doi:http://dx.doi.org/10.15414/afz.2015.18.si.68-70

Field spectroscopy for precision organic production

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Field spectroscopy performs non-destructive chemical measurements without manipulating the measured materials, while providing the possibility of a broad spatial overview and a high temporal flexibility of measurements. High-resolution remote sensing applications can consolidate sustainable, prevention- and precision-oriented crop management strategies by decreasing their production risks. In this short communication technical aspects and research focuses of high resolution remote sensing in context of sustainable agricultural applications are presented. More detailed we focus on narrow band indications in the range of 400–1100 nm which are anticipated to become the basis of the next generation of commercialized agricultural sensors due to their cost-efficiency, non-saturating behavior and high sensitivity. Non-scanning snapshot hyperspectral imaging spectroscopy may enable researchers to overcome the gap in the “point-pixel-image”-upscaling of proximal remote sensing, while providing a flexible solution for regular field applications such as soil and/or physiological vegetation paremeters.

Keywords: field spectroscopy, proximal sensing, sensors, precision farming

1 Introduction

When spectral and spatial field information are requested on regular temporal basis, remote sensing is often applied in many areas of agriculture (Lucas et al., 2004). Remote sensing performs non-destructive chemical measurements without actually using chemical agents and without physically manipulating the measured materials, while allowing a broad spatial overview and a demand driven application time. These features can be applied in low-input and organic agriculture systems to monitor environmental and plant physiological conditions and trigger action at the exact moment and spot when and where necessary. Remote sensing – as a powerful analytical tool – can have a crucial role in the early detection of agricultural risk factors, such as pests and diseases (Dammer et al., 2009), and the prevention or minimization of field scale chemical treatments. Remote sensing sensors and platforms can typically be characterized by four parameters; the spectral, spatial, temporal and radiometric resolution. Recent changes in resolution parameters of remote sensing techniques have initiated new applications and continually extend the user community both in science and industry. Nowadays the sensors are not only satellite based but also hand-held or vehicle-based with high potential for mobility and flexiblity

2 Material and Methods

Temporal resolution is a driver in agricultural remote sensing that controls the flexibility and even data availability. The periodical returns of satellites are typically not customized and the air-borne campaigns with high-temporal resolution are very cost-intensive and complex. Considering the application areas of remote sensing, agriculture is one of the most time-critical. The entire agricultural sector and production is based on time-critical processes including sowing plant protection, fertilizing, irrigating and all management decisions, which should be sensed at higher temporal rates to overcome present limitations, and allow

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targeted technological reactions. In spatial down-scaling when the measurement altitude drops down to 100, 10 and 1 m, the temporal, spatial and spectral resolution can be significantly increased and new demands such as mobility and flexibility can be given special attention. The temporal resolution affects not only the process accuracy but also the imaging process. Recent developments show that a novel kind of imaging technique (the snap-shot spectroscopy) enables high-rate spectral images to generate spectral video sequences that are an obvious advantage in on-line process monitoring and controlling of agro-environmental conditions both in field and in-door. In this short comunication we give a summarized review of agricultural remote sensing techniques and most relevant current trends.

3 Results

For historical and technical reasons, the multispectral satellite remote sensing initiated many agricultural applications. The spectrum-based methods initially used broad (50-100 nm) spectral bands, which have been narrowed by scientific high-resolution sensors over the last decades (Adam et. al 2010; Schlerf et al. 2005).

The VNIR spectral range will remain relevant in the next generation of crop sensor developments as well (Bendig et al. 2012; Zarco-Tejada et al., 2005) but it will likely be spectrally enhanced to produce high-resolution crop or soil sensors. The narrow- and broadband comparisons (Thenkabail et. Al, 2012) highlight best the benefits of the narrow-band indices such as non-saturating behavior or high sensitivity in vegetation dynamics (e. g. phenology). Thenkabail gave an excellent overview of using hyperspectral narrow bands for vegetation analysis and agricultural applications. After Thenkabail the narrow bands can be classified as very narrow bands (1 nm to 15 nm), narrow bands (16 nm to 30 nm), intermediate bands (31 nm to 45 nm) and broad bands (greater than 45 nm). Based on this classification, the first-generation crop sensors belong basically to the broadband detectors. For future VNIR crop sensor developments, the following spectral narrow-bands could be of interest (Tab. 1).

Table 1 Narrow band indices for biochemical and biophysical plant parameters

Wavelength	Parameter	Indications	Wavelength	Parameter	Indications
375 nm	biochemical	leaf water content	720 nm	biochemical	nitrogen stress
466 nm	biochemical	leaf chlorophyll	740 nm	biochemical	leaf nitrogen
515 nm	biochemical	leaf nitrogen	490 nm	biophysical	crop yield
520 nm	biochemical	pigment content	550 nm	biophysical	biomass
525 nm	biochemical	leaf nitrogen	682 nm	biophysical	crop yield
575 nm	biochemical	leaf nitrogen	845 nm	biophysical	biomass
675 nm	biochemical	leaf chlorophyll	915 nm	biophysical	crop yield
700 nm	biochemical	nitrogen stress	975 nm	biophysical	leaf moisture

Narrow-band studies (Schull et al. 2010; Bork et al. 1999) showed that classification accuracies have been clearly increased. Generally, the hyperspectral narrow bands explain about 10-30 % greater variability in quantitative biophysical models compared to broadband bands and are not sensible to saturation problems in biophysical estimations (Mutanga and Skidmore, 2004). These two benefits are to be considered in the design of future high-resolution imaging or non-imaging crop sensors. There is another important part in VNIR spectrum: the so-called red-edge region, which is likely becoming increasingly relevant for novel optical sensors.

4 Conclusions

It is recognizable that broad-band sensor concepts can be enhanced by narrow-band indices. Technological solutions and developments that can reduce the complexity of terrestrial hyperspectral measurements are of interest for agricultural professionals. Nowadays the lightweight hyperspectral imaging sensors still have their limitations in full-range diffuse reflectance spectroscopy because these need the entire spectrum from 400 up to 2500 nm to identify soil properties, while vegetation or agriculture spectroscopy can benefit from the range of 400-1100 nm as described in earlier paragraphs. Many applied fields of agricultural remote sensing are based on the knowledge of the biophysical and biochemical parameters of soils and plants. New sensing technologies will enrich remote sensing and will enhance the risk-management potential of many sustainable agricultural practices. Variable rate technology solutions that do not apply synthetic inputs but improve production efficiency with spatial-biochemical information are especially welcome and valued in low input, organic or integrated farming. There is a local and global need for the development of time-, cost- and natural resource-efficient methodologies for crop and soil analysis, and their application in everyday production. The growing demand for larger amounts of high-quality, inexpensive, and still sustainably produced agricultural products is our present challenge.

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