km^2 large Mueglitz River Basin in Eastern Germany. Subsets of the data have been used to train three different supervised machine learning algorithms (multiple linear regression, random forest and artificial neural network) based on 85 independent relevant dynamic and stationary features derived from public databases. The Random Forest model outperforms the other models (R2= ~0.8), relying on day-of-year, altitude, air temperature, humidity, soil organic carbon content and soil temperature as the five most influencing predictors.

After test and training the models, CRNS records for each day of the last decade are predicted on a 250 × 250 m grid of Mueglitz River Basin using the same type of features. Derived CRNS record distributions are compared with both, spatial soil moisture estimates from a hydrological model and point estimates from a sensor network operated during spring 2019. After variable standardization, preliminary results show that the applied Random Forest model is able to resemble the spatio-temporal trends estimated by the hydrological model and the point measurements. These findings demonstrate that training machine learning models on domain-unspecific large datasets of CRNS records using spatial-temporally available predictors has the potential to fill measurement gaps and to improve soil moisture dynamics predictions on a catchment scale.