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| **Digital forest inventory based on UAV imagery: Derivation of diameter at breast height through cast shadows of tree stems** |
| The conventional method of manual data collection for forest inventories, often through labor- and time-intensive field campaigns, is prone to providing uncertain and potentially non-representative samples. While techniques like terrestrial laser scanning provide high-resolution data on individual tree structure, cost and accessibility hinder widespread use. Similarly, intermittent data collection challenges airborne laser scanning, potentially leading to outdated information. Additionally, factors within the German forestry sector, such as climate change-related events, staffing shortages, shifts towards more diverse forests, and the growing emphasis on digitalization strategies, underscore the need for current and accurate digital forest databases.  This study investigates the application of Unoccupied Aerial Vehicles (UAVs) and Structure from Motion (SfM) techniques for conducting digital forest inventories, with the aim of addressing current challenges in sustainable forest monitoring. The research was conducted in the Hainich National Park, Germany, a region characterized by its unmanaged and structurally diverse deciduous forest, primarily composed of beech trees (Fagus sylvatica). A detailed digital representation, including 3D point clouds of the canopy, stems, and ground was generated by combining leaf-on and leaf-off data. Various flight configurations and camera setups were tested to ensure comprehensive data coverage, enabling the derivation of key forest parameters such as stem positions, individual tree crown delineation (ITCD), diameter at breast height (DBH), and coarse wood debris (CWD) using clustering algorithms, deep learning models, and object-based methods. This presentation specifically focuses on the derivation of DBH using a deep learning approach to classify the cast shadows of tree stems.  For the derivation of DBH values on an individual tree basis, UAV RGB data collection is conducted during leaf-off state and under sunny weather conditions. A SfM workflow is applied to process the images, generating a terrain normalized point cloud. Points associated with the canopy and stems are filtered out based on their height information, resulting in an orthomosaic that exclusively represents ground information, including tree cast shadows. A modified U-Net is trained using manually labeled training data and data augmentation. This trained model, in conjunction with rule-based assumptions about the form of shadows, is then used to classify shadow areas. An algorithm is developed to automatically derive DBH by analyzing the classified shadow areas, utilizing stem coordinates derived via a point cloud clustering algorithm and considering the location and sun elevation. The tree stem shadows can be classified with high reliability, as the U-Net classification yields an overall accuracy of 98.6% and an F1-score of 84.4%. Automatically derived DBH values using the proposed method are compared to in-situ values, resulting in a mean error of -1.52 cm and an RMSE of 17.6 cm. In total, DBH values for 26.1% of the overstory trees can be determined. These values also reflect the challenges posed by a dense and multi-layer forest structure, resulting in overlapping and obstructed cast shadows. It is demonstrated that automated derivation of DBH values using cast shadows from UAV-SfM data is feasible, although limited by the density and diversity of the forest stand. |