Investigating the two-way interaction between landslides and vegetation under climate change (Ref IAP2 -18-122)

Newcastle University, School of Engineering
In partnership with The Centre for Ecology and Hydrology and Durham University, Department of Geography

Supervisory Team

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Key Words

Landslides; vegetation succession; niche models; ecosystem services

Overview

Landslides occur in humid mountain regions worldwide, and are both the dominant agent of erosion and a damaging hazard - resulting in hundreds of deaths and billions of dollars of damage every year [Petley, 2012]. Vegetation plays an important role in maintaining the stability of mountain slopes but its characteristics are themselves influenced by the history of landsliding in a particular location. Climate and land management influence both the stability of the soil mantle and the structure and species composition of the vegetation. In the face of climate or land management changes the coupled behaviour of vegetation and soil has important implications for the future behaviour of both. By improving our understanding of this coupling the project will enable more informed decisions about how to manage steep landscapes whether in relation to the consequences of possible management strategies (such as ‘re-wilding’) or to the magnitude of change that should be expected and thus prepared for under climate change. Moreover, the project will prove the concept of using empirical niche models coupled with dynamic landscape evolution models for predicting the colonising pool of plant traits that are so significant to post-slip substrate stabilisation. For example, can niche models successfully filter the regional species pool predicting which trees, grasses or bryophytes will colonise given soil, management and climate in the aftermath of a landslide? If successful this will indicate that post-slip vegetation development can be usefully modelled without recourse to complex and costly local parameterisations of dynamic succession models.

![Fig 1. a) a landslide scar in 2005, 2 months after failure; b) the same scar 3 years after failure; c) the same valley in 2005. (Photographs: R. Johnson).](image)
particular promise in their ability to simulate species composition under past and future climates [e.g. Smart et al., 2010 & NERC Urgency Grant to S.Smart NE/P003044/1]. However, these approaches have never been coupled to examine the impact of climate change on landslides.

**RQ2** How do shallow landslide scars evolve in coupled eco-geomorphic terms? Are there different successional trajectories? If so what controls bifurcation of these trajectories? Landslides strip away soil and vegetation, initiating the co-evolution of topography and vegetation within their scars. The detail of this co-evolution strongly influences the scar’s subsequent susceptibility to erosion [Stark and Passalacqua, 2014]. Vegetation requires a substrate stable enough for plant establishment and with sufficient nutrients and water; however, landslide scars are commonly areas of sustained and sometimes vigorous overland flow washing away substrate and newly established vegetation [Johnson and Warburton, 2015]. The feedback between vegetation, hydrological processes and surface properties can follow radically different trajectories and appears to be highly sensitive to initial conditions. The conditions under which these different trajectories occur and the extent to which this might change with climate or vegetation change remain poorly understood.

**RQ3** What are the timescales over which these trajectories are followed and what controls these timescales? Whilst the coupled eco-geomorphic evolution of landslide scars has been investigated in a small number of conceptual and numerical models from ecological [e.g. Fig 2] and geomorphological perspectives [e.g. Runyan and D’Odorico, 2014; Stark and Passalacqua, 2014], the coupling between geomorphologic and ecological processes remains weak. Furthermore, the field observations necessary to parameterise even these models are sparse, particularly in the UK. As a result, the timescale over which re-vegetation occurs and even the extent to which re-vegetation is the inevitable outcome is unknown. Whilst in some cases re-vegetation may occur quickly enabling rapid soil development other scars may remain bare for decades.

In grazed systems such as some of the English Lake District fells we envisage a truncated y-axis to Fig 2 with a peak at lower grass-dominated biomass. We will investigate the extent to which the presence of grazers and lack of woody species shortens the time between landslides. The difference between scenarios with and without grazers will provide evidence to the debate around the value of rewilding.

**Methodology**

The project takes advantage of: niche modelling expertise and tools from Smart; an extensive chronosequence of landslides in the English Lake District; field and lab expertise in geomorphological (Warburton) and ecological (Smart) surveying of landslide scars and the surrounding landscape; and landslide modelling expertise and tools from Milledge.

**M1** (for RQ1): Couple ecological niche and geomorphological landslide models to examine climate impacts. The supervisory team has extensive experience with, and access to, ecological niche models (MultiMOVE [Henrys et al. 2015]) and landslide models (MD-STAB [Milledge et al., 2014; Bellugi et al., 2015]). These can be driven by downscaled UKCP climate model outputs to simulate future species composition and landslide properties.

**M2** (for RQ2 & 3): Develop and analyse a database of vegetation succession for UK upland landslide scars. n=100 scars of varying ages (<50 years) and conditions will be classified and characterized after recording different variables related to topography surrounding vegetation type, soil type, and soil erosion. Laboratory work will be carried out at Durham to quantify ecologically-relevant soil chemistry (e.g. pH, C:N ratios, nutrient contents).

**M3** (for RQ2 & 3): Test existing ecological models ability to predict successional trends and identify post-scar colonists. General successional trends can be inferred using an ordination approach [e.g. Moreno-de las Heras et al., 2008]; while MultiMOVE can be used with soil properties, vegetation height and local climate to predict post-scar colonists. Predicted assemblages will be summarised as abundance of root and shoot traits that vary in their ability to stabilise post-slip substrates. Initial model testing based on reproduction of patch-level species composition has produced encouraging results and these methods are now readily transferrable to new locations.

**M4** (for RQ2 & 3): Test existing geomorphological models for the co-evolution of vegetation and soil in scars. Existing models that link landslides, slope evolution, and vegetation change have yet to be applied in the UK but should provide a useful framework to analyse results from M2. Departures from expected behaviour will provide
insight both into the UK context and the adequacy of these models.

**M5 (to address project aims): Couple niche and geomorphological models of scar evolution.** Niche models (from M3) and geomorphological models (from M4) will be modified to improve their ability to reproduce observations (from M2); then coupled to present an alternative to the complex and costly locally parameterised dynamical succession models. Coupling these models will enable both: more informed decisions about how to manage steep landscapes; and improved prediction of the colonising pool of plant traits that are so significant to post-slide substrate stabilisation.

**Timeline**

**Year 1:** Couple ecological niche and landslide models (M1). Identify and establish time of failure of landslide scars for vegetation and soil analysis (M2).

**Year 2:** Implement existing geomorphological models for scar evolution (M4). Field work: vegetation and soil surveys at n~100 landslide scars identified in year 1 (M2). Lab work: examine scar soil properties (M2).

**Year 3/3.5:** Test ecological (M3) and geomorphological models (M4) for scar evolution against observed behaviour; then refine and couple models to improve process representation (M5).

**Training & Skills**

The School of Engineering requires each student to collect at least 60 PGRDP credits, corresponding to attendance of in-school delivered workshops, taught modules and other activities. Training is provided through four mechanisms: (i) a programme of taught modules; (ii) internal training ‘workshops’ that focus on key research skills and techniques; (iii) input from supervisors; and (iv) School and research group seminars by visiting and internal speakers and presentations by postgraduate students themselves. In addition to generic training offered by the University, the School provides training through a series of in-house ‘workshops’. Engineering research postgraduates normally take the following Workshops: ‘Scientific Writing’, ‘Research Ethics (Theory)’, ‘Data Management’, ‘Time Management’, ‘Document Management’, ‘Introduction to Learning and Teaching’ during their first year.

The student will benefit from the wide range of taught modules associated with MSc courses in ‘Engineering Geology’, ‘Mapping and Geospatial Data Science’. Modules particularly relevant for the project are ‘Geomorphics’, ‘Observation processes and analysis’, ‘Geohazards and Deformation of the Earth’. Most of these modules are delivered in one intensive week so well suited for PhD students.

Research training continues through the second and third years, and is based around a number of themes: (i) Recognition and validation of problems; (ii) Demonstration of original, independent and critical thinking, and the ability to develop theoretical concepts; (iii) Knowledge of recent advances within the research field and in related areas; (iv) Understanding relevant research methodologies and techniques and their appropriate application within the research field; (v) Ability to analyse and critically evaluate findings and those of others; and (vi) Summarising, documenting, reporting and reflecting on progress.

The student will undergo specialist training in the specific techniques and approaches used in the project. This includes vegetation surveys, GIS analysis, manipulation of large spatial data sets, and quantitative analysis using Matlab and R. The balance between these aspects of the project will depend on the skills, aptitude, and interest of the candidate.

**References & Further Reading**


**Further Information**

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