Application for the Steve Farrell Memorial Fund

Research Outline

The aim of my PhD is to advance process-based understanding of carbon dynamics in degrading semi-arid rangeland ecosystems.

Dryland landscapes cover ca. 40% of the terrestrial surface, and provide ecosystem services which directly support ca. 2.4 billion people. Importantly, dryland ecosystems are highly susceptible to change, including land degradation. One example this is the encroachment of woody shrubs into former grasslands, causing major changes in ecosystem structure and function. In the United States alone, woody shrub encroachment has impacted an area twice the size of the UK since 1850. This vegetation transition is thought to have major effects on terrestrial carbon dynamics.

Often on the basis of observations of biomass carbon stocks and vertical gas exchanges, studies to date have generally concluded that shrub-dominated ecosystems sequester more carbon than grass-dominated ecosystems. Shrub encroachment has therefore prompted estimates of significant carbon sinks (e.g. Pacala et al., 2001). However, the effects of changing plant functional type on ecosystem carbon dynamics vary across environmental gradients (Jackson et al., 2002), and in semi-arid contexts shrub-dominated ecosystems are characterised by much higher erosion rates (Wainwright et al., 2000), increasing in lateral transfers of carbon including the loss of previously stable soil carbon (Puttock et al., 2014). Therefore, the assertion that shrub encroachment invariably increases carbon sequestration in terrestrial ecosystems appears incomplete, and may by substantially overestimate the carbon sink in drylands.

To address this concern, I have used highly interdisciplinary approaches to study four 300 m^2 erosion plots distributed across a grass-shrub ecotone (Figure 1), to advance understanding of the distribution and erosion-induced redistribution of carbon in semi-arid ecosystems. This work has found significant increase in the erosion-induced yields of organic and inorganic carbon across the grass-shrub ecotone (Figure 2a). Furthermore, >2 mm aggregates stabilised by calcite precipitation were found to contain similar concentrations of organic carbon to the <2 mm particles (Figure 2b), and accounted for ca. 25% of the soil organic carbon stock. This is important because >2 mm particles are normally excluded from soil carbon inventories, which may substantially underestimate carbon stocks in dryland soils.

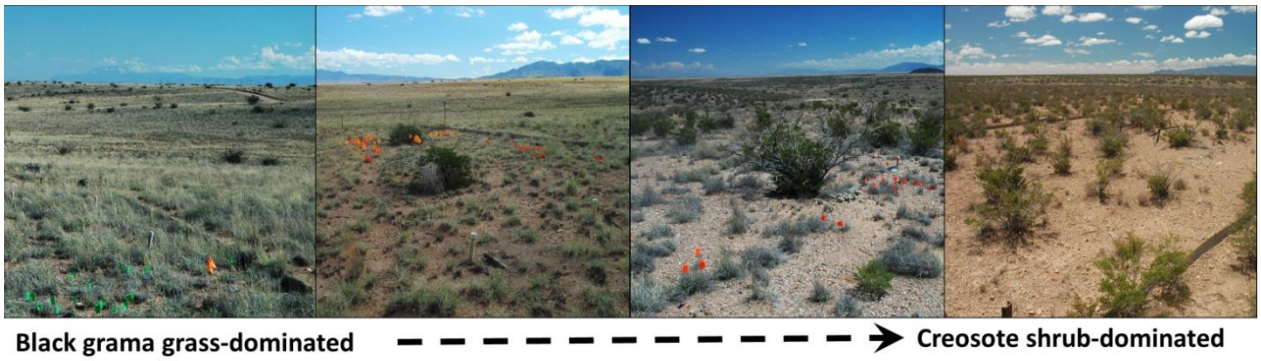

Figure 1. Change in ecosystem structure across the ecotone from grass- to shrub-dominated ecosystems.

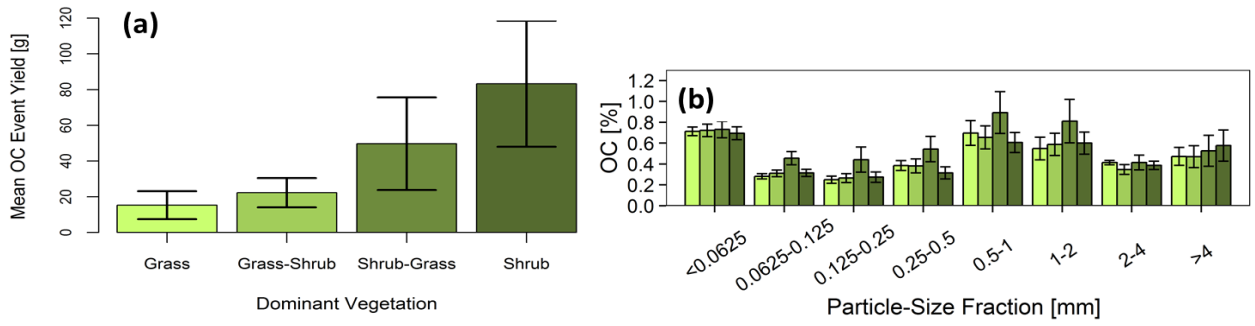

Figure 2. (a) Changes in mean organic carbon yield from erosion events across the grass shrub ecotone. (b) organic carbon concentrations across particle size fractions across grass-shrub ecotone.

Eroded sediment was found to be enriched in organic carbon, exhibiting complex enrichment dynamics apparently arising from differences in microtopographic structure across the grass-shrub ecotone (Figure 3). Such dynamics are not apparent in previous studies generally undertaken using simpler artificial runoff plots. A report of these findings is undergoing final edits for publication in the Journal of Geophysical Research: ES.

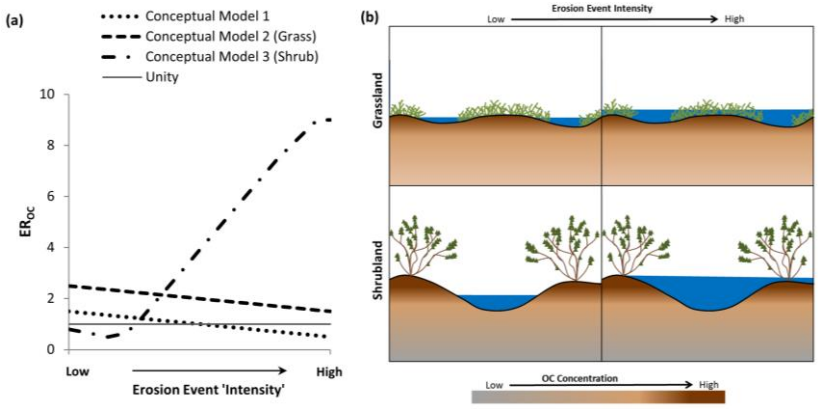

Figure 3. (a) Conceptual models illustrating expected relationships between organic carbon enrichment ratios (ER_{OC}) and rainstorm/erosion event intensity in (b) grass- versus shrub-dominated landscapes.

To better understanding semi-arid ecosystem carbon dynamics, I also pioneered the application of drone-based proximal remote sensing to produce very high-precision maps quantifying the biomass and microtopography of these landscapes. These techniques are ground-breaking and have formed the basis of two major proposals to advance globally understanding of dryland carbon dynamics. Integrating information from erosion flux monitoring with remote sensing products in order to support upscaling to larger extents, I am working with Prof John Wainwright to simulate the erosion-induced redistribution of organic and inorganic carbon using a process-based erosion model (MAHLERAN).

I am hoping to attend the European Geophysical Union's General Assembly in Vienna, Austria, in April 2016, and am therefore applying to the BSRG for partial support towards the costs of this conference. This diverse conference offers a valuable opportunity to interact with the multiple disciplines of researchers investigating the terrestrial carbon cycle, and I have submitted abstracts to present my work at two sessions: SSS6.7: Dissolved and particulate organic matter - linking terrestrial and aquatic ecosystems and SSS12.18 Unmanned Aerial Systems: Platforms, Sensors and Applications in the Geosciences. Networking with international researchers is very important to me personally, and my previous attendance at EGU (2014) fostered collaboration with two international labs to evaluate carbon determination methods. I would attend several sessions on modelling soil erosion, which will provide to inform my ongoing work to improve the process representation of simulated erosion-induced carbon fluxes. In summary, the opportunity to receive feedback on my work and network with other researchers is extremely valuable for my career development, particularly in terms of future employment.

References:

Jackson, R.B., Banner, J.L., Jobbágy, E.G., Pockman, W.T., Wall, D.H., 2002. Ecosystem carbon loss with woody plant invasion of grasslands. Nature 418, 623–626. doi:10.1038/nature00910

Pacala, S.W., Hurtt, G.C., Baker, D., Peylin, P., Houghton, R.A., Birdsey, R.A., Heath, L., Sundquist, E.T., Stallard, R.F., Ciais, P., Moorcroft, P., Caspersen, J.P., Shevliakova, E., Moore, B., Kohlmaier, G., Holland, E., Gloor, M., Harmon, M.E., Fan, S.-M., Sarmiento, J.L., Goodale, C.L., Schimel, D.S., Field, C.B., 2001. Consistent land-and atmosphere-based US carbon sink estimates. Science 292, 2316–2320. doi:10.1126/science.1057320

Puttock, A., Dungait, J.A.J., Macleod, C.J.A., Bol, R., Brazier, R.E., 2014. Woody plant encroachment accelerates erosion of previously stable organic carbon from dryland soils. J. Geophys. Res. Biogeosci. 2014JG002635. doi:10.1002/2014JG002635

Wainwright, J., Parsons, A.J., Abrahams, A.D., 2000. Plot-scale studies of vegetation, overland flow and erosion interactions: case studies from Arizona and New Mexico. Hydrological Processes 14, 2921–2943.

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Academic Background

2012 - Present NERC-funded PhD studentship at the **University of Exeter**. Supervised by Professor Richard Brazier and Dr Karen Anderson. Title: *Investigating the effects of woody shrub encroachment into grasslands on ecosystem carbon dynamics and erosion-induced redistribution of organic carbon in the semi-arid southwestern US.*

2011 - 2012 MSc in Catchment Dynamics and Management at the **University of Leeds**, funded by a merit scholarship. Graduated *Summa cum Laude* with a Distinction. Published dissertation as first author in Water Resources Research, where the Editor-in-Chief (Professor John Selker) commented that it had received one of the most positive reviews he has seen in his four years as editor.

2008 - 2011 BSc (Hons) in Physical Geography at the **University of Exeter.** Graduated *Summa cum Laude* with a 1st, two out of three departmental awards and the Dean's Commendation. Under graduate project on modelling sediment transport was nominated for the British Society for Geomorphology's Marjorie Sweeting national award.

Training and Skills: I have undertaken three NERC-funded short courses: (i) Applications and methods in soil science (British Society of Soil Science; 2014), (ii) Statistical analysis of environmental data in R (University of Glasgow; 2014), and (iii) Terrestrial Laser Scanning for Environmental Research (University of Durham; 2015). In 2012 I worked as a field research assistant sampling lacustrine sediments in the Lake District for Dr. Graeme Swindles. I've analysed sediments for organic and inorganic carbon contents, using dry combustion, and am experienced in the use of drones and Structure from Motion photogrammetry for high-precision ecosystem surveying. Throughout my doctorate I have sought opportunities to teach, completing over 260 hours on a range of physical geography modules including fluvial geomorphology, erosion modelling and landslide risk mapping. Twice I have been selected to co-teach a seven-day fieldcourse on dryland geomorphology and sedimentology in the Sorbas and Tabernas Basins in southeast Spain.

Peer-reviewed publications **(1) Cunliffe, A.,** Brazier, R., Anderson, K., (In Review – following moderate revisions). Ultrafine spatial resolution landscape-scale monitoring of dryland vegetation structure with drone-acquired structure-from-motion photogrammetry. *Remote Sensing of the Environment.* **(2) Cunliffe, A.,** Puttock, A., Turnbull, L., Wainwright, J. and Brazier, R., (In Review – final edits) Dryland, calcareous soils store (and lose) more organic carbon than previously thought, *Journal of Geophysical Research: Earth Surface*. **(3)** Puttock, A., **Cunliffe, A.,** Anderson, K., Brazier, R., (2015). Monitoring the impact of Eurasian beaver reintroduction on ecosystem structure using aerial photography collected from a multi-rotor drone. *Canadian Journal of Unmanned Vehicle Systems.* doi:10.1139/juvs-2015-0005. **(4) Cunliffe, A.,** Baird, A. and Holden, J. (2013) Hydrological hotspots in blanket peatlands: Spatial variation in peat permeability around a natural soil pipe, *Water Resources Research*, 49, doi:10.1002/wrcr.20435.

Conference papers **(1) Cunliffe, A.,** Puttock, A., Anderson, K. and Brazier, R., The distribution and fluvial redistribution of soil organic carbon in semiarid rangelands, European Geosciences Union General Assembly (Session SSS2.11, 29th of April, 2014). (2) **Cunliffe, A.,** Anderson, K. and Brazier, R., Soil organic carbon in semiarid rangelands, British Society of Soil Science AGM (3rd-5th September 2013).

Awards Received: Research Fellowship awarded by the Sevilleta LTER ($4000; 2014); Travel grant awarded by BSG (£725; 2014); Travel grant awarded by BSG (£125; 2014); Research Fellowship awarded by the Sevilleta LTER ($4000; 2013); Merit Scholarship awarded by Santander (£5000; 2011). I am a named Research Co-Investigator reflecting my contributions to two major grant proposals **(£2.6 Million)** submitted in January 2016).

Budget

I am applying for £300 from BSRG to partially support conference attendance at the EGU's General Assembly in Vienna, Austria. Acquiring data for my doctoral research necessitated two extended overseas field campaigns, which has consumed the research support grant awarded as part of my studentship. Despite this, because of the studentship I was awarded, I am not eligible to apply for departmental or college funding to support attendance at this conference. In total attendance at this conference will cost £795 (budget below). If this application is successful, I will make up the difference (£495) from my stipend.

Item	**Cost**
Conference Abstract Processing Charges	£60 (E80)
Conference Registration Fee	£160 (E210)
Travel (Bus Exeter to London and flight London to Vienna return)	£220
Accommodation in a budget hotel (£25/day x 8 days)	£200
Subsistence (£25/day x 7 days)	£175
Total	**£795**