Towards quantifying stress factors in wheat and maize monitoring – a comparison of LAI modeled with a mechanistic plant growth model and satellite measurements

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Monitoring above ground biomass production contributes important indicators for crop growth and is thus relevant for numerous agricultural applications such as biomass and yield estimation and farming practices (fertilizing, irrigation).

The study targets the quantification of total growth stress impacts on wheat and maize fields in order to estimate actual biomass production. Two biomass modeling approaches are compared. On one hand the Leaf Area Index (LAI), is modelled using the mechanistic crop growth model CropSyst (LAI_{mod}), on the other hand the LAI will be derived from optical remote sensing data (LAI_{RE}) in form of RapidEye images provided by the RapidEye Science Archive Project (RESA – 50 EE 07010) funded by the BlackBridge AG. Eventually, two estimates for the LAI will be available LAI_{mod} and LAI_{RE}. The advantage of remotely sensed data is that the actual situation of the vegetation is represented, already accounting for a mixture of stress factors. Subsequently the two LAIs will be separately used as input to the CropSyst model in order to estimate biomass production. We state the hypothesis that the biomass calculations of the two model runs differ, whereas the results of the model driven by LAI_{RE} are to be inferior to the model driven by the LAI_{mod}, which is estimated under optimal conditions and accordingly represents the potential biomass. This relation between the two calculations can be used as a first approximation of the actual biomass, without the exact quantification of each possible stress factor.

The study area DEMMIN (Durable Environmental Multidisciplinary Monitoring Information Network) is an agricultural test site hosted by the German Aerospace Center (DLR), which is explicitly used for the calibration and validation of remote sensing applications in the context of ongoing and upcoming research projects (TERENO, CEOS, QA4EO, SMOS). This test site offers a dense environmental monitoring network and excellent coverage of remote sensing data.

In order to estimate potential biomass of the targeted fields the CropSyst model is purely driven by daily meteorological data from the DEMMIN test site. Two model runs are applied, one using mean temperature development and another based on the actual situation 2014. Within this modelling approach the LAI_{mod} is calculated through the accumulation of thermal time (Growing Degree Days), which describes the transition of the plants phenological stages. This approach works well under optimal circumstances but stress factors such as water scarcity, high temperatures, variations of nitrogen and others modify the plants growth and are difficult to account for. Therefore, they are initially neglected in this mechanistic approach. Fortnightly RapidEye data of 2014 is used to estimate the LAI_{RE} by a regression analysis between field measurements and suitable spectral indices (SAVI, NDVI, EVI). Since the beginning of 2014 a extensive field campaign is being conducted on multiple wheat and maize plots, where an established sampling scheme with each three repetitions is applied. On these plots weekly measurements were and are recorded using the LAI2000 device, so that a time series will be available for the complete growth cycle of 2014. Additionally plant nitrogen content and plant height are measured weekly. In June 2014 the LAI was scanned manually on six wheat and three maize plots to calibrate the handheld sensor.

The presented research is subject to an ongoing master thesis in the framework of a new Sentinel mission preparatory project. At present the climate data based model runs are established and the field data is processed for the derivation of the LAI. Further research has to be dedicated to identify the explicit stress factors, which the LAI accounts for. For the quantification of water, heat and nitrogen stress this can be accomplished by running multiple complete CropSyst models, including the estimation of the above mentioned stress factors resulting in the actual biomass. Other stress factors will be difficult to account for without changing the model to a more physical based approach. The DEMMIN test site offers optimal conditions to supply the adequate environmental information leading the way to achieve these objectives.