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Evaluation of a Modified SEBAL Algorithm to Estimate Actual Evapotranspiration in Cotton Ecosystems of Central Asia using Microwave and Optical Remote Sensing Data

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Being recognized as an essential component of both the water and the energy cycle, actual evapotranspiration (ETa) plays in important role in order to describe the complex interactions within the climate system of the Earth. Here, remote sensing is a powerful tool to estimate regional ETa to support the regional water management. For instance, the water withdrawal of the agricultural sector in OECD countries is on average about 44 %, but in the states of Central Asia it achieves more than 90 %. This fact is identified as one of the main reasons for the increasing water scarcity in this region. An accuracy assessment of the methods used for determining ETa is necessary concerning an appropriate use of the model results to support agriculture and irrigation management.

Within Central Asia the Khorezm region in Uzbekistan is a case study region for the problems of irrigated agriculture. For Khorezm the seasonal ETa based on MODIS data was calculated for the years 2009 – 2011 using a partly modified surface energy balance algorithm for land (SEBAL). SEBAL was implemented based on MODIS time series to calculate the energy balance components like net radiation (Rn), sensible heat (H), latent heat (LE), and soil heat flux (G). Whilst SEBAL is using an empirical equation for the estimation of G, a more physically based method was introduced in this study. This method uses microwave soil moisture products (ASAR and ASCAT-SSM) as an additional model input. The input parameters and the model results of all energy balance components (Rn, H, LE, and G) were intensively validated by field measurements with an eddy covariance system and soil sensors.

The model shows very good performance for Rn with average model efficiency (NSE) of 0.68 and small relative errors (rRMSE) of about 10%. For turbulent heat fluxes good results can be achieved with NSE of 0.31 for H and 0.55 for LE, the rRMSE are about 21% (H) and 18% (LE). Soil heat flux estimation could be improved using the physically based approach. While the empirical equation leads to negative NSE and rRMSE of about 57%, the improved approach shows rRMSE of 35 % and NSE of 0.19. Whereat, the impact of the improvement in G estimation on the ET modelling result is low due the relatively small proportion of G in the total energy balance, compared to the components Rn, H, and LE. For cotton, the seasonal actual ET varies between 500 mm in dry years and 750 mm in years with higher water availability. Hence, water use efficiency is small compared to other irrigated cotton ecosystems with seasonal ET of about 400 mm. Considering the required amount of irrigation water for the entire area of the irrigation system of 10 million ha with a proportion of cotton of about 30%, illustrates the dimension of water diversion in CA. Thus, in the studied case only cotton disturbs the natural cycles by ET in the desert ecosystem. However, for an exact quantification transfer of this method into other irrigated systems of CA, regional meteorological observations are necessary.