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Elevating Insights: Harnessing Drones for Precision Data Collection

A technical description of how we utilised drone-based data capture and processing for the TaiM project.

Drone survey data were collected using a DJI M350 RTK quadcopter equipped with a Zenmuse L2 LiDAR system and an integrated RGB camera. The LiDAR system features a ranging accuracy of 2 cm at 150 m and a point cloud rate of 1,200,000 points per second for multiple returns. The RGB camera, with a 4/3 CMOS sensor and 20 MP resolution, was used for point cloud coloring and orthomosaic generation.

Flight planning was conducted using DJI Pilot 2 software. First, Digital Terrain Maps (DTM) with Geoid corrections were created and imported into the program. Survey areas were manually marked in Area Route mode, with altitude mode set to AGL (Above Ground Level) to ensure the drone maintained a consistent height above the terrain. This adjustment was crucial for data quality, as flying at a fixed altitude above the takeoff point would lead to variations in ground clearance, affecting overlap between survey runs and LiDAR point density.

For optimal data capture, flight parameters were set to 50% side overlap for LiDAR scans and 85% front overlap for RGB image capture. The LiDAR was configured for five returns (penta) to maximize structural detail for downstream processing (Figure 1). Surveys were conducted at the legal altitude limit of 120 m AGL to maximize coverage per battery set, with a flight speed of 15 m/s.

In the field, a real-time kinematic (RTK) base station was set up over an arbitrary point, broadcasting its location to the drone to enhance positional accuracy during the flight. A take-off location was chosen near the centre of the survey area, ensuring firm ground and an unobstructed line of sight. After setup and pre-flight checks, the survey was conducted.

During the flight, the drone autonomously followed the pre-programmed route, flying parallel lines over the area to maintain the required LiDAR scan overlap. LiDAR and RGB image data were recorded onto a microSD card throughout the survey. Upon returning from the field, the data was transferred to Hutton systems for processing in DJI Terra Pro. This processing produced a point cloud, a Digital Terrain Model (DTM), and an orthomosaic—a composite of orthorectified images captured during the flight.

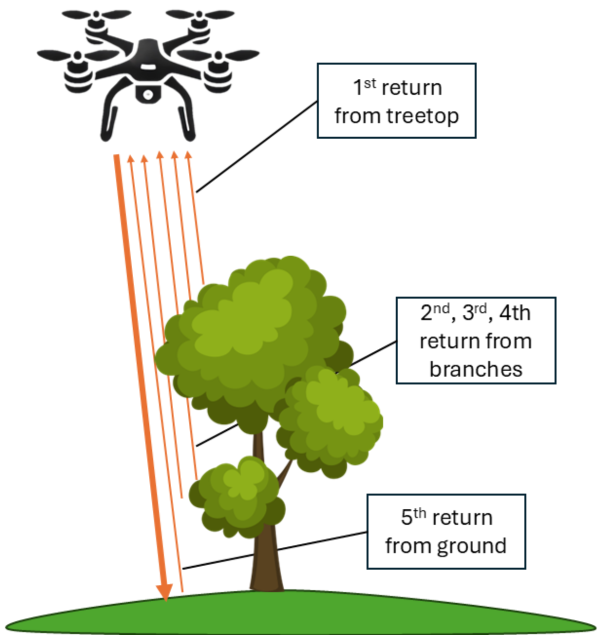

Figure 1: Graphical illustration of how drone-based LiDAR gathers structural data from vegetation.

The initial point clouds generated in DJI Terra were extremely large, often consisting of hundreds of millions of points. These large file sizes would make online browsing and further analysis impractical for most users. To optimise usability, the point clouds were therefore reduced and cleaned using an open-source software workflow, following these steps:

1. **Remove Overlapping Points:** Identified and removed duplicate points from overlapping flight lines.
2. **Point Cloud Thinning:** Applied the Poisson method to preserve the irregular spatial structure rather than reducing it to a uniform grid.
3. **Outlier Removal:** Eliminated noise and erroneous points.
4. **Height Thresholding:** Further refined the dataset by removing additional outliers based on height.
5. **Generate Digital Surface Model (DSM):** Created a gridded DSM from the cleaned and reduced point cloud.
6. **Calculate Height Above Ground:** Used the previously generated Digital Terrain Model (DTM) to determine the height above ground for each point, allowing for precise filtering of canopy points.

7. **Extract Canopy Height Model (CHM) Points:** Isolated vegetation points for canopy analysis.
8. **Outlier Removal in CHM:** Removed additional noise from the extracted canopy height points.
9. **Generate Gridded CHM:** Created a rasterised CHM representation.
10. **Mask Buildings:** Used OS building footprints to exclude structures from the CHM.

All raster outputs were generated at a 0.5m resolution by default, with the flexibility to refine this to resolutions between 0.2m and 3m, depending on project requirements.

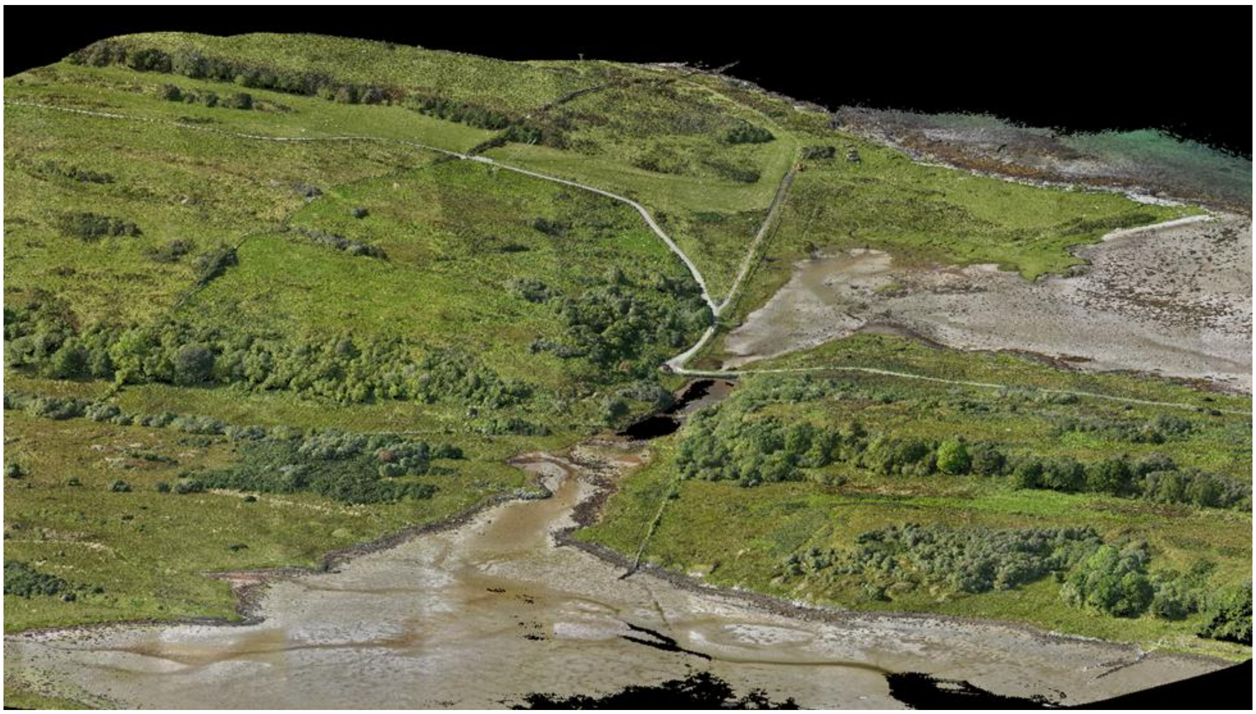

Figure 2: Point cloud of the Danna-Ulva causeway in Tayvallich, (427 million points) after kernel filtering and flightline overlap removal. The visible lines are changes in illumination from the boresight camera imagery.

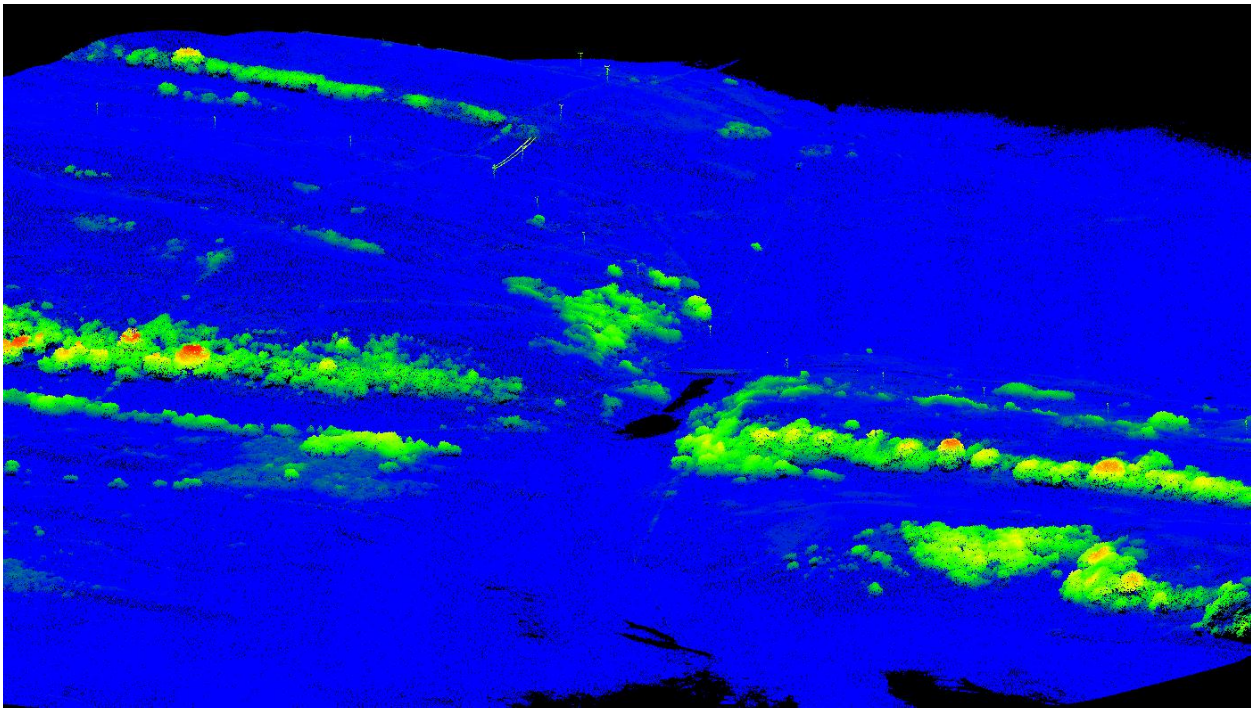

Figure 3: Height above ground of the Danna-Ulva causeway in Tayvallich (3.3 million points) calculated from the DTM on the points and used to create the CHM points and raster.

In addition to the filtered point clouds, DSM and CHM, Plant Area Density (PAD) and Plant Area Index (PAI) were calculated as 2D and 3D aggregate measures of vegetation density. These were derived using 1m³ voxel-based analysis and output as multi-band and single-band rasters, respectively.

- **PAD (Plant Area Density):** Calculated for each voxel based on the fraction of LiDAR pulses entering and exiting it. This fraction represents the amount of plant material attenuating the LiDAR pulses, serving as a proxy for the surface area of vegetation within the voxel.
- **PAI (Plant Area Index):** Computed as the sum of PAD values across the vertical profile of the forest. Since PAI aggregates PAD over height, it should be interpreted as a relative score or dimensionless index rather than an absolute measurement.

The data were then ready for further analysis by project partners.

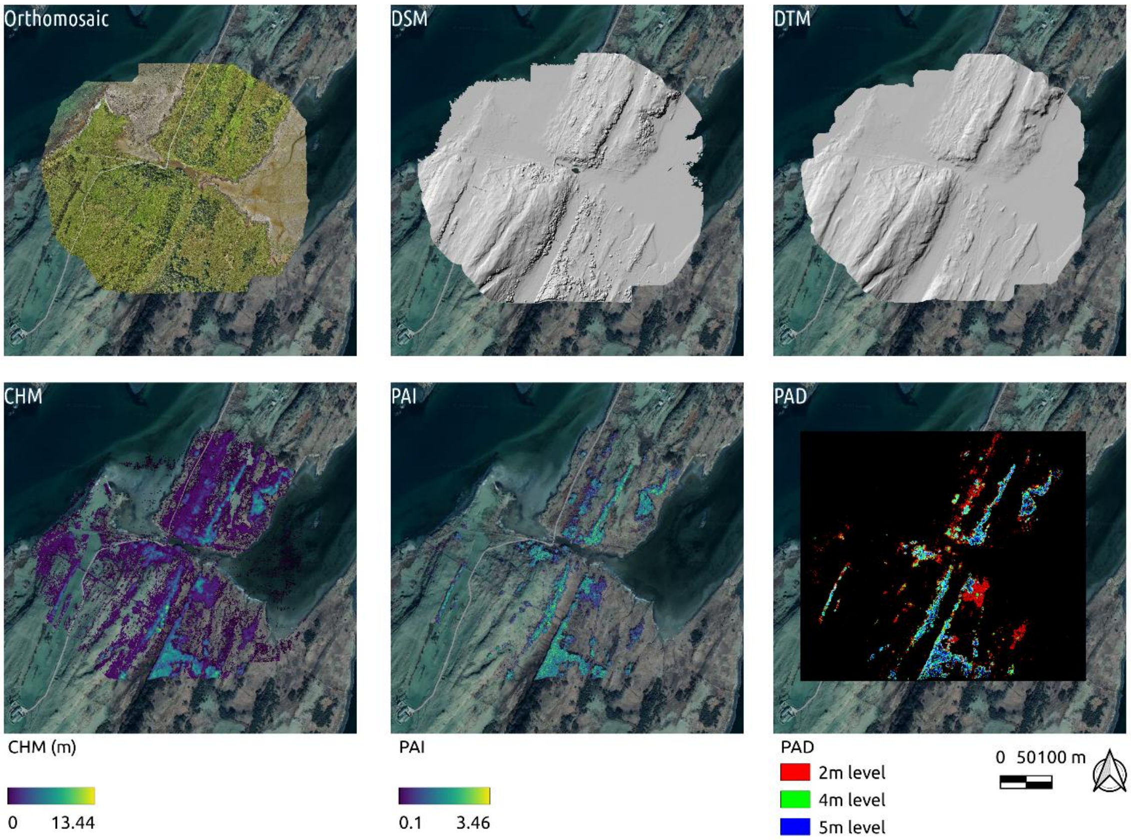

Figure 4: Survey processing outputs for the Danna-Ulva causeway in Tayvallich, with DSM and DTM displayed as hillshade.