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# Spatial and temporal analyses for multiscale monitoring of landslides: Examples from Northern Ireland

Andrew Bell (1), Jennifer McKinley (1), and David Hughes (2)

(1) School of Geography, Archaeology and Palaeoecology, Queens University Belfast, BT7 1NN, Northern Ireland, UK (abell19@qub.ac.uk), (2) School of Planning, Architecture and Civil Engineering, Queens University Belfast, BT7 1NN, Northern Ireland, UK

Landslides in the form of debris flows, large scale rotational features and composite mudflows impact transport corridors cutting off local communities and in some instances result in loss of life. This study presents landslide monitoring methods used for predicting and characterising landslide activity along transport corridors. A variety of approaches are discussed: desk based risk assessment of slopes using Geographical Information Systems (GIS); Aerial LiDAR surveys and Terrestrial LiDAR monitoring and field instrumentation of selected sites.
A GIS based case study is discussed which provides risk assessment for the potential of slope stability issues. Layers incorporated within the system include Digital Elevation Model (DEM), slope, aspect, solid and drift geology and groundwater conditions. Additional datasets include consequence of failure. These are combined within a risk model, presented as likelihoods of failure. This integrated spatial approach for slope risk assessment provides the user with a preliminary risk assessment of sites. An innovative "Flexviewer" web-based server interface allows users to view data without needing advanced GIS techniques to gather information about selected areas.
On a macro landscape scale, Aerial LiDAR (ALS) surveys are used for the characterisation of landslides from the surrounding terrain. DEMs are generated along with terrain derivatives: slope, curvature and various measures of terrain roughness. Spatial analysis of terrain morphological parameters allow characterisation of slope stability issues and are used to predict areas of potential failure or recently failure terrain.
On a local scale ground monitoring approaches are employed for the monitoring of changes in selected slopes using ALS and risk assessment approaches. Results are shown from on-going bimonthly Terrestrial LiDAR (TLS) monitoring of the slope within a site specific geodectically referenced network. This has allowed a classification of changes in the slopes with DEMs of difference showing areas of recent movement, erosion and deposition. In addition, changes in the structure of the slope characterised by DEM of difference and morphological parameters in the form of roughness, slope and curvature measures are progressively linked to failures indicated from temporal DEM monitoring.

Preliminary results are presented for a case site at Straidkilly Point, Glenarm, Co. Antrim, Northern Ireland, illustrating multiple approaches to the spatial and temporal monitoring of landslides. These indicate how spatial morphological approaches and risk assessment frameworks coupled with TLS monitoring and field instrumentation enable characterisation and prediction of potential areas of slope stability issues. On site weather instrumentation and piezometers document changes in pore water pressures resulting in site-specific information with geotechnical observations parameterised within the temporal LiDAR monitoring. This provides a multifaceted approach to the characterisation and analysis of slope stability issues. The presented methodology of multiscale datasets and surveying approaches utilising spatial parameters and risk index mapping enables a more comprehensive and effective prediction of landslides resulting in effective characterisation and remediation strategies.