UNIVERSITÄT INNSBRUCK, INSTITUT FÜR ÖKOLOGIE
A-6020 Innsbruck, Sternwartestraße 15 (Austria)

Tel. ++43 (0)512 507 51640 • Fax 51699 • Cell phone ++43 (0)664 4162207
E-Mail: Georg.Wohlfahrt@uibk.ac.at
web: http://www.biomet.co.at

Assoz. Prof. Dr. Georg Wohlfahrt

Innsbruck, 10th May 2016

Review of PhD dissertation by MSc Ing. Karolina Sakowska entitled *"On the assessment of carbon dioxide fluxes and spectral characteristics of selected terrestrial ecosystems"*

In the following I summarise the contents of the dissertation, continue with an assessment of its scientific value and the qualification of the applicant and finally conclude with my recommendation regarding the fulfilment of the conditions specified in art. 13 paragraph 1 of the Polish law Act from 14th of March 2003 about academic degrees and scientific titles as well as about degrees and titles in the arts, together with later modifications.

Summary of the contents of the dissertation

The dissertation consists of five main chapters: Chapter 1 sets the state of the dissertation by introducing the scientific background underlying the dissertation. This introduction is followed by a section summarising the aims of the dissertation (section 2) and the methods used to reach these (section 3). The main study site was a sub-alpine grassland in Northern Italy, Monte Bondone. The net ecosystem CO_2 exchange was measured with a state-of-the-art application of the eddy covariance method. Reflectance measurements included multispectral (Publication I) and hyperspectral (Publication II and III) measurements using a multispectral and a hyperspectral radiometer, respectively. A unique *in situ* automated white reference system was developed for the hyperspectral radiometer (Publication II). Reflectance measurements were cast into a number of reflectance indices (VIs) and used to predict several ecosystem physiological (e.g. parameters of net ecosystem CO_2 exchange) and biophysical (e.g. LAI) parameters. These relationships were analysed using regression statistics.

The major finding of Publication I is, based on an impressive multi-year data set, that the multi-spectral VIs exploiting the red edge are superior to more classical ones relying on the contrast between reflectance in the visible and near-infrared wavelengths. This is reasoned to be due to rapid saturation at relatively low LAI values in the visible range, not affecting the red-edge in a similar fashion. Another key finding is the important role, which diffuse, as opposed to total, photosynthetically active radiation plays in governing ecosystem CO_2 uptake.

Publication 2 introduces a newly developed automated *in situ* white reference system for continuous measurements with a hyperspectral radiometer and exploits its potential for unattended high-quality hyperspectral reflectance measurements.

The white reference system and the resulting data are exploited in Publication 3 with the additional aim of evaluating the potential of the new Sentinel-2 data for monitoring seasonal changes in mountain grassland biophysical parameters.

The dissertation concludes with a summary and an outlook to potential future work. The main issues raised regard the question of how transferable the results obtained within the frame of the dissertation at a single grassland study site are and the candidate recommends testing these findings at other, structurally and functionally different, ecosystem types.

Assessment of the scientific value of the dissertation

Significance of the work: In order to quantify changes of the global biogeochemical cycles we, as a scientific community, would like to be able to measure "everywhere all the time". Remote sensing (RS) is coming closer to this ideal than many other methods in our portfolio and thus has significantly gained importance during the past decades. RS however also suffers from a number of drawbacks. With regard to assessments of the major biogeochemical cycles, these are the fact that remote sensing quantifies only proxies of many processes and that there is generally a mismatch in spatial scale to ground-based measurements, which makes it difficult to assess the accuracy of RS-based assessments. This gap is filled in by proximal sensing, which is much less affected by atmospheric corrections and operates at spatial scales much more compatible with ground-based measurements of canopy attributes or micrometeorological flux measurements. This is exactly the overall theme of the dissertation submitted by the candidate, which thus contributes towards improving the accuracy and general value of RS for monitoring global changes of the earth.

Scientific value of the work: Proximal sensing is a relatively young scientific field and has gained considerable momentum during the past couple of years. Instruments in use have, however, often not been designed for continuous outdoor deployment and there exist few, if any, agreed common protocols for making proximal sensing measurements. There is thus a need for methodological improvements, as well as for investigating, and possibly revisiting, the suitability of established approaches and the relationship between proximal sensing information and ecosystem structural and functional attributes. The dissertation contributes towards methodological improvements by introducing a novel *in situ* white reference system (Publication 2), which provides a milestone for making long-term unattended hyperspectral reflectance measurements from towers, such as those used for eddy covariance flux measurements. I can very well imagine that this, or similar systems building upon this idea, might become a standard in the near future. As mentioned above, the justification for proximal sensing is to complement and validate larger-scale RS activities. Publication 3 follows up this idea and uses detailed hyperspectral measurements to simulate the characteristics of the new Sentinel-2 satellite measurements and test the information content for estimating grassland biophysical properties. The results obtained within the frame of Publication 3 will help to guide scientists to make best use of Sentinel-2 data for estimating ecosystem biophysical properties. Given the considerable costs of hyperspectral sensors and their high requirements with regard to environmental conditions and calibration, the question whether simpler, multi-spectral sensors may do the job as well, is an important one. Publication 1 tackles this question by using a multi-year data set gathered with such a multi-spectral sensor, showing its great potential for estimating the parameters of the net ecosystem CO_2 exchange.

Taken together, the original work presented within the frame of this dissertation is of international scientific significance and contributes to, and in fact advances, the state-of-the-art in the field of proximal sensing for estimating ecosystem biophysical and physiological attributes.

Qualification of the candidate: The candidate is the first author on all three multi-author papers contained in the dissertation and conducted most of the experimental work, analyses and writing. The spread of the publications contained within the dissertation, which covers a wide range of methods and processes, the rigor of the scientific analyses and finally the general introduction of the dissertation testify that the candidate has fully familiarized

herself with the necessary general and specific theoretical background, is able to apply this knowledge in practical terms and thus is in the possession of all the necessary skills to independently conduct scientific research in this field.

Recommendation

In my opinion, the candidate, MSc Eng. Karolina Sakowska, has demonstrated through the submitted dissertation that she fulfils, in terms of international standards, as well as in particular with regard to art. 13 paragraph 1 of the Polish law Act from 14th of March 2003 about academic degrees and scientific titles as well as about degrees and titles in the arts, together with later modifications, the requirements to be awarded the scientific degree of Doctor of Philosophy in agricultural sciences within protection and development of the environment.

Declaration

I declare no conflict of interest, whatsoever, with this review.

Kind regards,

(Assoc. Prof. Univ.-Doz. Dr. Mag. Georg Wohlfahrt)