Poster: Towards in-situ Sensor Network assisted Remote Sensing of Crop Parameters

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ABSTRACT

Remote sensing data acquired from satellites are a vital information source for precision agriculture to assess current crop conditions. Field measurements of plant parameters, like the leaf area index (LAI), serve as a crucial basis to validate parameter maps derived from satellite images. Traditionally, in-situ LAI measurements are collected manually. Therefore, the assessment is cost-intensive and the temporal availability of measurements is limited. Measurements provided by small sensor devices organized in a wireless sensor network (WSN) are a low-cost alternative to manual field measurements. They allow a precise LAI determination with high temporal resolution at many different locations in a field or even an entire region. These information are highly demanded for the validation of spatial information on crop conditions derived from image data acquired by modern satellites like Sentinel-2.

CCS Concepts

•Networks → Sensor networks; •Applied computing → Agriculture;

1. INTRODUCTION

Agriculture will face different challenges caused by climate change and the rapid increase of the world population. Agricultural management has to consider these changing conditions by selecting adapted crop types and applying modified irrigation and fertilization techniques to increase yields. In 2012, the European Commission already declared the further development and the rapid diffusion of sustainable agricultural practices and precision agricultural approaches as two of the major objectives in the coming decade [3]. Remote sensing is a key technology in precision agriculture because proximal, air- and spaceborne sensors provide spatial, spectral, and temporal information of agricultural fields that can be used to identify infield variability and support decision-making. Empirical-statistical regression and radiative transfer models allow to link remote sensing data with in-situ measurements for the spatial assessment of crop characteristics like biomass, LAI, and fraction of absorbed photosynthetically active radiation (fPAR). The LAI is one of the most important plant parameters and defined as the ratio of the total one-sided leaf surface area per unit soil surface area. As an indicator for the current biotic and abiotic conditions, the LAI provides information about the photosynthetic 'potential' of plants and is an important parameter for yield modeling.

Nowadays, the LAI is usually measured by hand with specific instruments on the ground. This method is very time consuming, costly, and often limited to small areas [2]. Hence, there is a need for advanced sensor technology to spatially explore the bio-physical and bio-chemical characteristics of crops in the field with suitable temporal resolution. This paper gives an overview about common procedures of linking remote sensing data with LAI, manually measured in the field, and additionally outlines a new approach using a WSN that enables autonomous LAI measurements at distinctly higher temporal and spatial resolution.

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2. SPATIAL ASSESSMENT OF LAI

2.1 Linking in-situ LAI Measurements with Remote Sensing Data

In recent years, two complementary groups of approaches have been developed for LAI estimation from remote sensing data. On the one hand, the inversion of physically based radiative transfer modeling approaches provides the possibility to retrieve the LAI and other vegetation parameters [7]. On the other hand, empirical-statistical regression models can be calibrated with in-situ LAI measurements to establish a relation to reflectance spectra or spectral vegetation indices [6]. In both ways, the in-situ assessment of LAI is a prerequisite for model calibration, validation, or both.

2.2 Traditional in-situ LAI Assessment

Various methods for LAI determination exist, differing in the type of measurement methodology and the requirements of the technical equipment [2]. Destructive methods for measuring LAI generally provide more precise results, but the assessment is time consuming, expensive, and therefore often limited to small areas. The increasing use of non-destructive measuring devices in recent decades has significantly improved the in-situ assessment of LAI. These devices use the absorption of irradiance by plants to estimate the LAI. However, the measuring devices are relatively expensive and manual in-situ measurements are still necessary.

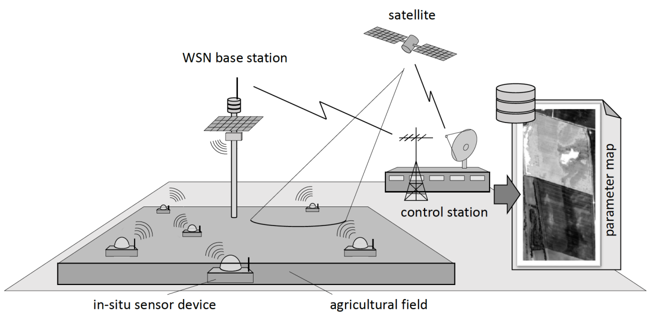

Figure 1: Joined LAI assessment enabled by in-situ WSN monitoring combined with remote sensing. Fusing the data derived by both methods provides validated parameter maps of the agricultural field.

2.3 wireless sensor network for in-situ LAI Assessment

The plurality of low-cost, low-power, and resource-constrained sensor devices, wirelessly interconnected in a self-organizing manner, forms a WSN, cf. Fig. 1. Environmental sensing and data collection as well as data transmission to a dedicated base station, generally via multi-hop communication, is the main task of each individual sensor device whose sensing accuracy might be rather limited. However, this limitation is compensated by the large number and the spatial density of collaborating sensors within WSNs. WSNs are designed for large-scale, long-term, and mostly unattended deployments and, thus, tailored for in-situ monitoring applications, in particular in the area of precision agriculture.

First experiences and challenges of WSN research in that area emerged with a preliminary deployment a decade ago [4]. These challenges comprise robustness and reliability of the network mainly caused by energy constraints and impacts of a harsh outdoor environment. Indeed, with further progress in this research domain, more agriculture deployments and testbeds were developed and first commercial solutions arise. However, these WSNs mainly focus on soil moisture and climate monitoring applications. Only few approaches exist that take crop parameters such as the LAI into account, e.g., [1, 5, 8]. In [1], we presented fundamental investigations of commercial off-the-shelf sensor hardware for the non-destructive LAI assessment and highlighted its great potential for WSNs. Moreover, we describe a basic setup of a future deployment which consists of a base station (possibly with UMTS uplink) above canopy level and several sensors below the canopy in order to gather the plants' transmittance of irradiance, as outlined in Figure 1.

3. COMBINING WIRELESS SENSOR AND REMOTE SENSING TECHNOLOGY

The combination of in-situ LAI measurements provided by WSNs with optical satellite data from satellites (cf. Fig. 1) like Sentinel-2, which is part of the European Union Copernicus program, enables the monitoring of agricultural fields with high temporal and spatial resolution. A first study [5] linking LAI data from a WSN with satellite data has already been presented. It shows the potential and the practicability of LAI measurements from a WSN as validation basis for LAI maps derived from satellite images. Sentinal-2A (launched in June 2015) in combination with its identical sister satellite Sentinel-2B (planned launch 2016) will allow image data acquisition of the same location of the Earth's surface every five days. The high temporal resolution, the spatial coverage and the spectral characteristics of Sentinal-2 are well suited to establish a long term monitoring system of agricultural crops. Therefore, the linkage of satellite images with WSN technology can make a valuable contribution in precision agriculture to develop and apply optimal management strategies for agricultural fields.

4. CONCLUSIONS

The validation of maps derived from satellite images that provide information about the spatial distribution of plant parameters is still a major challenge in precision agriculture. Often, there is only a small number of in-situ measurements available that can be used for validation. This paper highlights a concept based on WSN technology which enables the autonomous LAI assessment of an agricultural field with high spatial and temporal resolution. Thus, it will be possible to simultaneously collect in-situ LAI measurements of several locations within a field at the time of satellite overpass. Therefore, the use of WSNs in precision agriculture can partly substitute manual field measurements. This will allow a more precise validation of the high temporal and spatial resolution information of agricultural fields provided by Sentinel-2A and B in near future.

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