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# Estimating soil displacement in skid trail construction through the comparison of pre- and post harvesting aerially captured data

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Harvesting timber in steep terrain is traditionally carried out using cable based systems. However, a more effective method uses a wheeled harvester working alternately with an excavator which opens temporary access trails, making it possible to traverse side slopes. This method is fully mechanized, which greatly reduces the workload. However, there is a real risk of erosion from the un-stabilized embankments and the channeling effect of the trails.

The aim of this study was to quantify the changes to the topography in the forest stand after harvesting, by collecting data on inclination, width, cut height, segment length and cut volumes from the trail network. These data were to be used in evaluating the risk and extent of erosion or smaller landslides as a result of the application of this harvesting method. Given that the stands are large and difficult to access, and that 500-1500 m of skid trails are created per ha., metrics needed to be based on accurate, remotely sensed data to alleviate what would otherwise be an infeasible task.

A 7ha stand in W. Norway (UTM32-E 364 323m, N 6 741 123m), which had been harvested with excavator assistance, was used as a case study. Imagery was captured from two UAV's. A fixed wing plane, the Gatewing X100™ from Trimble® flew in an automated flight path perpendicular to the slope direction, while a multi-rotor helicopter was used in a fully manual flight, up and down the slope.

With the help of computer vision process - structure from motion (SFM) a feature descriptor such as Scale Invariant Feature Transform (SIFT) was used to support automated image matching as well as retrieving camera position and orientation and sparse point cloud reconstruction. The whole model was geo-referenced with available ground control points (GCP) using a 7 parameter Helmert transformation, and camera alignment was optimized by fitting camera parameters. Finally, a dense reconstruction in ultra-high resolution was processed.

To calculate the soil displacement volumes, a pre-harvest LiDAR derived terrain model was used as the 'control' terrain before the skid trails were constructed. To verify the terrain model precision, a number of critical points on four road profiles were marked in the field using Differential positioning (DGPS). By comparing the surface models before and after the harvesting operation, estimates of cut & fill soil volumes from skidding trails could be computed. The cut volumes were used as a direct indicator of site disturbance. Reconstructing the camera external orientation with help from the GCPs allowed for a highly accurate (8 cm error) terrain model to be developed from the multi-rotor UAV which had neither GPS or IMU.