Project title: Does soil microbial diversity and function alter with vegetation across biomes?

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Project background: Ecosystems are unique ensembles of plant and animal diversity and functional traits related to their environment (climate, disturbance and soils). However, soils are rich in fungal and bacterial biodiversity and are not simply static or passive components to an ecosystem (1). Soils are critical to the establishment and ecology of plants, as well as housing important diversity and important in the terrestrial carbon cycle (1, 2). Vast amounts of carbon are stored in soils and soil microbial communities play a critical role in regulating the soil carbon cycle via respiration and plant decomposition (3). Given that the distribution of ecosystems is related to environmental variation, it stands to reason that soil microbial communities would be similarly responsive to environmental variation, and that just as aboveground ecosystems are characterised by unique ensembles of traits it may be the same belowground. Soil microbial communities represent a critical and fascinating, yet totally under explored, link between biodiversity, plant functional ecology and ecosystem ecology. This project is of applied relevance as vegetation in South Africa is changing at an alarming rate via the unexplained encroachment of woody plants across different land use and vegetation types. It is unknown to what extent soil characteristics and soil microbial communities retard or facilitate current vegetation change. This is because there is a limited understanding of the biogeography of soil microbial communities and how they differ in diversity and function among vegetation types. Initial analyses suggested that patterns in microbial diversity and function do not follow those observed above ground, although emerging data are beginning to challenge this view. The area is fast developing and makes use of leading edge metagenomics and ecological measurement methods (4, 5). This research will work at the interface between plant functional ecology, ecosystem ecology and metagenomics in South Africa working with a team of researchers in plant ecology, plant physiology and microbial genomics.

Figure 1. *Biomes of South Africa*. Forest (left) is located along the North-eastern edge of South Africa. C3 grasslands occur at high altitude in the Drakensburg Mountains but shift to dominance by C4 grasses at lower elevations (centre). Savanna (right) is a seasonally dry vegetation type where fire and mega-herbivory drives rapid change in vegetation structure and composition, and these ecosystems cover half of Africa. Rainfall, temperature and disturbance differ among these key South African biomes although whether microbial diversity and function changes similarly across these gradients is unknown.

Key research questions: How do microbial communities change with tropical vegetation across gradients in rainfall, elevation and disturbance? Are there systematic changes in the function of microbial communities with altitude, rainfall and disturbance, and does this differ between fungal and bacterial communities?

Methodology: This PhD will use a wide variety of methods, ensuring that the student will gain a wide range of skills over the course of the project. It will mix ecological fieldwork, experimental design and ecological genomics with spatial and ecological modelling. This project will take advantage of excellent existing savanna, shrubland and forest study sites in three potential location in South Africa: Drakensburg Mountains; Hluhuwe-Umfolozi National Park; and, Kruger National Park. The sites provide options for the direction of research as the project could focus on examining soils and vegetation along 1) elevation gradients in the Drakensburg Mountains where there are shifts in grass photosynthetic types related to altitude and temperature; 2) rainfall and disturbance gradients in Hluhuwe-Umfolozi National Park across grassland, savanna and forest vegetation types; or 3) long-term fire and herbivore experiments in Kruger National Park manipulated over the last 50 years. In each case there is pre-existing information on the vegetation, but much less is known about the soils. Field work will require the student to undertake measurements of soil characteristics and respiration. In Edinburgh, the student will utilise Illumina sequencing of 16S and 18S rRNA gene amplicons and metagenomes to characterise the microbial communities. These techniques enable characterisation of both fungal and bacterial communities (4,5). Data collection will be able to be extended to manipulative laboratory experiments and potentially manipulative field experiments. The student will work with the research group to extend the questions and hypotheses outlined above to develop their research direction of these overarching questions. ***Timetable***: Literature review, experimental design of field and lab work, training in Illumina sequencing, first fieldtrip (*Year 1*); Laboratory and/or field experiments, data analyses and write up of first paper (*Year 2*); Complete laboratory work and data analyses and focus on writing and submission of papers for peer review (*Year 3 - 3.5*).

Training: A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. The student will receive training in and apply advanced analytical techniques; including chemical (e.g. carbon fluxes, nutrient extractions, enzyme assays), molecular (e.g. DNA sequencing) and statistical tools. The student will also be trained in presenting their science orally, in written form for scientific journals, and for a wider audience if they are interested in contributing to our successful outreach and teaching programmes. The breadth of the supervisorial team will ensure that the individual will also develop the ability to communicate complex ideas within and between disciplines. The studentship will therefore develop an individual with a highly sought after and widely applicable set of hard and soft skills.

Requirements: A student with an MSc (&/or outstanding BSc) in natural, environmental, chemical, physical or biological sciences; experience of, or demonstrated ability to undertake, (sometimes challenging) tropical field work. The student will be expected to demonstrate or potential for creativity in thought, for hypothesis development and experimental design; strong quantitative and organizational skills; excellent oral and written communication skills. An aptitude and appetite for writing and publishing their research. The student will need to able to work independently and as part of a larger team. An ability to work in different cultures and an interest in speaking relevant foreign languages are both desirable.

References: (1) Baxendale et al. (2014) Are plant–soil feedback responses explained by plant traits? *New Phytologist* 204: 408-423. (2) van der Putten et al. 2013. Plant–soil feedbacks: the past, the present and future challenges. *Journal of Ecology* 101: 265–276. (3) Wieder et al. (2013) Global soil carbon projections are improved by modelling microbial processes. *Nature Climate Change* 3: 909-912. (4) Caporaso et al. (2012) Ultra-high-throughput microbial community analysis on the Illumina HiSeq and MiSeq platforms. *ISME Journal* 6: 1621-1624. (5) Hugerth et al. (2014) Systematic design of 18S rRNA gene primers for determining eukaryotic diversity in microbial consortia. *PloS ONE* 9: e95567.

Summary: Does the biogeography of soil microbial communities reflect the biogeography of vegetation? Combining ecological genomics and plant ecology the student will work at the leading edge of functional ecology.