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An unconsidered climate warming feedback: loss of inorganic C stored in caliche in drylands

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In partnership with University of Glasgow, School of Geographical and Earth Sciences

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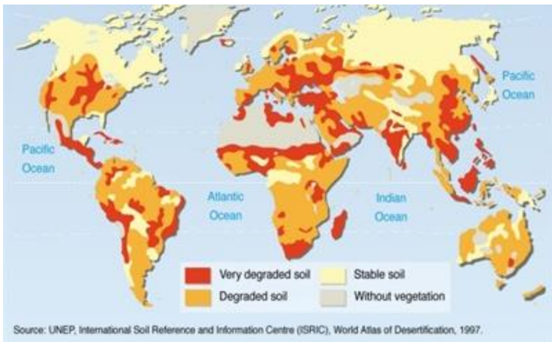
Overview

Over the last decade there has been a major focus on reducing carbon emissions to the atmosphere due to increasing concerns over climate change. The role of drylands in either mitigating or potentially exacerbating the climate-change problem, is seldom considered in any great detail. Currently, drylands have the capacity to store c.95 % of the world's inorganic carbon via caliche formation (Marion et al., 2008), and this store of inorganic carbon in caliche (calcrete) is generally considered to be stable over long time periods (thousands to millions of years). However, there is considerable uncertainty over the role of this soil inorganic carbon pool in relation to climate change and soil degradation.

Caliche layer, Alicante, Spain

Drylands across the world are experiencing significant soil degradation (Middleton and Thomas, 1997) which has the potential to increase CO_2 efflux (a climate warming feedback) as surface soil becomes eroded, exposing caliche layers. The caliche becomes more susceptible to carbonate dissolution, and so this 'stable' store of carbon may become unstable and result in net CO_2 release to the atmosphere, further amplifying the climate warming feedback. Recent evidence suggests that dissolution occurs under conditions of acidic rainfall, CO_2 may be released to the atmosphere (Emmerich, 2003).



Spatial distribution of soil erosion

The magnitude of this abiotic CO_2 efflux is poorly constrained in drylands and little is known about the conditions that affect its spatial and temporal variability. The implications of this poorly constrained CO_2 efflux in drylands are great: at present, biogeochemical cycling models that are used to quantify the relative importance of different parts of the C cycle and the relative importance of different C stores do not consider these abiotic C-cycling processes and potential depletion of stores of inorganic C. Therefore, at present, we may be underestimating the role of degrading drylands in contributing to the problem of elevated atmospheric CO_2 concentrations.

Constraining this abiotic CO_2 efflux is complicated as other processes also contribute to CO_2 efflux from dryland soils, particularly organic matter respiration (net CO_2 release via decomposition, degradation and diffusion processes). Therefore, to quantify the relative importance of CO_2 efflux from this abiotic process, it is necessary to distinguish between CO_2 from biotic sources (e.g., respiration) and abiotic sources (e.g., dissolution). This project will use experimental laboratory-based research and process-based modelling of abiotic C-cycling to generate new understanding of the importance of abiotic C cycling on the C storage in drylands and the magnitude of CO_2 release to the atmosphere under dryland climatic conditions. Using the experimental data, a process-based model will be developed by the student to model inorganic C-cycling in dryland soils, including mechanisms for CO_2 efflux. This model can be subsequently used to evaluate the stability of soil inorganic carbon over future decades and how projected changes in climate will alter CO_2 efflux from dryland soils.

Research Aim and Questions

The overarching aim of this project is to determine the importance of abiotic CO_2 efflux from soils rich in caliche under dryland climatic conditions. Research questions to be addressed are:

1. What is the relative contribution of abiotic CO_2 efflux to total CO_2 efflux from dryland soils under ambient climatic conditions?
2. How does the progressive exposure of the caliche layer at the soil surface alter soil inorganic C cycling?
3. How will projected changes in climate and land degradation change the amount of CO_2 efflux from abiotic mechanisms?

Methodology

To fulfil the overarching aim and research questions this project will employ laboratory-based experimentation and process-based modelling. Laboratory-based experimentation will be carried out to address questions 1 and 2, to isolate the role of abiotic processes in inorganic C-cycling in dryland soils under replicated and controlled climatic conditions in environmental chambers at Durham University. Field work will be undertaken in one or more dryland regions to collect suitable soil sections that will be used in subsequent laboratory analyses. Controlled experiments will then be conducted to determine how variables such as temperature and rainfall distribution alter soil CO_2 efflux. To constrain the contribution of abiotic mechanisms to total soil CO_2 efflux it will be necessary to differentiate between CO_2 from biotic and abiotic sources which will be based on identifying unique isotopic signatures for each source (Amundson et al, 1998). A molecular sieve sampling system will then be used to trap CO_2 released from the soil (Hardie et al, 2005), upon which isotopic analysis can then be carried out to determine the relative contribution of CO_2 from each source. To address question 3, processed-based, 1-dimensional modelling of soil inorganic carbon cycling will be developed from existing models of biotic mechanisms of soil-carbon cycling (e.g. CENTURY [Parton et al, 1994] and DayCent [Parton et al, 1998]). This modelling will be used to test the empirical understanding that the student will derive from laboratory-based experimentation, and to evaluate interactions between biotic and abiotic mechanisms of C-cycling and CO_2 efflux. This modelling approach will then be used to investigate how projected changes in climate and land degradation will affect inorganic C cycling and resulting CO_2 efflux. The student may then consider methods for upscaling this approach to consider regional and global carbon budgets.

Timeline

Year 1: Develop an understanding of carbon cycling in drylands and experimental and modelling approaches used to investigate/quantify elements of C cycling. Training in statistical and modelling techniques. International field work and set up laboratory-based experimentation.
Year 2: Laboratory based experimentation and development of process-based modelling
Year 3: Model testing. Prepare draft publications and present outcomes to IAPETUS and at international conference; draft thesis.
To end Year 3.5: Submit thesis; finalize publication manuscripts; attend an international conference.

Training & Skills

The student will join the Catchment and Rivers research cluster in the Department of Geography. A key focus of this cluster is on monitoring and modelling the interactions and feedbacks between geomorphology, hydrology, vegetation and water chemistry in hillslope and river systems.
In Glasgow the student will be part of the Carbon Landscape Research Group (www.carbonlandscapes.org), a thriving research group active in furthering understanding of C and macronutrient flow from terrestrial stores to the atmosphere. Research in this group focuses on systems sensitive to anthropogenic disturbance and

changing climate e.g. wind farms, oil palm plantations, the Amazon rainforest.
The student will receive instruction in data collection, scientific method, contextualizing and problematizing research in physical geography, planning for laboratory work and group work in physical geography through the taught module 'Implementing Research Design' during their first year. In addition the students will benefit from enhanced employability through research and transferable skill training offered by IAPETUS and by the University of Durham.

References & Further Reading

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Further Information

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