Title
Monitoring Erosion using Terrestrial Laser Scanning

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Abstract
The Catterline Bay, located in North East Scotland, is prone to erosion processes. Using Terrestrial Laser Scanning (TLS) two point clouds were obtained in 2019 and 2022 from this area of ca. 0.2 km^2. Here, a methodology was proposed and tested to assess how erosion processes can be monitored from high resolution point clouds in small study areas. Filtering of ground points from the point clouds was done using a full 3D approach. The local dimensionality on multiple scales was used to generate features for the classification, for which Linear Discriminant Analysis was used. The algorithm was able to precisely separate non ground points from ground points with a precision on test data sets of 94.7% on ground points and 94.3% on non-ground points.

The ground points provided a basis for the Digital Terrain Model (DTM) raster. Several geomorphological quantities could be derived from this DTM. Next to these quantities, also information about vegetation height and 3D change detection using the Multi-scale Model to Model Cloud Comparison (M3C2) was extracted.

From a combination of the Terrain Ruggedness Index (TRI), change detection using the Multiscale Model to Model Cloud Comparison (M3C2) technique and photos, erosion zones were derived. Also stable, non-erosion, zones were identified. Various statistics from the geomorphological quantities were analysed for both zone types. Erosion zones have clear edges of high TRI values, indicating the scarps of landslides. The erosion zones also contain groups of negative M3C2 distances, indicating depletion zones. Not only the TRI and M3C2 distances have significantly different statistics for erosion and non-erosion zones, also the slope is steeper in these zones and the Topographic Wetness Index is smaller. The mean slope for erosion zones is 39.3° compared to 30.9° for non-erosion zones. To capture the behaviour of the TRI in the defined zones, p_{TRI} was introduced which gives a rate of how many cells have a high TRI value in a defined zone. The p_{TRI}, the rate of TRI values above 0.06 m, is more than 4 times larger for erosion zones (0.17) than for non-erosion zones (0.04).

Changes in vegetation height could be linked to locations of implemented Nature Based Solutions (NBS). The results were in agreement with changes in NDVI, which were calculated from optical satellite imagery.

In conclusion, the new methodology has great potential to identify erosion zones in complex sloped terrain and monitor changes in vegetation.