Water balance models to inform daily landslide hazard assessments in Scotland

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The occurrence of contemporary landslides in Great Britain is dominated by relatively small (10^2-10^5 m^3) rainfall-triggered events that have a disproportionate effect on the economy where these impact transport infrastructure or construction (Gibson et al., 2013; Dijkstra et al. 2014; Postance et al., 2017; Fig. 1). Research is ongoing to enhance an operational national daily landslide hazard assessment (DLHA) that has been issued since 2012 by the British Geological Survey (BGS) as part of the UK Natural Hazards Partnership (NHP; Dijkstra et al., 2017; Hemingway and Gunawan, 2018). The preparation of a DLHA is largely based on a heuristic approach where antecedent ground conditions and rainfall patterns (spatial/temporal) are evaluated and contextualized with reference to a range of BGS mapped data sources that include information on (near-)surface lithologies, and derived products such as landslide susceptibility maps and landslide domains (Dashwood et al., 2017). Further understanding of landslide occurrence is derived from detailed analyses of the BGS National Landslides Database (Pennington et al., 2015).

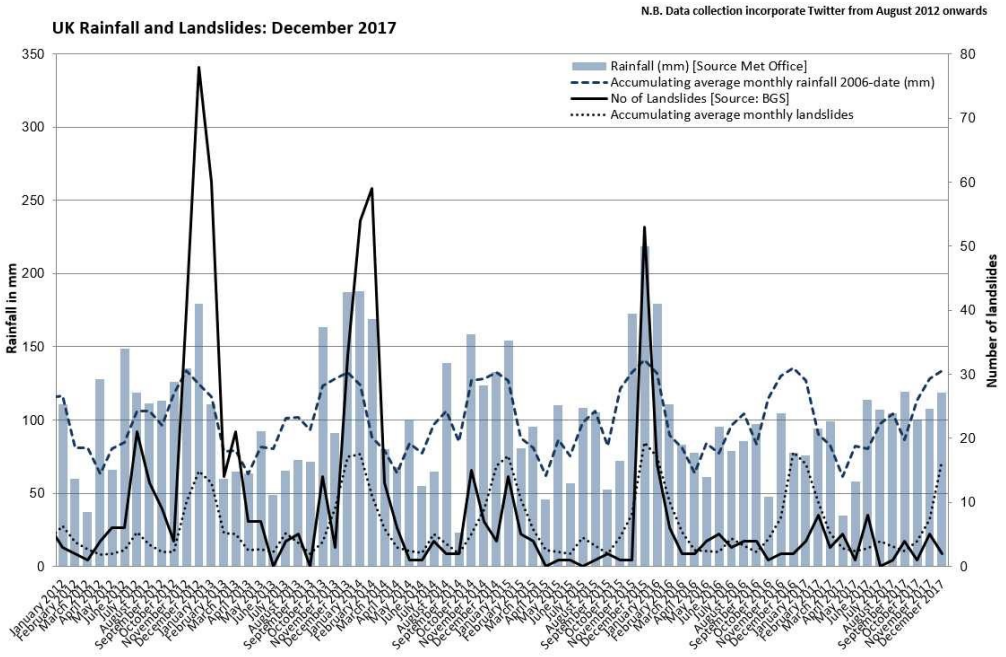

Figure 1. UK rainfall and landslides from January 2012 until December 2017.

The DLHA concentrates on forecasting the occurrence of shallow translational slides and debris flows. The forecasts of rainfall distribution and intensity have become increasingly informative and a response was required to capture spatio-temporal variations in antecedent ground conditions. This was achieved through the implementation of a water balance model, operational in an ArcGIS environment and representing hydrogeological processes in dominant near-surface lithologies on a 1 km^2 grid in Scotland (Fig. 2). The soil is represented by a dual-porosity water balance model and model parameters are based on pedo-transfer functions that translate lithology to characteristic soil properties. Further boundary conditions of the water balance model are determined by average daily precipitation, relative humidity and temperature. Establishment of hazard assessment level is based on a further evaluation of how much soil moisture is available in relation to how much rainfall is forecast for the following day. Experience with the operational effectiveness of the model has been mixed. It is still a coarse model that requires further refinement. It is observed that the model provides outputs that highlight particular regions where an increased risk of landslides is apparent. However, it remains difficult to establish conclusions regarding how many and what type of landslides may be the result of this heightened risk. Performance assessment has been carried out against the physical-conceptual distributed hydrological model Grid-to-Grid (G2G) developed by the Centre for Ecology & Hydrology (Cole and Moore 2009). Tests are ongoing to evaluate the BGS water balance model performance for historical landslides that occurred in Scotland from 2004-2015. One of the main limitations in further testing of the model is the relatively small number of landslides in the test period, coupled with their regionally specific reporting (generally limited to where landslides affect infrastructure and construction). Efforts are underway to extend the coverage more widely in GB. This provides further complexities, but also offer greater opportunities to drive model performance evaluation and model evolution.

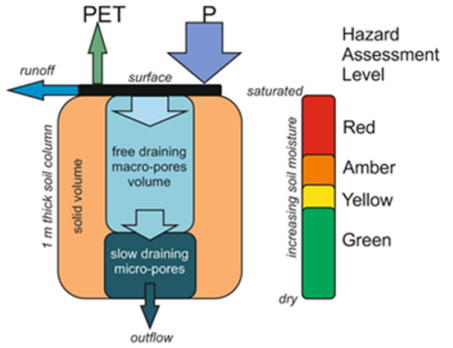

Figure 2. The water balance model underpinning the DLHA.

Keywords: daily landslide hazard assessment, rainfall-triggering, landslide impact, operational system.

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