PGGE11214 *(20 credits)*

Novel strategies for carbon storage in soil

COURSE HANDBOOK (v1.0)

Session 2017–18

Teaching Team: Dr Saran Sohi (CO), Dr Ondrej Masek, Prof David Manning

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Contents

v1.02 typos corrected p5-6 09.01.18
v1.01: Uploaded 08.01.18

1. Introduction

Soils have a central role in the global carbon cycle. The exchange of carbon between the coupled plant-soil system and the atmosphere is greater than between the ocean and the atmosphere. The same amount of CO_2 passes through the plant–soil system every 5–7 years as exists in the entire atmosphere. To mitigate the effects of fossil fuel combustion by removing atmospheric CO_2 – the greenhouse gas removal (GGR) signalled in the Paris Agreement – working with the plant–soil system may be our best chance. Can we intervene with meaningful impact? This course explores some current options for doing so.

Soil carbon and land use background

The amount of *organic* (plant-derived) carbon stored in the World's soils is twice as large as that in the atmospheric CO_2 pool. Organic carbon in only in slow transit back to the air via slow decomposition: deposited by plants and used by micro-organisms. Half of the carbon fixed in photosynthesis is returned via the soil rather than from immediate respiration by plants. This cycling of carbon is still six times greater than that arising from burning fossil fuel.

Soil is not only central to these stocks and transfers, but ubiquitous. Up to 5000 Mha of land is also under some form of agricultural management and 150 Mha in plantation forestry. One third of plant primary productivity is thought to be under some form of control through human use of land. The potential to manipulate soil for the storage of organic carbon from air is clear.

Soils also contain a vast amount of *inorganic* carbon. This is mainly in the form of carbonate minerals inherited from parent rock, with extremely long residence times. But carbonates can also form in soil through mineral weathering reactions. This natural process (carbonation) can be augmented by adding minerals such as olivine and plagioclase. Calcium and magnesium released in weathering react with CO_2 that is elevated in soil by root and other biological activity.

Urban landscapes now account for 2% of the Earth's surface and since 2014, more than half of people live in cities. Urban land is highly managed and manipulated – it is of especially high value. Initial measurements suggest that 1 Mt CO_2 could be removed each year by optimising just 12,000 ha of urban land for carbonation.

Novel Strategies for Soil Carbon Storage focuses on opportunities to manage soil carbon at a grand scale – a scale relevant to the mitigation of climate change. We are particularly interested in technologies that work with nature while at the same time having specific economic and policy drivers, beyond those linked to carbon storage.

Peatland expansion has value to biodiversity and other ecosystems services. Carbonation could provide a means to tie the development of land in an urban context to the management of carbon balance. Biochar production and use could be of special importance, with a potential to address multiple issues embedded in the water–energy–food nexus.

We consider these disruptive and/or transformative approaches in the way they affect soils and achieve soil carbon storage, considering other (and future) demands on land and natural resources. These technologies are at the interface of conventional soil management options and those classified by some as engineering for greenhouse gas removal (GGR).

The opportunity and challenges around the development and use of such technologies extends far beyond soil science. In our course, we consider each technology as part of a wider system, bringing in aspects of engineering as well addressing the policy and legislative / regulatory context.

Those approaching the course from an engineering or social science angle will learn about agriculture as a system of natural but heavily manipulated processes - and how these are managed.

2. Course aims and learning outcomes

Course aims

(i) To emphasise the inter-relationships between the physical environment and land management practices and ecological situations.

(ii) To develop an appreciation that many environmental questions can only be answered by a good process-based understanding of the physical and chemical principles.

Learning outcomes

By the end of the course, students will be expected to be able to:

- Recognise transformative technology options for land management and their purpose;
- Appreciate the diversity of soil as a matrix and how carbon, nutrient and mineral composition affects the associated agriculture, energy and resource systems;
- Assess strategies for use of technologies for their flexibility, systems fit and policy context in deployment mode;
- Form opinions based on science that can contribute to wider public and policy debate.

The course will encourage you to think about technologies that are not only transformative, but harness the scale and ubiquity of natural processes. It considers possibilities for their adoption in the context of multiple global challenges.

At a technical level the course will encourage understanding of the connections between soil, land-use and wider biophysical and socio-economic systems. At a practical level it will stimulate innovative thinking and problem solving, facilitated through group work.

3. Course outline and timetable

The course will cover:

- Biochar production, function and use
- Biochar systems
- Carbonation
- Peatland.

The course is connected to the UK Biochar Research Centre (www.biochar.ac.uk) and the SUCCESS project at Newcastle (https://research.ncl.ac.uk/success). This provides students direct access to the findings of current research around the course topics.

Lectures (8) are on Thursdays 09:00–10:50. These will be held in Room 5 of the Crew Building Annexe (School of GeoSciences), King's Buildings campus. This room is equipped for recording audio / content, which will be enabled for this course.

Tutorials (9) associated with each preceding lecture are on Wednesdays 15:00–16:30. These will be held in Room 4.09 of the Darwin Building (School of GeoSciences), Drummond Street.

There are two **Practicals**, held at the King's Buildings campus (Week 6 and Week 11). The first involves a tour of the biochar pilot plant, the second consideration of site survey for carbonation. For both practicals, please meet outside the Crew Building Annexe.

Note: There is no Lecture, Tutorial or Practical scheduled in Week5.

The overall course structure and timetable is shown in the table below:

Wk	Day / time	Type	No	Topic	Staff
1	Wes 17 Jan 15:00–16:30	-	-	-	-
1	Thu 18 Jan 09:00–10:50	*LECTURE* Crew Building (Annexe) Rm5 King's Buildings	1	Introduction: Engineering soils for carbon storage	SS
2	Wes 24 Jan 15:00–16:30	*TUTORIAL* Darwin 4.09, Drummond St.	1		SS
2	Thu 25 Jan 09:00-10:50	*LECTURE* Crew Building (Annexe) Rm5 King's Buildings	2	Biochar principles and systems	SS
3	Wes 31 Jan 15:00–16:30	*TUTORIAL* Darwin 4.09, Drummond St.	2		SS
3	Thu 1 Feb 09:00–10:50	*LECTURE* Crew Building (Annexe) Rm5 King's Buildings	3	Biochar production systems	OM
4	Wes 7 Feb 15:00–16:30	*TUTORIAL* Darwin 4.09, Drummond St.	3		OM
4	Thu 8 Feb 09:00–10:50	*LECTURE* Crew Building (Annexe) Rm5 King's Buildings	4	Biochar properties and soil functions	SS
5	Wes 14 Feb 15:00–16:30	-	-	-	-
5	Thu 15 Feb 09:00–10:50	-	-	-	-

Flexible Learning week					
6	Wes 28 Feb 15:00–16:30	*TUTORIAL* Darwin 4.09, Drummond St.	4		SS
6	Thu 1 Mar 09:00–10:50	*PRACTICAL* Meet outside Crew Building Annexe King's Buildings	1	UKBRC pyrolysis facilities (University of Edinburgh)	OM
7	Wes 7 Mar 15:00–16:30	*TUTORIAL* Darwin 4.09, Drummond St.	5		OM
7	Thu 8 Mar 09:00–10:50	*LECTURE* Crew Building (Annexe) Rm5 King's Buildings	5	Biochar systems fit: biomass and bioenergy	OM
8	Wes 14 Mar 15:00–16:30	*TUTORIAL* Darwin 4.09, Drummond St.	6		OM?
8	Thu 15 Mar 09:00–10:50	*LECTURE* Crew Building (Annexe) Rm5 King's Buildings	6	Biochar systems fit: soils and agriculture	SS
9	Wes 21 Mar 15:00–16:30	*TUTORIAL* Darwin 4.09, Drummond St.	7		SS
9	Thu 22 Mar 09:00–10:50	*LECTURE* Crew Building (Annexe) Rm5 King's Buildings	7	Introduction to peatland management	SS
10	Wes 28 Mar 15:00–16:30	*TUTORIAL* Darwin 4.09, Drummond St.	8		SS
10	Thu 29 Mar 09:00–10:50	*LECTURE* Crew Building (Annexe) Rm5 King's Buildings	8	Introduction to carbonation	DM
11	Wes 4 Apr 15:00–16:30	*TUTORIAL* Darwin 4.09, Drummond St.	9		DM
11	Thu 5 Apr 09:00–13:00	*PRACTICAL* Meet outside Crew Building Annexe King's Buildings	2	Carbonates in soil – site survey exercise	DM SS

Staff abbreviations: DM – David Manning; OM – Ondrej Masek; SS – Saran Sohi (CO)

4. Teaching team

The Course Organiser is **Dr Saran Sohi**; any queries regarding the course as a whole or on the biochar section in general should be addressed to him (Rm 119, Crew Building, King's Buildings, (saran.sohi@ed.ac.uk or 0131 651 4471). **Dr Ondrej Masek** has responsibility for the part about biochar production and the bioenergy context, including the first practical (Room 110, Crew Building, King's Buildings (ondrej.masek@ed.ac.uk or 0131 650 5095). Prof David Manning is an Honorary Professor at Edinburgh. He can be reached via our School of GeoSciences staff list, or at his base at Newcastle University (david.manning@newcastle.ac.uk).

5. Course secretary

The Course Secretary is **Susie Crocker** (Room 332, Grant Institute, King's Buildings, susie.crocker@ed.ac.uk). The Course Secretary helps with routine enquiries about the course, notification of absence, and submission and return of course assignments.

6. Submitting coursework

Section 9 provides details of Course Assessment. Submissions for in-course assessment must be made via *Turnitin*, using the link provided on *Learn* page for this course. The two in-course submission deadlines are: **Monday 12th March 17:00** and **Monday 16th April 17:00**.

7. Lecture content

Wk	Topic and content	Staff
1–2	Introduction: Engineering soils for carbon storage Soil in the global carbon cycle. Sources and fate of soil carbon. Geographic aspects of soil carbon stocks and fluxes. Established strategies for managing soil carbon. Policies and inventories.	SS
2–3	Biochar principles and systems Carbon stabilisation – chemistry. Processes. Stability changes resulting from thermal treatment. Biomass pyrolysis feedstock and products. Connected systems. Policies. Regulation. Economics – cost, price … benefits? Counterfactuals. Life cycle analysis.	SS
3–4	Biochar production systems Mechanics and dynamics of pyrolysis processes. Feasibility and feedstock flexibility; product precision. Environmental impacts and risk. Unit scale and logistics. Carbon co-products (value chain). Technology Readiness Level.	OM
4 / 6	Biochar properties and soil functions Properties and diversity. Key functions in soil and crop. Meta-analysis. Dose–response, time. Synergies.	SS
7–8	Biochar systems fit – biomass and bioenergy Definition of efficiency. Key factors in energy balance and importance to life cycle analysis. Related technologies and processes. Optimisation. Uncertainties. Technology maturity and lock-in. Bioenergy subsidies as opportunity and barrier.	OM
8–9	Biochar systems fit – soils and agriculture Maximising value / benefits. Matching biochar and soil types. Fit to different crop and farming systems – biophysical and socio-economic dimensions. Modes of deployment, integrated products and co-amendments. Policy. Regulation. Prospects.	SS
9–10	Introduction to peatland management Global carbon stock in peatland. Occurrence and origins of peatland. Carbon sequestration rates in peatland. Susceptibility of peatland carbon. Opportunities beyond protection – expansion. Co-benefits and policy context.	SS
10–11	Introduction to carbonation Physical / chemical principles. Measured rates and duration of carbon sequestration. Urban context and global potential. Commercial relevance and links to policy context. Life cycle analysis and logistics. Possible implications for ecology, risks.	DM

8. Recommended Reading

These books provide comprehensive information on biochar and carbonates in soil. Although these approach the topics from a technical / biophysical point of view, the Routledge book does also consider economics and systems.

1. **Lehmann J and Joseph S (2015) Biochar for Environmental Management: Science and Technology (2nd edition), Routledge, 976pp.**

2. **Kimble JM and Stewart BA (1999) Global Climate Change and Pedogenic Carbonates, CRC Press, 320pp.**

A bibliography of key journal articles will be posted on Learn as the course progresses.

9. Course Assessment

Assessment is entirely in-course. It will involve two submissions, summarised below.

In-course assessment		
1	Report – Evaluate pyrolysis processing based on observations of the pilot-scale facility in Practical 1. Highlight salient challenges, constraints / limitations and risks, when extrapolating to commercial / industrial situations. Word limit: 1000 (total). Submission deadline: Monday 12th March	30%
2	Essay – outline a system-based strategy for deployment of biochar in a defined agricultural or other land management context. Include schematics and a quantitative estimate of potential (highlighting uncertainties). Word limit: 2000 (excluding references, captions, appendices). Submission deadline: Monday 16th April	70%