The role of geomorphic processes in driving nutrient and carbon cycling in Andean rain forests

Supervision. Patrick Meir (pmeir@ed.ac.uk) & Tibor Dunai (Edinburgh Univ.); Michael Bird & Ruth Robinson (St Andrews Univ.)

Summary: Erosion rates and carbon cycling in soil will be quantified to assess the role of landslides in determining carbon storage and nutrient availability in the tropical montane rain forests of Peru.

Background and Hypothesis. The montane forest ecosystems of the Peruvian Andes are of globally recognised importance for climatic, biological, geomorphological and archaeological reasons. These areas are characterized by steep slopes covered with nutrient and carbon-rich soils that are highly prone to landsliding. As part of a UK/USA-funded consortium we have been studying the carbon cycle and geomorphic processes in the national park of Manu, Cusco, Peru. Our recent data demonstrate that soil carbon density in this ecosystem is exceptionally high (greater than total carbon density in lowland rain forest), but that it, and the nutrient supply from soil to plants, may be strongly influenced by the very high rates of landslides in the region, which we have also estimated using remote sensing. Results from elsewhere confirm the importance of quantifying the influence of landscape dynamics on forest growth and carbon burial/loss through erosion and sedimentation. For example, Stallard (1996, *Global Biogeochemical Cycles*, 12, 231) has suggested that around 10^{15} g C per year maybe buried on land. Landslides represent a mechanism for burying carbon below the active soil layer, while at the same time providing gaps for new forest growth and additional carbon uptake. These processes may represent an appreciable carbon sink in unstable montane forest environments but data are currently completely lacking. This project will quantify soil erosion rates and the impact of landslides on soil nutrient and carbon dynamics to test the underlying hypothesis that landslips are the dominant geomorphic process governing forest growth and carbon source/sink strength in the region. The project will estimate the potential carbon sequestration associated with this process.

The student will measure the evolution of carbon and nutrient stocks with depth on both landslide deposits and landslide scars over time using archived imagery and local knowledge to identify landslides that have occurred at known times back to the 1960s. He/she will determine ages of landslides beyond this period using standard geochronological techniques. These data will be compared with data from undisturbed soils collected as part of current research. Using additional project data provided by current research on forest growth, the soil carbon cycle and climate, the results of this study will enable the student to: (i) challenge classical theory predicting differences in phosphorus (P) and nitrogen (N) availability at low and high elevations in tropical ecosystems, and its influence on growth; and (ii) quantify the importance of geomorphic processes in controlling the carbon cycle on land, especially in the soil.

This project exploits cross disciplinary geomorphic and carbon cycle expertise as well as exceptional inter-institutional analytical capabilities within SAGES. The research is likely to yield genuinely novel and far-reaching understanding of the role of these fragile montane ecosystems in the Earth system.

Experience gained by the student: 1. Quantification of the rates of geomorphic processes (utilizing ^{137}Cs profiles, and cosmogenic in-situ ^{14}C and ^{10}Be); **2.** Measurement and quantification of physical characteristics of landslides; **3.** Analysis of soil carbon and nutrient properties; **4.** Modelling of landscape scale processes and their impact on the carbon cycle over time informed by remote sensing imagery over time; **5.** Experience of working in a cross-discplinary field, and in a large international consortium led by scientists in UK, USA & Peru; **6.** Scientific, collaborative, foreign language, project management, field+laboratory skills.

Training summary. The student will learn to combine the analysis of geomorphic and ecological processes to gain understanding of the functioning of a tropical montane ecosystem in an Earth system context, particularly via a focus on the carbon cycling of carbon and nutrients at different scales of space and time.

PAGE 2: Statements on facilities, advertising and SAGES links

1. Facilities.

Depends on facilities at SUERC (137Cs counting and AMS measurements for 10Be & 14C), at UEdin (sample preparation for 10Be & 14C) and St Andrews (OSL); soil carbon and nitrogen analyses will be conducted at St Andrews using existing resources in the Facility for Earth and Environmental Analysis, with analytical costs borne by Bird from existing resources. Thus, the relevant facilities are in place. Expenditure will be covered from lab budgets (UEdin, St Andrews); scintillation counting and AMS measurements would be performed as SUERC consortium samples (e.g. no cost charged to the project).

2. Advertising summary description.

Erosion rates and carbon cycling in soil will be quantified to assess the role of landslides in determining carbon storage and nutrient availability in the tropical montane rain forests of Peru.

3. Links to SAGES Themes.

The project makes exceptional use of pooled expertise and analytical facilities within SAGES: this is exactly the kind of multi-faceted, but widely scientifically relevant project that would be difficult or impossible without SAGES. SAGES Theme coverage by supervision panel:
Dunai (UEdin) and Robinson (St Andrews) are in SAGES Theme 1
Meir (UEdin) and Bird (St Andrews) are in SAGES Theme 2

Thus, Themes 1 & 2 are represented at both universities involved in this project, creating a network that is new, efficient and scientifically creative. We know that this supervision panel can work because of past successful collaborative experience between individuals, as well as separate but complementary scientific knowledge of the study region among the supervisors.

4. Issues addressed by the project that directly address central SAGES themes.

1. The project addresses the core SAGES aim of understanding the interactions between main elements of the Earth system, principally solid earth and biosphere, but also atmosphere
(relevance: core SAGES statement).
2. The project directly addresses the aims of studying processes affecting landscape dynamics, soil erosion, and the impact of climatic change on landscape processes, with the added potential for the results to be incorporated as constraints to landscape modeling frameworks
(relevance: Theme 1 statement)
3. The project directly addresses the aims of quantifying carbon storage, exchange and dynamics, especially in relation to land-atmosphere interactions, both by direct study of carbon dynamics, nutrient controls on ecosystem processes affecting carbon storage, and climate sensitivity of carbon storage (relevance: Theme 2 statement).
4. The project addresses the aims of quantifying landscape and ecosystem function processes over current and historical timescales, and will provide: (i) parameters that are of direct use to Earth system modelling activity, part of which contributes to the research portfolio of the lead supervisor, through NERC-QUEST. (relevance: Themes 3 and 4 statements); and (ii) overall results that link very closely with land use and human-Earth system interactions because of the explicit conservation and policy outputs of the consortium project this PhD will join (relevance: Theme 5 statement)
5. The project cuts across all themes, but focuses on research expertise in Themes 1 and 2. The project is an exciting and novel outcome of on-going discussion fostered through interactions made active via the SAGES research structure.