Assessment of doctoral thesis

Thesis title: **Mapping of terrain and vegetation structure with spaceborne lidar**
                  (Mapování terénu a struktury vegetace satelitní laserovou altimetri)

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This thesis investigates the quality of relatively new spaceborne laser scanning data from the ATLAS and GEDI instruments and their usability for terrain and vegetation structure assessment. It also evaluates their potential for species distribution modelling. Laser scanning is a modern and very accurate tool for mapping vegetation structure. Considering that not all countries have wall-to-wall airborne laser scanning data with relatively high point density that can be used to map the structure and composition of terrestrial ecosystems (e.g. in terms of height distribution, biomass, fractional cover or density of vegetation), satellite laser scanning data with global coverage can fill this gap. As satellite laser scanning data is still a relatively new and scarce source of information, it is important to explore its capabilities and potential, how well it can be used to map vegetation structure and what its limitations are. I therefore consider the topic of this thesis to be scientifically sound, timely and highly relevant for ecological applications.

The thesis was prepared in collaboration with the Institute of Botany of the Czech Academy of Sciences. It is based on four peer-reviewed articles. At the time of writing this opponent assessment all articles have been published, although the submitted thesis states that only two papers have been published, one accepted and one under review. These publications are:
Study I - The role of the vegetation structure, primary productivity and senescence derived from airborne LiDAR and hyperspectral data for birds diversity and rarity on a restored site. Published in Landscape and Urban Planning (IF 7.9).
Study II - Effects of environmental conditions on ICESat-2 terrain and canopy heights retrievals in Central European mountains. Published in Remote Sensing of Environment – the top journal in the field of remote sensing with IF 11.1
Study III - How to find accurate terrain and canopy height GEDI footprints in temperate forests and grasslands? Published in Earth and Space Sciences (IF 2.9)
Study IV - Comparison of three global canopy height maps and their applicability to biodiversity modeling: Accuracy issues revealed. Published in Ecosphere (IF 2.7)

Considering that all papers have gone through the full peer-review process, this is a clear guarantee of scientific soundness and quality. Doc. Moudrý is the first author of all four publications, which shows his major contribution to the work.

The main objective is clear and four specific goals of the study obviously correspond to the main objectives of four publications (Chapter 2). On the one hand, I appreciate the synthesising effort of the results/discussion section (Chapter 4) to link the individual studies, but on the other hand, I missed the essential extract of the main results and conclusions for each study. It would make the flow and reading

of the thesis easier to follow. The theoretical part (Chapter 3) is well written and provides comprehensive insight into the topic. Recent publications are cited.

I appreciate the honest statement of Mr Moudrý that his original intention was to use machine learning methods to develop a continuous canopy height model at fine resolution for the Czech Republic. However, as the first attempts were not very successful and several other authors heave developed relatively useful global models in the meantime, he decided to evaluate the quality and usability of existing models. However, as his study IV shows, the global models do not perform so well at the regional or local scales and are not very useful for biodiversity modelling. Considering that the airborne laser scanning data in the Czech Republic are not up to date, I still believe that it would be useful to have a CHM product at the national level that is regularly updated. Although such a product is being developed by ÚHUL - a normalised digital surface model from the national aerial photography organised by ČÚZK - to my knowledge it is not publicly available and has been evaluated for forestry applications mainly. Therefore, joint efforts and cooperation between institutes such as ČZU, CzechGlobe, ÚHUL could develop a pressure on ČÚZK to consider the acquisition of periodic airborne laser scanning data and to develop robust, wall-to-wall canopy height maps suitable not only for forestry but also for other applications.

My questions are:
1) What would be your vision how to develop regularly updated CHM for the Czech Republic?
2) CHM are often evaluated for forest ecosystems, can you comment on the accuracy of local, airborne-based and global, satellite-based CHM for low vegetation cover (e.g. grassland, wetland, shrub or savannah type of ecosystems)?
3) Did you try to combine LiDAR variables and hyperspecral indices in Study I?
4) Can you comment on the effect of seasonality on the LiDAR signal and derived CHM and how this may affect species distribution / biodiversity modelling?

In conclusion, my overall opinion of the thesis is very positive. It well designed, the methods are up to date, the text is clearly structured and written, all papers have been published. It contributes to the knowledge of how to use laser scanning data for vegetation structure assessment and species and biodiversity modelling. Therefore, I fully recommend the submitted thesis for defence and I agree to award the second Ph.D. degree.

In Brno, 20. 11. 2024

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