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## Geo-monitoring of tree species, vitality, and maintenance condition of fruit trees in meadow orchards using UAV technology

*Abstract (max 500 words)*

Traditional orchards comprised of extensively cultivated fruit trees and meadows are hotspots of biodiversity in Central Europe, providing a habitat for more than 5000 different plant and animal species. Meadow orchards contribute to soil and ground water conservation by forgoing the use of pesticides and are important areas for local recreation and tourism, therefore providing a wide range of ecosystem services. However, in the second half of the 20<sup>th</sup> century, many orchards were cleared due to policy changes and low economic profitability. Despite recent efforts of nature conservation initiatives, orchard areas are still declining, quantitatively as well as qualitatively concerning vitality and maintenance condition of stands. In order to preserve the remaining orchards, comprehensive data on the current number, spatial distribution and state of trees is needed for directed measures of pruning untended trees and replacing dying individuals.

The feasibility of assessing the current state of orchards using unmanned aerial vehicles (UAVs) was tested near Bad Schönborn in southwestern Germany. Images were taken with two cameras mounted to the UAV: a high-resolution RGB camera and a camera with additional red edge and near-infrared channels. Selected test areas comprising a total of approx. 25 ha were flown at a height of 30 m above ground three to four times during the vegetation period. Subsequently, the complete, ca. 500 ha large area was flown at a height of 80 m above ground. The resulting orthomosaics and digital elevation models had a spatial resolution in the sub-centimeter range and of several centimeters, respectively. Using the size of the trees, the normalized difference vegetation index (NDVI) and texture measures applied to each spectral band in combination with ground-truthing data, a model was created to determine the tree species, vitality and maintenance condition of the fruit trees based on the UAV images.

Images taken in mid-April proved to be best suited for determining tree species with up to 87% true positive rate for apple trees, while images from June produced the most accurate vitality predictions. The time of flight did not have a relevant effect on the model accuracy for maintenance condition. The majority of trees was found to be in good health, but in need of pruning. The model-generated information about tree species, vitality and maintenance condition is made available to the general public through an interactive online geographic information system (WebGIS), which can be used to connect tree owners with people interested in tending and harvesting trees.

It is concluded that it is feasible to assess large orchard areas on the individual tree level using UAV technology as a basis for long-term monitoring and quality surveillance of orchard stands.