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Measuring Evapotranspiration of five Alley Cropping systems in Germany using the Eddy-Covariance- and Bowen-Ratio Energy-Balance methods

Christian Markwitz, Alexander Knohl, and Lukas Siebicke
Bioclimatology, Georg-August University, Göttingen, Germany (christian.markwitz@forst.uni-goettingen.de)

The inclusion of trees into the agricultural landscape of Europe is gaining popularity as a source for energy production. Fast growing tree species such as poplar or willow are included as short rotation coppice or alley cropping systems, which consist of tree alleys interleaved by annual rotating crops or perennial grasslands. Estimating turbulent fluxes of those systems using the eddy-covariance- (ECEB) and bowen-ratio energy-balance (BREB) method is challenging due to the methods limitation to horizontally homogeneous terrain and steady state conditions. As the conditions are not fulfilled for those systems the energy-balance is commonly not fully closed, with the non-closure being site specific. An underestimation of measured heat fluxes leads to an overestimation of the latent heat fluxes inferred from the ECEB method.

The aim of our study is to 1) quantify the site specific non-closure of the energy-balance and 2) characterize the performance of both methods, compared to direct eddy-covariance measurements using a high frequency infra-red gas analyzer (LI-7200, Licor Inc.). To assess continuous evapotranspiration (ET) rates on a 30-minute time scale we installed a combined ECEB and BREB system at five alley cropping and five agricultural reference sites across Germany. For time periods of four weeks we performed direct eddy covariance flux measurements for H_2O and CO_2 over one crop- and one grassland alley cropping- and their respective reference systems during the growing season of 2016.

We found a non-closure between 21 and 26 % for all sites, considering all day- and night-time data. The residual energy was highest during the morning and lowest in the afternoon. Related to that the energy-balance ratio (EBR), i.e. the ratio between the turbulent heat fluxes and available energy, was below one in the morning hours and increased slightly during the day up to 1.8, until the EBR decreased sharply after sunset. The EBR correlated to the daily cycle of solar radiation, the main driver of turbulent fluxes. Corresponding, we found an increasing EBR with increasing friction velocity, indicating, that under turbulent condition the energy-balance closure improves. Further, we found that the turbulent fluxes estimated by the BREB method compared well with direct eddy-covariance measurements and that the accuracy improved with increasing sensor distance.

We conclude, when calculating ET rates on a 30-minute time scale using the ECEB method the site specific non-closure should be assessed beforehand by eddy-covariance. In the current study, ignoring the non-closure would have lead to an overestimation of the latent heat flux of about 25 % for the ECEB method. For a longer averaging period of one day the overestimation was reduced to less than 5 %.