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Deep learning approach for calibrating Cosmic-Ray Neutron Sensors (CRNS) in area-wide soil moisture monitoring

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Traditional field calibration of cosmic-Ray neutron sensors (CRNS) for area-wide soil moisture monitoring is based on time-consuming and often expensive soil sample collection and conventional soil moisture measurement. This calibration requires two field campaigns, one under dry and one under wet soil conditions. However, depending on the agro-ecological context more field campaigns may be required for calibration, due to for instance crop biomass water interference. In addition, the current calibration method includes corrections considering several parameters influencing neutron counts, the proxy for soil moisture, such as soil lattice water, organic carbon, and biomass which need to be measured.

The main objective of this study is to investigate and develop an alternative calibration method to the currently available field calibration method. To this end, a Deep Learning model architecture under the TensorFlow machine learning framework is used to calibrate the Cosmic-Ray sensor.

The Deep Learning model is built with more than 8 years of CRNS data from Petzenkirchen (Austria) and consists of four hidden layers with activation function and a succession of batch normalization. Prior to build the Deep Learning model, data analysis consisting of pertinent variables selection was performed with multivariate statistical analysis of correlation. Among nine features, five were effectively pertinent and included in the machine learning artificial neural network architecture. The five input variables were the raw neutrons counts (N1 and N2), humidity (H), air pressure (P4) and temperature (T7).

The preliminary results show a linear regression with an R^2 of 0.97 and the model predicted the soil moisture with less than 1% error.

These preliminary results are encouraging and proved that a machine learning based method could be a valuable alternative calibration method for CRNS against the current field calibration method.

More investigation will be performed to test the model under different agro-ecological conditions, such as Nebraska, USA. Further, additional input variables will be considered in the development of machine learning based models, to bring in agro-ecological information, such as crop cover, growth stage, precipitation related to the CRNS footprint.