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Lessons Learned from a Past Series of Bayesian Model Averaging studies for Soil/Plant Models

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In this study we evaluate the lessons learned about modelling soil/plant systems from analyzing evapotranspiration data, soil moisture and leaf area index. The data were analyzed with advanced tools from the area of Bayesian Model Averaging, model ranking and Bayesian Model Selection. We have generated a large variety of model conceptualizations by sampling random parameter sets from the vegetation components of the CERES, SUCROS, GECROS, and SPASS models and a common model for soil water movement via Monte-Carlo simulations. We used data from a one vegetation period of winter wheat at a field site in Nellingen, Germany. The data set includes soil moisture, actual evapotranspiration (ETa) from an eddy covariance tower, and leaf-area index (LAI).

The focus of data analysis was on how one can do model ranking and model selection. Further analysis steps included the predictive reliability of different soil/plant models calibrated on different subsets of the available data. Our main conclusion is that model selection between different competing soil-plant models remains a large challenge, because

1. different data types and their combinations favor different models, because competing models are more or less good in simulating the coupling processes between the various compartments and their states,
2. singular events (such as the evolution of LAI during plant senescence) can dominate an entire time series, and long time series can be represented well by the few data values where the models disagree most,
3. the different data types differ in their discriminating power for model selection,
4. the level of noise present in ETa and LAI data, and the level of systematic model bias through simplifications of the complex system (e.g., assuming a few internally homogeneous soil layers) substantially reduce the confidence in model ranking and model selection,
5. none of the models withstands a hypothesis test against the available data,
6. even the assumed level of measurement noise changes model ranking.

Typically, we found a clear interrelation between the outcome of Bayesian model weights and the models' relative performance with respect to the data that is used for conditioning. All four crop models exhibit a similar ability to fit the soil moisture data because they all share Richards' equation as a common sub-model for soil water movement. Results show that soil moisture has a much lower utility for model discrimination compared to ETa and LAI data (where the considered models disagree the most).

Looking at predictive reliability, we investigated the worth of different data types and packages towards model-predictive reliability for ETa and soil water drainage. Soil moisture alone carries only little information for ETa predictions. In combination with LAI, however, the deeper (15 cm depth) soil moisture data showed a higher data utility than the shallower (5 cm depth) data for predictive reliability. This is related to a better representation of plant-available water dynamics at 15 cm depth and has possible implications on the utility of corresponding remote sensing data that mostly access the shallow soil moisture. LAI could perhaps serve as a substitute for ETa. In contrast to ETa predictions, soil moisture has the largest utility for constraining predictions of soil water drainage because it directly feeds information into the Richards' equation that is used for simulating soil water movement. The best predictive reliability for drainage is obtained when soil moisture observations are combined with either ETa or LAI. This is related to the fact that, for dense crops, these data types help to better constrain the soil water balance.