IP i3: OBIA4RTM - Object-based plant parameter retrieval using radiative transfer modelling of vegetation

Course: Integrated Project: Interdisciplinary | Integrated | Interactive

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Introduction

The accurate and reliable assessment of crop parameters such as the leaf area index (LAI) provides essential information about plant growing conditions for wider areas. Such information is highly required by farmers to adopt farming measures accordingly.

Optical remote sensing provides comprehensible, reproducible methods to determine plant parameters by means of radiative transfer modelling (RTM). Through their underlying physical equations, RTM are nearly universally-applicable and have proven successfully in many agricultural applications (Atzberger, 2013; Jacquemoud et al., 2009). However, the solution of the inverse problem to retrieve e.g. the LAI from optical imagery using RTM is not well posed (Larsen, 1975). To overcome the ill-possedness of radiative transfer theory the introduction of spatial constraints was identified by Atzberger (2004) as a promising approach to enhance retrieval accuracy. This finding was confirmed in the literature (Atzberger & Richter, 2012; Laurent, Schaepman, Verhoef, Weyermann, & Chávez, 2014; Laurent, Verhoef, Damm, Schaepman, & Clevers, 2013). Therefore, the object-based image analysis (OBIA) paradigm (Blaschke et al., 2014) seems to offer potentials for improved plant parameter derivation. Moreover, the usage of image objects instead of single pixels allows for generating information more tailored to actual user requirements: Human beings tend not to think in pixels but about graspable objects such as single field parcels (Couclelis, 1992).

Although there are obvious advantages of using RTM and OBIA in a combined manner, to the author's best knowledge, no ready-to-use solution exists to derive plant parameters from optical imagery based on image objects rather than single pixels. Therefore, the OBIA4RTM software tool was recently proposed (Graf & Papp, 2019).

This study aims to apply the proposed approach for the first time to agricultural land with in-situ reference data. The focus will be on the derivation of the LAI using the widely used ProSAIL model (Jacquemoud et al., 2009). In addition, the creation of a prototype will help to better match the needs of the target group, farmers.

In this extended abstract, the materials and methods to be used in the study are presented and an overview of the expected results is given.

Material and Methods

For this study, an agricultural area in southern Germany will be investigated for which in-situ LAI measurements are available on selected areas for three types of fruit (winter wheat, winter triticale and maize silage). The measurements were collected by the Department of Geography of the LMU Munich in 2017 for the duration of one vegetation period in one to two weekly intervals (Danner, Berger, Wocher, Mauser, & Hank, 2019). A map of the study area is given in Figure 1. Figure 1 shows the location of the single field parcels (N=5) as well as the position of the LAI sampling points. The LAI was measured using a LI-COR LI-2200-C Plant Canopy Analyser. Despite the availability of in-situ reference data, the selected study area is assumed to reflect typical mid-latitude agro-ecosystems in terms of fertilizer usage and pesticide application (Graf, Kausch, Bach, & Hank, 2019).

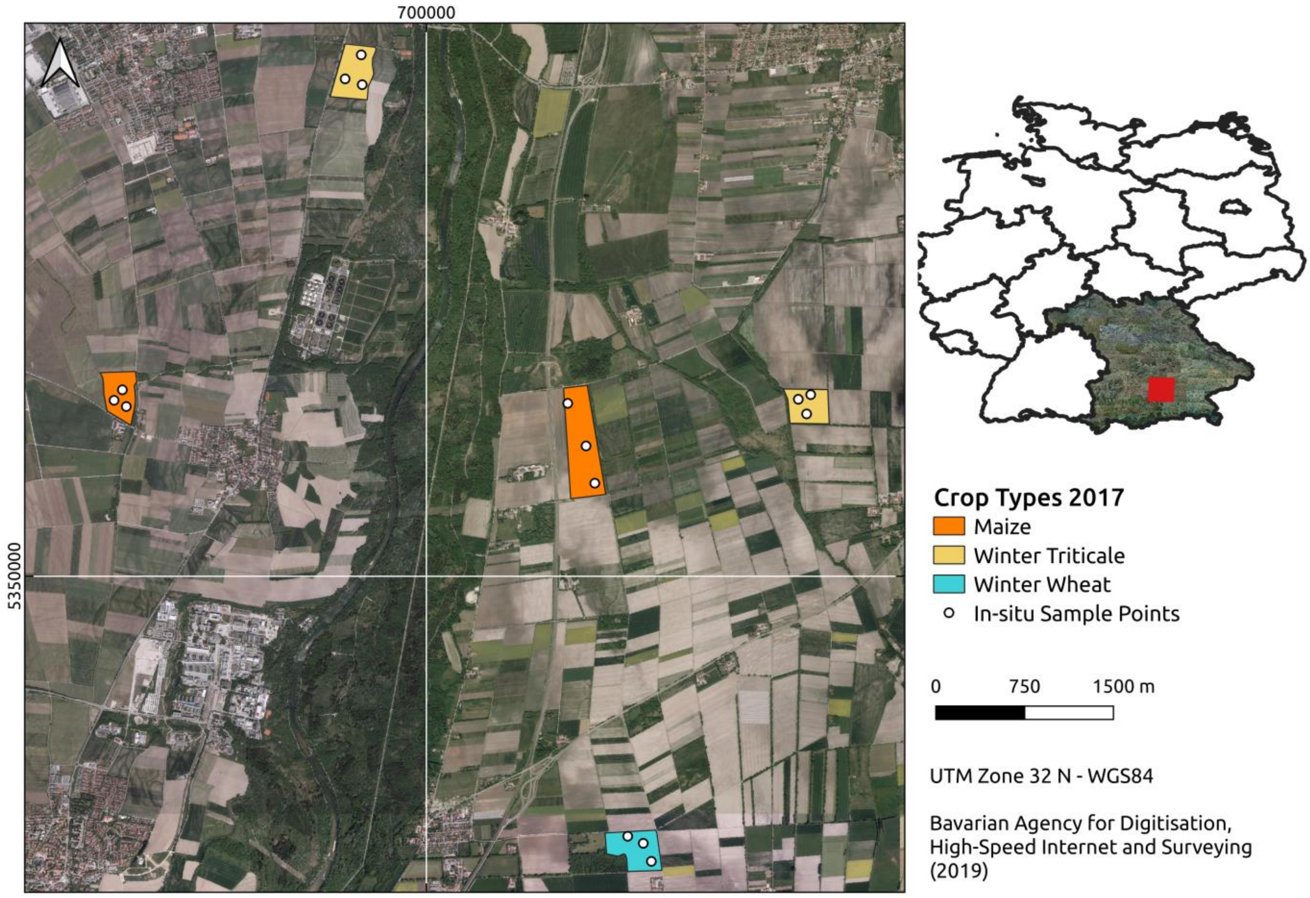

Figure 1: Overview map showing the location of the LAI in-situ sample points and the location of the study area in Germany (right).

To conduct the LAI retrieval, the open-source OBIA4RTM software will be used. OBIA4RTM is free for non-commercial research and education written in Python 3.x and makes use of geospatial databases (PostgreSQL with PostGIS extension) in a fully Open-Geospatial-Consortium (OGC) compliant way.

Sentinel-2 data are used as satellite images, which are characterized by high spectral and spatial resolution and are used operationally in farming applications. The data is pre-processed using the Google Earth Engine interface provided by OBIA4RTM: This includes an atmosphere correction with the atmospheric radiation transfer model 6S (Kotchenova, Vermote, Matarrese, & Klemm, 2006) as well as cloud and cloud shadow masking. The pre-processed satellite data is passed to the OBIA4RTM back-end database on the per-field level using the average reflectance per field. For each cloud free acquisition date, a lookup-table is generated from ProSAIL forward runs containing synthetic satellite spectra for the single crop types. The synthetic spectra are compared to the observed satellite spectra using a cost function. For reasons of simplicity, the root mean squared error (RMSE) will be used to find the closest match between simulated and observed spectra. Such a lookup-table based inversion has proven successfully in many scientific studies to invert RTM.

The retrieved LAI values are stored in the database to allow for time series analysis and dissemination of the results using OGC-compliant web-services such as the OGC Web Feature Service (WFS).

Expected Results

The usage of image objects instead of single pixels during the inversion process is assumed to suppress noise inherent in the satellite imagery and to effectively address the ill-posed nature of radiative transfer theory. Therefore, more stable as well as accurate results are expected compared to pixel-based approaches. OBIA4RTM could consequently contribute to enhance the capacities of individual farmers to adopt their farming practice to current crop growing conditions. This could result in reduced fertilizer and pesticide supply and mitigate harmful impacts of agriculture on the environment and human health.

Moreover, image objects provide richer opportunities for human interpretation and integration into existing GIS environments which are increasingly important for digital farming. The OBIA paradigm has shown to deliver more meaningful information to decision and policy makers than pixel-based approaches (Fisher, 1997) and could therefore enhance the capacity of farmers to better understand the information derived from remote sensing.

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