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Mapping forest tree species in high resolution UAV-based RGB-imagery by means of convolutional neural networks

Felix Schiefer[1], Teja Kattenborn[2], Annett Frick[3], Julian Frey[4,5], Peter Schall[6], Barbara Koch[5], and Sebastian Schmidtlein[1]

[1]Institute of Geography and Geoecology, Karlsruhe Institute of Technology, Karlsruhe, Germany
[2]Remote Sensing Centre for Earth System Research, Leipzig University, Leipzig, Germany
[3]Luftbild Umwelt Planung GmbH, Potsdam, Germany
[4]Chair of Forest Growth and Dendroecology, University of Freiburg, Freiburg, Germany
[5]Chair of Remote Sensing and Landscape Information Systems, University of Freiburg, Freiburg, Germany
[6]Silviculture and Forest Ecology of the Temperate Zones, University of Göttingen, Göttingen, Germany

With consumer-grade unmanned aerial vehicles (UAVs) on the rise, which enable easy, time-flexible, and cost-effective acquisition of very high-resolution RGB data, the mapping of forest tree species using solely RGB imagery is of high interest, as it does not rely on sophisticated sensors, does not require extensive calibration and preprocessing and, therefore, enables the application by a wide audience. In combination with convolutional neural networks (CNNs), which particularly exploit spatial patterns and, therefore, highly benfit from very high-resolution remote sensing, this offers great potential for accurately mapping forest tree species.

Here, we present the findings of our recent study, in which we used very high-resolution RGB imagery from UAVs in combination with CNNs for the mapping of forest tree species. In this study, we used multicopter UAVs to obtain very high-resolution (<2 cm) RGB imagery over 51 ha of temperate forests in the Southern Black Forest region, and the Hainich National Park in Germany. To fully harness the end-to-end learning capabilities of CNNs, we used a semantic segmentation approach (U-net) that concurrently segments and classifies tree species from imagery. With a diverse dataset in terms of study areas, site conditions, illumination properties, and phenology, we accurately mapped nine tree species, three genus-level classes, deadwood, and forest floor (mean F1-score 0.73). We found that a coarser spatial resolution substantially reduced the model accuracy (mean F1-score of 0.26 at 32 cm resolution) and that larger tile sizes during CNN training negatively affected the model accuracies for underrepresented classes. Additional height information from normalized digital surface models slightly increased the model accuracy but simultaneously increased computational complexity and data requirements. Our results highlight the key role that UAVs can play in the mapping of forest tree species, given that air- and spaceborne remote sensing currently does not provide comparable spatial resolutions. Given the end-to-end learning capabilites of CNNs extensive preprocessing becomes partly obsolete, whereas the use of a large and diverse dataset facilitates a high degree of generalization of the CNN, thus fostering transferability. The synergy of high-resolution UAV imagery and CNN provide a

fast and flexible yet accurate means of mapping forest tree species.

In this contribution, we will give an outlook on how the combination of UAV imagery and CNNs can be integrated with multitemporal satellite imagery (Sentinel-1 and Sentinel-2) in order to extrapolate the UAV-based tree species maps to larger areas.