Geophysical Research Abstracts
Vol. 17, EGU2015-11376-2, 2015
EGU General Assembly 2015


# Comparing terrestrial laser scanning with ground and UAV-based imaging for national-level assessment of upland soil erosion

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Quantifying soil loss through erosion processes at a high resolution can be a time consuming and costly undertaking. In this pilot study 'a cost effective framework for monitoring soil erosion in England and Wales', funded by the UK Department for Environment, Food and Rural Affairs (Defra), we compare methods for collecting suitable topographic measurements via remote sensing. The aim is to enable efficient but detailed site-scale studies of erosion forms in inaccessible UK upland environments, to quantify dynamic processes, such as erosion and mass movement. The techniques assessed are terrestrial laser scanning (TLS), and unmanned aerial vehicle (UAV) photography and ground-based photography, both processed using structure-from-motion (SfM) 3D reconstruction software.

Compared to other established techniques, such as expensive TLS, SfM offers a potentially low-cost alternative for the reconstruction of 3D high-resolution micro-topographic models from photographs taken with consumer grade cameras. However, whilst an increasing number of research papers examine the relative merits of these novel versus more established survey techniques, no study to date has compared both ground-based and aerial SfM photogrammetry with TLS scanning across a range of scales (from $m^2$ to 16ha). The evaluation of these novel low cost techniques is particularly relevant in upland landscapes, where the remoteness and inaccessibility of field sites may render some of the more established survey techniques impractical. Volumetric estimates of soil loss are quantified using the digital surface models (DSMs) derived from the data from each technique and subtracted from a modelled pre-erosion surface.

The results from each technique are compared.

- The UAV was able to capture information over a wide area, a range of altitudes and angles over the study area. Combined with automated SfM-based processing, this technique was able to produce rapid orthophotos to support ground-based data acquisition, as well as a DSM for volume loss measurement in larger features. However, the DSM of erosion features lacked the detail of those captured using the ground-based methods.
- Terrestrial laser scanning provided detailed, accurate, high density measurements of the ground surface over long (100s m) distances, but size and weight of the instrument made it difficult to use in mountainous environments. In addition, deriving a reliable bare-earth digital terrain model (DTM) from TLS was at times problematic due to the presence of tall shrubby vegetation.
- Ground-based photography produced comparable data sets to terrestrial laser scanning and was the most useful for characterising small and difficult to view features.

The relative advantages, limitations and cost-effectiveness of each approach at 5 upland sites across the UK are discussed.