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| **Rapid structural characterisation of tropical savanna woody vegetation with UAV-LiDAR** |
| Timely and spatially explicit structural assessment of the woody vegetation has been a major aspiration for earth observers and ecosystem managers. Thus far, remote sensing techniques have been unable to achieve meticulous estimations of forests within a reasonable timeframe and over ecologically meaningful areas. Advancements in Unoccupied Aerial Vehicle (UAV)-LiDAR provide high-density point clouds approaching data properties provided by terrestrial laser scanning (TLS), the current gold standard. Modern UAV-LiDAR sensors are advocated to be an appropriate solution for digital twin creation over large areas (km2) and might be able to overcome logistical and processing constraints, providing a solution for monitoring ecosystem dynamics over time.  We tested the ability of current state-of-the-art UAV-LiDAR technology in capturing the structure of individual trees in a one-hectare tropical savanna plot in comparison to high-resolution TLS. The UAV-LiDAR data was acquired using an Acecore NOA hexacopter airframe with a Riegl VUX-120 sensor. A Riegl VZ-2000i scanner was used to collect TLS data in the same area, using a 20 m grid spacing to digitise above ground structure in rich 3D detail. After co-registering the TLS and UAV-LiDAR point-clouds, we clipped the datasets to a 1 ha plot and automatically segmented them into individual trees. We volumetrically reconstructed each tree object to access differences in wood volume estimates between the two scanning approaches. We used RayCloudTools (a new open-source C++ library) for all segmentation and reconstruction steps.  Our results showed that UAV-LiDAR could estimate total plot level tree woody volume to within 1% of the TLS estimation, and mean tree DBH and height differed by less than 3%. The UAV-LiDAR estimate of stem density was 15% lower than the TLS estimate, which can be attributed to the higher capacity of TLS in rendering understorey vegetation and producing more fully sampled stems, while UAV-LiDAR data is less sensitive to fine-scale understorey vegetation elements. Sub-plot individual tree patterns, adjusted to fit the size of GEDI footprint (25 m sub-plots), illustrated the structural heterogeneity in the area and show the potential of UAV-LiDAR for calibration of GEDI-derived data for the assessment of above ground biomass in savanna landscapes. The coupling of high-resolution UAV-LiDAR with the novel modelling capabilities of RayCloudTools provides a powerful avenue for highly detailed monitoring of ecosystems elements, and a scaling pathway for the calibration and validation of satellite-derived products. |