STARS
Soils Training And Research Studentships

Future Global Challenges for Soil Science

Conference Programme



14-17 January 2019
Low Wood Hotel, Windermere
http://wp.lancs.ac.uk/stars/home/conference-jan-2019/

#CelebrateSTARS

Contents

Introduction by the Organising Committee

Welcome to the Soils Training and Research Studentships (STARS) conference '*Future Global Challenges for Soil Science'*. Over three days, the conference will bring together the UK NERC and BBSRC funded consortium of universities and research institutes across England, Scotland and Wales: the forty PhD students that make up the unique STARS college along with the internationally renowned experts that comprise its supervisory team.

Not only will the conference be a great opportunity to both broaden and deepen our collective understanding of the ground beneath our feet but also to hear about a diverse array of novel approaches, methods and techniques that have been applied in the pursuit of finding answers to some of the most critical research questions within soil science. By its very nature as a research consortium, the STARS CDT has made and continues to make an active contribution to a wide range of sub-disciplinary discourses within soil science, including root-soil interface research, soils and ecosystem services, the resilience and response of soil functioning to global changes and the modelling of the soil ecosystem at different spatial and temporal scales. These four programmes of research were conceived at the founding of STARS and will form the main themes of the conference. We are delighted that the principle sessions will be formally opened by keynote speakers, all of whom have contributed seminally to these respective themes.

In what we believe is an exciting programme, there will be a host of different platforms from which to consider, discuss and debate the future of the discipline. Among the more traditional oral and poster presentations, we have endeavoured to ensure that there are plenty of opportunities for discussion and whether it's on a panel, during a workshop or across a bread roll at dinner, we hope that you will find the experience both enriching and thought-provoking. Whilst we hope that the suite of activities within the programme reflects the consortium's broad range of interests, there is plenty of space within the itinerary for you to 'break out' with your established and newfound colleagues and we hope that the beautiful vistas afforded from the venue will act as an inspiring backdrop to enhance your discussions.

The conference, of course, cannot aspire to cover every aspect of soil science and our four themes are not an exhaustive inventory of areas pursued by soil scientists. Indeed, even within STARS, we realize that many of our research agendas may sit on the border between two or more of our themes or even beyond. Nevertheless, we hope that the STARS conference will be a venue to explore these themes, take stock of the research gaps outstanding and consider what questions we, as soil scientists, should be asking in the remaining decades of this century. After all, the mission that launched STARS was always to cultivate the next generation of soil scientists, adept and prepared to tackle the many 'future global challenges' that we will face on Earth. As we know, the answer to them all may just lie in the earth itself.

Our very best wishes for a memorable conference,
STARS Conference Committee

Hannah Cooper, Jasmine Burr Hersey, Paul George, Chris McCloskey, Emily Dowdeswell-Downey, Dan Evans, Andrew Tweedie, Martha Ledger, Phil Haygarth, Steve McGrath, Guy Kirk, and Eric Paterson.

Foreword and Welcome

Dear Colleagues,

It is my great pleasure to welcome you to the STARS Conference.

Just for a moment stop, reflect. The times really do not get much better than this moment for British Soil Science. Here today we are celebrating 40 PhD students from across the nation, coming together for a few days to share their thoughts, vision, and ideas for the future. What a moment to savour.

Doing a PhD is never easy, but a modern soils PhD experience requires not just laboratory and field skills, but crucially skills for working with people and society. What better way to prepare students for the future than to hand them the ownership of creating managing and delivering this week's event? As part of the organising committee it has been a pleasure to see the student team working, to observe the dynamics and see the embryos of our future leaders emerge. As the journey towards conference organisation proceeded, I had to increasingly pullback from influencing the committee, as I realised the vision for this workshop was in very capable, student hands. Let's hope that is a good example for the future of our soil science too.

I want to take this moment to highlight two opportunities for you this week. Firstly, we have a film crew on-site and I want to encourage small teams of students with supervisors to gather and promote live discussions around key issues of soil science that we will film and publish as part of the STARS legacy. It's not too late to get involved folks. Also, I'm delighted to announce the opportunity for students and supervisors to publish their work in a special issue of the *European Journal of Soil Science*, these are really opportunities not to be passed over. Details of both these opportunities are in this conference document.

This week we have a diversity of experience which I hope you will enjoy. We have an exciting agenda planned around four cutting-edge themes of Soil Science; we have international keynote speakers accompanied by dynamic PhD mentors from across the STARS community; we have a beautiful hotel in perhaps (in my opinion) the most beautiful place in the world. What's not to like about this folk? Please enjoy.

Phil Haygarth, Director of STARS, Lancaster University
21st December 2018

Venue

The Low Wood Bay hotel is on the A591, between Windermere and Ambleside. The postal address is:

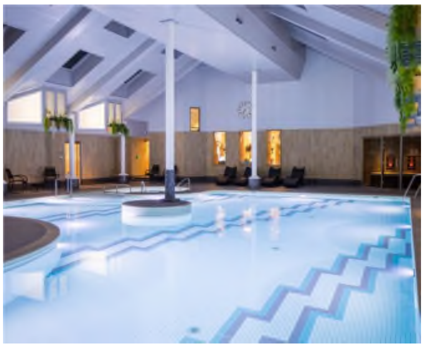
Low Wood Bay
Ambleside Road
Windermere
Cumbria
LA23 1LP

Car parking is to the rear of the hotel, accessed by the new drive, 100 meters north of the hotel. There is a bus stop outside the front of the hotel. The nearest railway station is Windermere.

The venue was chosen in part due to its beautiful and inspiring location, overlooking Lake Windermere in the heart of the Lake District. In addition, it is able to accommodate the large number of participants expected and can provide spacious and comfortable conference, meeting and workshop rooms. The hotel has recently undergone a very substantial extension and refurbishment and provides excellent accommodation and facilities.

As a guest at the Low Wood Bay, you will have access to the health club, which includes a 50-foot pool, squash court, gym, steam room, Jacuzzi and infrared sauna, so do not forget to pack your sports gear and walking shoes.

Please note breakfast is available between 7.00 and 10.00 am. Check in is from 3pm, upon checkout bags can be left in the hotel luggage room if desired. It will be your responsibility to settle any additional costs charged to your room during your stay.



Announcing a Special Issue for the STARS CDT in the European Journal of Soil Science
"Innovations in Soil Science to address Global Grand Challenges"

Editors Phil Haygarth, Guy Kirk, and Davey Jones
Contact: stars@lancaster.ac.uk

The Soils Training and Research Studentships (STARS) Centre for Doctoral Training (CDT) is a UK NERC and BBSRC funded consortium of eight universities and research institutes from around England, Scotland, and Wales training the next generation of soil scientists. We have just entered the peak phase where we have 40 PhD students in the college and in January we will be celebrating this with a three-day conference to be held at the Low Wood Hotel, Lake Windermere (Lake District), with organization and presentations from students as well as a number of international guest speakers. This provides the perfect timing and opportunity to propose a special issue to be published in EJSS because it is a BSSS journal working with the British Soils CDT.

Volunteer papers comprised of teams of students and supervisors are now encouraged around the theme of the STARS CDT 'Innovations in Soil Science to address Global Grand Challenges' and around the STARS sub themes:
- 1. Understanding the soil–root interface
- 2. Soils and the delivery of ecosystem services
- 3. Resilience and response of functions in soil systems
- 4. Modelling the soil ecosystem at different spatial and temporal scales

The timetable:

- End December 2018: STARS and EJSS reach agreement on principle and agree modus operandi; start to form the Editorial team.
- Early January 2019: Launch concept by email and ask for proposed authors to signal intent and title.
- Mid-January 2019: Promotion at STARS conference.
- End January 2019: Corresponding authors send provisional papers titles and author list to stars@lancaster.ac.uk
- April–June 2019: Window for receipt of papers.
- End December 2019: Reviews, responses, revision and resubmission to be complete.

All papers will be subject to strict independent peer review. It is primarily open to STARS PhD students and supervisors in the first instance, but other relevant soils PhD students are welcome to enquire and discuss the possibility of being included.

Invitation to make a Soil Science Film at the STARS Conference

In order to help create a lasting legacy from the STARS College, we are providing the opportunity to make some short Soil Science films with a professional film team led by Roger Appleton.

Roger and his team will be at the conference Tuesday morning until Thursday lunchtime and will be based in a room close to the conference action. We are looking for volunteer small groups of, say, 2-6 of you to self-organise and form around thematic areas of your passion and choice. In the groups we want it to be a mix of students with more experienced scientists together and we wish to film you sitting around a table, talking, reflecting and debating on your chosen topic. It may be for example - say soil erosion, soil carbon - or anything soil related indeed that lights your fire. One dynamic that Roger thinks works well is when earlier career scientists quiz the older scientists. Roger's experience says that you don't need to worry too much about scripting and planning, it works well if perhaps the a few questions are planned in advance, but mostly natural free flowing conversation works best. A filming session may take about 30-45 minutes maximum with a final film of about 5-10 minutes. You will have a full opportunity to see the draft before it is published on the web.

So, we are calling for volunteers, maybe 4 or 5 groups over the duration of the conference. You will have to work out a best time to fit the session in or around the conference schedule, but we are hoping this will be a great opportunity to create an inspiring legacy!

If you have alternative approaches you would like to suggest, your ideas are welcome too.

Please see Phil Haygarth, Roger Appleton or Olivia Lawrenson if you are interested.

Conference schedule

All activities to take place in Main Conference Room unless otherwise stated

Monday 14th January	
15.00 – 17.00	Check in; free time to walk in the local area, use hotel facilities, etc.
16.45 – 18.00	Registration (entrance to Lakes Suite) and poster mounting (Gallery)
18.00 – 19.15	**Official start to the meeting** Introduction to the meeting with Professor Steve McGrath and introduction to working with Global Challenges
19.45	Dinner (Windermere Restaurant)
Tuesday 15th January	
8.00 - 9.00	Time for uploading presentation slides and checking AV
9.00 – 9.15	Welcome Note – Professor Phil Haygarth
9.15 – 10.00	**Opening Keynote:** Professor Steve Banwart *Chair: Professor Phil Haygarth*
Session 1: Soils and the delivery of ecosystem services	
10.00 – 10.45	**Keynote:** Professor Richard Bardgett *Chair: Paul George*
10.45 – 11.15	Coffee break (Gallery)
11.15 – 11.45	**Panel Discussion:** Professor Steve Banwart, Professor Richard Bardgett, Dr Emma Sayer, Dan Evans, Luke Hillary *Chair: Paul George*
	Oral Presentations *Chair: Chris McCloskey*
11.45 – 12.00	Andrew Tweedie: *Temporal changes in phosphorus forms in cultivated Scottish soils*
12.00 – 12.15	Anchen Kehler: *An investigation into low redox systems and the fate and behaviour of phosphorus forms within them*
12.15 – 12.30	Sam Reynolds: *Elucidating the role of cover crops on influencing organic phosphorus in arable soil*

12.30 – 12.45 12.45 – 13.00	Dan Evans: *Ground-making research: the first arable soil formation rates* Beckie Draper: *Effects of different zinc nanoparticles on soil and ryegrass*
13.00 – 14.00	Lunch (Windermere Restaurant)
14.00 – 14.30	**Poster Pitches** *Chair: Hannah Cooper*
Session 2: Modelling the soil ecosystem at different spatial and temporal scales	
14.30 – 15.15	**Keynote:** Professor Hans-Jörg Vogel *Chair: Luke Hillary*
15.15 – 15.45	**Panel Discussion**: Professor Hans-Jörg Vogel, Professor Dave Chadwick, Fiona Seaton, Andrew Tweedie *Chair: Luke Hillary*
15.45 – 16.30	**Coffee break; poster picos from 15.55 (Gallery)** *Chair: Fiona Seaton* **Poster presenters:** Tom Bott: *Bio-monitoring: monitoring fugitive methane emission using microbiology* Mihai Cimpoiasu: *Combining X-ray and electrical resistivity tomography methods towards a new methodology of soil hydraulics properties assessment* James Edgerley: *Direct and indirect effects of drought and warming on nutrient availability in an upland grassland in the UK* Luke Hillary: *Viromics detects long-term persistence of faecally associated viruses in biosolid amended soils* Jack Lort: *Dermal bioavailability of PAH: the route forward* George Themistocleous: *Modelling variety dependent least limiting water range: assessing the limits to root elongation in field soil*

 16.30 – 16.45 16.45 – 17.00 17.00 – 17.15 17.15 – 17.30	**Oral Presentations** *Chair: Andrew Tweedie* John Beale: *The significance of soil properties to the uncertainty in estimating soil moisture from Synthetic Aperture Radar* Lewis Rose: *Variability of gas diffusion in soils* Hannah Cooper: *Zero-tillage could offer a long term strategy to mitigate climate change* Fiona Seaton: *The impact of soil and plant diversity upon soil microbial diversity*
17.30 – 19.30	Free time
19.30	Dinner (Windermere Restaurant)
Evening	Pub quiz (Buckley Room)
Wednesday 16th January	
8.00 – 9.00	Time for uploading presentation slides and checking AV
Session 3: Understanding the soil-root interface	
9.00 – 9.45	**Keynote:** Dr Saoirse Tracy *Chair: Emily Dowdeswell-Downey*
9.45 – 10.15	**Panel Discussion:** Dr Saoirse Tracy, Dr Eric Paterson, Chris McCloskey, Malika Mezeli *Chair: Emily Dowdeswell-Downey*
10.15 – 10.45	Coffee break (Gallery)
 10.45 – 11.00 11.00 – 11.15 11.15 – 11.30 11.30 – 11.45 11.45 – 12.00 12.00 – 12.15	**Oral Presentations** *Chair: Dan Evans* Emma Burak: *Does root architecture influence the formation of rhizosheath?* Jasmine Burr-Hersey: *Can roots influence soil structure via reorganisation of the rhizosphere?* Lucy Greenfield: *Protein breakdown in soil along a grassland altitudinal gradient* Chris McCloskey: *Measuring plant-driven soil carbon dynamics in field conditions* Heather Ruscoe: *The impacts of land management on beneficial Pseudomonad communities* Malika Mezeli: *In-soil trophic interactions between plants, rhizosphere bacteria and nematodes: Improving availability of soil organic phosphorus*

12.15 – 13.15	Lunch (Windermere Restaurant)
13.15 – 14.15	Workshops in parallel: **Careers Workshop** *Convenor: Heather Ruscoe* **Integrating Soil Science in Policy** *Convenor: Paul George*
14.15 – 15.00	**Coffee break; poster picos from 14.25 (Gallery)** *Chair: Jack Lort* **Poster presenters:** Marta Cattin: *Estimation of carbon use efficiency (CUE) and CO2 production after application of digestate on grassland* Rose Durcan: *Drivers of soil carbon changes in subtropical and tropical grasslands: a review* David Fidler: *Comparative metagenomics and GeoChip analysis reveals functional shifts in microbial community with soil carbon depletion* Harry Harvey: *The impact of soil structure on microbial response to environmental change* Katy Wiltshire: *Tracing the origin of sediments and C across the terrestrial-aquatic continuum: A holistic approach to assess climate change and water quality threats*
15.00 – 16.00	Workshop in parallel: **Our Role as Scientists** *Convenor: Harry Barrat*
16.00 – 17.30	Management Board meeting (Buttermere Room)
16.00 – 19.00	Free time
19.00	Drinks reception (Gallery)
19.30	Conference Dinner (main conference room)

Thursday 17th January	
8.00 – 9.00	Time for uploading presentation slides and checking AV
Session 4: Resilience and response of soil functions and global changes	
9.00 – 9.45	**Keynote:** Dr Kate Buckeridge *Chair: John Beale*
9.45 – 10.15	**Panel Discussion**: Dr Kate Buckeridge, Dr Federica Tamburini, Emily Dowdeswell-Downey, Alex Williams *Chair: John Beale*
10.15 – 11.00	**Coffee break; poster picos from 10.25 (Gallery)** *Chair: Heather Ruscoe* **Poster presenters:** Leigh-Anne Kemp: *The role of soil fertility in the function of mycorrhizal associations* Corina Lees: *Which grass species or mixture will stand the test of time with regards to soil erosion mitigation?* Samuel Musarika: *Fresh organic matter effects on carbon dioxide, methane and nitrous oxide emissions on cultivated peat* Francis Parry Roberts: *Infiltrating agriculture: hydrological implications of land use and management across the UK* Jessica Potts: *Acetamiprid transport and mobility within UK agricultural soils - A comparison of commercial mixtures under different soil organic matter treatments*

	Oral Presentations *Chair: Jasmine Burr-Hersey*
11.00 – 11.15	Alex Williams: *Characterising shifts in the resistome and microbial community structure of cattle slurry fertilised agricultural soil*
11.15 – 11.30	Paul George: *Diverging trends of belowground richness but not beta diversity revealed within temperate ecosystems*
11.30 – 11.45	Emily Dowdeswell-Downey: *The effects of climatic conditions on (de)stabilising processes in aggregate microcosms*
11.45 – 12.00	Rosanne Broyd: *High and dry: are oceanic-alpine ecosystems resilient to summer drought?*
12.00 – 12.15	Martha Ledger: *Determining regional-scale carbon losses from tropical peatlands using InSAR*
12.15 – 12.30	Harry Barrat: *Of moisture and microbes*
12.30 – 13.30	Legacy review and final remarks from Professor Davey Jones; Prizes and Acknowledgements
13.30 – 14.30	Lunch (Windermere Restaurant)
14.30	Departure

Workshops

Careers Workshop *Convenor: Heather Ruscoe. Wednesday, 13.15 – 14.15*
The careers workshop will host a range of speakers from different backgrounds and career progression points. Attendees will hear what life is like after a PhD for graduates Laura O'Keefe- a Research facilitator at Lancaster University and Flora O'Brien- a Root biologist at the National Institute of Agricultural Botany (NIAB). Additionally, Jane Ince will be joining us from the Food Standards Agency (FSA) to talk about her role as a civil servant within the Chief Scientific Advisors (CSA) team and to talk through an exciting internship opportunity at the FSA. A panel discussion will follow with all speakers, joined by students Jasmine Burr-Hersey and Hannah Cooper who both successfully completed an internship within a government department. Overall this is an opportunity to be inspired by potential career routes outside of academia and to have an informal discussion regarding different careers, internships and career progression advice.

Integrating soil science in policy *Convenor: Paul George with Ian Rugg. Wednesday, 13.15 – 14.15*
The session will be very interactive and largely image based. It will focus on behaviours, roles and challenges of developing - and successfully influencing - policy. Content:

1. Working with and influencing policy makers (20 minutes).
2. Soil policy in Europe – issues, challenges and the future (20 minutes):
3. Workshop / discussion session (20 minutes): How can you improve your influence on policy?

Ian works in the soil policy team of Welsh Government and is chair of the Welsh Soils Discussion Group. He has an MSc in Pedology and Soil Survey and is a specialist in Agricultural Land Classification. He has field surveyed soils in England, Wales and Scotland. Ian has a varied career including environmental regulation and monitoring, technical advice to policy makers, working with researchers and commissioning of research. Ian has worked extensively at UK level and has been involved with an number of EC initiatives. These include the Soil Framework Directive and Areas of Natural Constraint revision.

Our Role as Scientists *Convenors: Harry Barrat and Andrew Tweedie. Wednesday, 15.00 – 16.00*
The aim of this workshop is to provide a formal setting to discuss the broader aspects of science and society. Discussions will be built around 3 main areas:

1. The different roles of science in society
2. The responsibilities we have as individual scientists
3. The possible avenues towards fulfilling these responsibilities

It's easy to go through a whole PhD without addressing these ideas, yet they form a foundation to your work. We hope to have a range of career experiences there, from PIs to post-docs. If these questions tickle your fancy, then come join us for a thought-provoking hour.

Harry & Andy

Keynote Speakers

Professor Steve Banwart

Steve Banwart is the University of Leeds Leadership Chair in Integrated Soil/Agriculture/Water research and an international leader in the study of reactive processes in soil and groundwater. His core science expertise is basic chemistry that is also applied to the study of soil systems and natural waters. His achievements include combining laboratory experimentation, theoretical mathematical modelling, and data from field studies in order to describe water flow and transport and mechanism of chemical transformations that quantify:

- Weathering of rock and minerals to deliver solutes to drainage waters in catchments and river basins including the release of contamination from mining sites
- Role of the geological barrier to contain civilian high level nuclear waste within underground repositories constructed in bedrock
- Biogeochemistry and natural biodegradation of hydrocarbon pollution in groundwater aquifers
- Soil functions that produce crops, store and filter infiltrating water, transform nutrients, store carbon from the atmosphere as organic matter, provide habitat and sustain biodiversity

Professor Richard Bardgett

Richard Bardgett is British ecologist and Professor of Ecology at The University of Manchester.
His research is broadly concerned with understanding the role of interactions between plant and soil communities in regulating the structure and function of terrestrial ecosystems, and their response to global change. A particular goal is to develop a mechanistic and conceptual understanding of how: (1) plant species and their traits influence soil biodiversity and ecosystem processes, such as carbon and nutrient cycling; (2) soil biodiversity influences nutrient cycling and plant community dynamics across different temporal and spatial scales; and (3) these interactions are affected by, and can potentially mitigate, climate change. A major focus currently is applying these concepts to the development of sustainable management options for agriculture, biodiversity and the delivery of ecosystem services, especially carbon sequestration and efficient nutrient cycling.

Professor Hans-Jörg Vogel

Hans-Jörg Vogel is Professor of Soil Physics at the Helmholtz Centre for Environmental Research – UFZ. His principal research interests include modelling soil as complex systems, the impact of agricultural soil management on soil functions, soil hydrology and solute transport, soil structure/function relations, and non-invasive imaging and quantification of soil structure including temporal dynamics.

Dr Saoirse Tracy

Saoirse Tracy is Assistant Professor in Applied Plant Biology at University College Dublin, Ireland. Previously she worked at the University of Nottingham in the Hounsfield Facility for Rhizosphere Research. Her research interests are plant and soil interactions and belowground processes that impact on plant productivity.

Dr Kate Buckeridge

Kate Buckeridge is an ecosystem ecologist, studying the living and non-living components of ecosystems and their interactions, and how they direct the functions of the ecosystem. Her interests include the interactions between soil geophysical qualities, the soil microbial community, and the cycling of carbon, nitrogen and phosphorus in the soil, plants and atmosphere. And of course, how these interactions are altered by, or alter, the direction of global change.

Kate enjoys the combination of field research and mechanistic studies in the lab, and have carried those out in the Arctic (Northwest Territories, Alaska and Greenland), the Boreal forest (Newfoundland and Ontario) and in grasslands (Ontario and currently, the United Kingdom). In natural systems, Kate has investigated the relationship between changing seasonality (warmer winters), plant communities (shrub expansion) and temperature with microbes and nutrient cycling. In agriculture systems, she has investigated how grassland management intensity (UK agricultural grasslands) alters microbial resistance and resilience, nutrient cycling, and plant and microbial carbon and nitrogen stabilization.

Oral presentations: Session 1: Soils and the delivery of ecosystem services

Temporal changes in phosphorus forms in cultivated Scottish soils

Andrew Tweedie[a*], Phillip Haygarth[b], Anthony Edwards[c], Allan Lilly[a], Nikki Baggaley[a], & Marc Stutter[a]

[a]*The James Hutton Institute, Craigiebuckler, Aberdeen AB15 8QH*
[b]*Lancaster Environment Centre, Library Avenue, Lancaster University, Lancaster LA1 4YQ*
[c]*Scotland's Rural College (SRUC), Ferguson Building, Craibstone Estate, Aberdeen AB21 9YA*

Cycling of phosphorus (P) in modern agricultural soils is dominated by regular inputs of inorganic P fertilizer in each yearly growing season and removal of P in the crop. This in contrast to the tight recycling of P found in many natural systems related to its scarcity. However, in many cases the majority of agricultural P input is made unavailable to crops by soil chemical processes and microbial cycling. This is thought to have led to the build-up of P stocks and corresponding changes in the relative proportions of P species in these cultivated soils over a relatively short period of time (decades). These changes may negatively impact the capacity of these soils to deliver many eco-system services by disrupting the naturally developed nutrient cycling systems. We investigated the hypothesis that phosphorus forms and availability in agricultural soil have changed over a period of rapid agricultural intensification. Geographically paired samples of soil from 34 agricultural sites in North East (NE) Scotland was collected at two timepoints. The first samples were taken between 1951 and 1981 and in all cases the resampling took place in the autumn of 2017. The set of soils sampled was representative of the range of cultivated soils in NE Scotland. Soil extractions were performed including a national agronomic P index test, also N, P and DOC forms by water extraction and Fe, Al, P by the stronger extractant acid ammonium oxalate to investigate the soil P exchange complex. Concentrations of Al, Fe and P by acid ammonium oxalate extraction were not found to have changed between the two time points. However, in water extractions inorganic phosphate concentrations were found to have increased and organic P decreased. Statistically significant reductions in concentrations of both DOC and N were also detected in water extracts over time. These results show that changes in P in cultivated soil are detectable between the two timepoints under certain extraction conditions.
Further work will include extraction by NaOH-EDTA and subsequent 31P NMR analysis of organic P forms. Knowledge of the P-cycling response of soils under agricultural land-use over periods of decades as provided by this dataset, provides an opportunity to understand changes in soil nutrient concentrations, balances and availability and inform studies seeking to improve the sustainable management of soil fertility.

Keywords: temporal, phosphorus, cycling

An investigation into low redox systems and the fate and behaviour of phosphorus forms within them

Anchen Kehler[a*], Martin S.A. Blackwell[a], Philip M. Haygarth[b], Adrian Guy[c], & Federica Tamburini[d]

[a]*Rothamsted Research*
[b]*Lancaster University*
[c]*Elemental Digest Systems Limited*
[d]*ETH Zürich*

Reduced phosphorus forms hold a key to closing the phosphorus biogeochemical loop. Until recently it was thought that the phosphorus cycle is the only biogeochemical cycle without a gaseous phase; however, it is understood that there is in fact a highly reduced phosphorus compound known as phosphine, which enters the atmosphere from land and marine emissions. Phosphine and research on reduced phosphorus forms is however under investigated, leaving a lot of questions open about their potential impacts on our soils and wider environment. Reduced phosphorus forms are produced in primarily anaerobic conditions i.e. waterlogged soils and farmlands that frequently apply slurry. According to IPCC reports, the UK and other temperate climates will experience heavier and prolonged episodes of rainfall in the winter, this of course effecting and altering our current soil climates. Conditions are expected, based on these reports, to induce more anaerobic and reducing soil conditions through waterlogging, and it is predicted that this, combined with the current issue of the overuse of phosphorus fertilizers, poses many negative future impacts. This project aims to predict which type of effects are likely to take place in the next ten years, how drastic they might be and the systems that are most at risk from these changes in weather pattern.

Keywords: soil, phosphine, phosphorus, cycling

Elucidating the role of cover crops on influencing organic phosphorus in arable soil

Sam Reynolds[a*]

[a]*University of Nottingham & Rothamsted Research*

Cover crops are unharvested and grown between cash crops to improve or protect soil health. Their inclusion within arable rotations is increasing in popularity and claimed benefits surrounding soil phosphorus are often unsubstantiated. This project is investigating the use of cover crops as an aid to soil phosphorus cycling. Phosphorus (P), a macronutrient required for plant growth, is a non-renewable resource which can be lost from soil into aquatic ecosystems and cause eutrophication. P exists in the soil in several forms, with only a small portion being in a form available for plant uptake. The remainder is either sorbed onto soil minerals, or exists as organic phosphorus (Po) which is bound to an organic molecule and requires enzymatic hydrolysis from phosphatase to release the P before it can then be utilised by plants or microorganisms (Stutter et al, 2012). The enzymes are classified by their ability to work at low pH – acid phosphatase – or high pH – alkaline phosphatases (Nannipieri et al, 2011). The aim of this project is to understand whether cover crops can influence phosphatase activity in soil, and whether this impacts Po dynamics. Field experiments at The Allerton Project have been complemented with controlled glasshouse experiments. The first-year field trial showed that different cover crop species can influence the activity of acid and alkaline phosphatase activity, but this was not replicated in the second year of the trial. The glasshouse experiment took regular measurements of phosphatase activity in soil which had common cover crop species growing, species used were oat, phacelia, lupin, vetch, buckwheat and a bare soil control. Phosphatase activity fluctuated with time, increasing until the plants reached maturity and decreasing back to the initial levels, but did not differ between the cover crop species, or the control pot. This is to be compared with the amount of plant available P over the same time to determine whether the increased phosphatase activity corresponds with increased plant available P. Cover crops can have an influence on the soil P cycle in arable farming systems, but the interactions are complex and differences between species are not yet clear.

Keywords: cover crop, organic phosphorus, arable

Ground-making research: the first arable soil formation rates

Dan Evans[a*], J. N. Quinton[a], J. Davies[a], A. M. Tye[b], S. M. Mudd[c], & A. Rodes[d]

[a]*Lancaster University*
[b]*British Geological Survey*
[c]*University of Edinburgh*
[d]*Cosmogenic Isotope Analysis Facility*

The increasing pressure humans place on the land has led to the acceleration of soil erosion, to an extent where human-induced erosion of the soil is expected to outpace the production of new soil by more than an order of magnitude. The consequential trajectory of soil thinning is one that, left uninterrupted, leads to the removal of the soil cover and the exposure of the underlying parent material. Given that the thickness of the pedosphere is a first order control on soil functions, with thicker soils having a greater capacity for water, carbon and nutrient storage, the continued thinning of non-renewable soil profiles and the associated consequences on their productivity and health is arguably one of the most significant threats to soil sustainability. Despite the fact that the future long-term security of soils depends on mitigating soil erosion rates down to (and below) the rates of soil formation, our knowledge of the latter is surprisingly meagre. Recent developments in cosmogenic radionuclide analysis have catalysed greater investment in the derivation of soil formation data, and yet there still exists no isotopically-constrained study of soil formation in arable contexts. Arable soils are often the loci for accelerated erosion but in the absence of comparative soil formation data, the magnitude of the threat this accelerated erosion places on arable soils is unknown. Future policy to ensure their long-term security, and the delivery of multiple ecosystem services, demands greater work in quantifying soil formation in these contexts. Our research is the first in the world to respond to this call and here we present the first soil formation rates under arable soils. Saprolite was extracted at the soil-bedrock interface down a catena sequence at Rufford Forest Farm (Nottinghamshire) and processed through cosmogenic radionuclide analysis. Further samples from a catena sequence in an ancient woodland near Quatt (Shropshire) were also processed. We will use our isotopically constrained rates to make two integral contributions to the wider discourse of soil sustainability and the delivery of ecosystem services. First, our results show that although zones of eroding soil promote greater bedrock weathering, surface loss rates at Rufford Forest Farm remain an order of magnitude greater, threatening the long term sustainability of the soil profile. We will then demonstrate, using a first-order soil lifespan model, the range of lifespans expected at both sites.

Keywords: soil formation; soil erosion; soil sustainability; soil lifespan

Effects of different zinc nanoparticles on soil and ryegrass

Beckie Draper[a*]

[a]*University of Nottingham & British Geological Survey*

Zinc (Zn) nanoparticles (NPs) can enter soil environments via a number of routes, including the use of Zn NP-containing biosolids as fertilisers. Plants form the base of many terrestrial food webs and so Zn NP bioavailability in soils and toxicity to plants could have far reaching affects and impact wider ecosystems.

The objectives of this study were to compare the effects of ZnO NPs, ZnS NPs, Zn3(PO4)2 particles and ZnSO4 on the growth and Zn content of Lolium perenine (Dwarf ryegrass) and to evaluate whether the available Zn content of soil treated with the different Zn species was correlated with any observable effects on the plants growing on them.

Soils were spiked with these Zn species at 3 different concentration levels and ryegrass grown on them for a total of 18 weeks. During this time, the grass was harvested 3 times. It was measured and weighed and the Zn content determined. The available Zn content of the soils was assessed weekly.

The results so far have shown that the Zn content of the grass and the available Zn content of the soils spiked with ZnO NPs and ionic Zn (ZnSO4) are high and very similar to one another, whereas the results from the ZnS NPs and Zn3(PO4)2 particles show significantly lower concentrations.

In recent years, a significant number of studies have looked into Zn NP bioaccumulation and phytotoxicity in a variety of different plant species, however, these studies all use ZnO NPs despite it having been confirmed that ZnS NPs and Zn3(PO4)2 are the main species that are present in biosolids. The results of this study are currently showing that examining the effects of biosolid application using ZnO NPs is likely to give an over estimation of Zn NP dissolution, ionic Zn availability and Zn uptake in plants. There is a growing consensus that research into the release of NPs into the environment needs to begin to focus on realistic conditions and relevant aged species rather than "pristine, as-produced particles" as has often been the case in the past.

Keywords: nanoparticle, zinc

Oral presentations: Session 2: Modelling the soil ecosystem at different spatial and temporal scales

The significance of soil properties to the uncertainty in estimating soil moisture from Synthetic Aperture Radar

John Beale[a*], Boris Snapir[a], Toby W Waine[a], Ronald Corstanje[a], & Jonathan Evans[b]

[a]*Cranfield University*
[b]*Centre for Ecology and Hydrology*

Soil Moisture varies significantly in spatial and temporal extent, as it responds to land use, soil type, drainage, tillage, vegetation, solar radiation, air temperature, wind, rain and other factors. Significant differences are observed between and even within fields. Soil moisture maps are needed that combine wide scale for regional and national studies, whilst capturing the local variability that is needed by most users. C-band SAR satellites, such as Sentinel-1, offer high spatial and temporal resolution but the estimation of soil moisture from SAR requires correction for many contributing factors that soil properties influence. This review considers the potential significance of soil texture and organic matter content concluding that each factor may contribute to a 10% error if an incorrect assumption is made. Soil moisture retrieval over agricultural fields in northern latitudes requires any algorithm to account for rapid and large changes in SAR backscatter due to crop growth and harvesting, tillage operations and freezing of the soil surface. This has particular significance for the validity of change detection approaches in such locations. Previously published data provides guidance in setting soil roughness parameters following farming operations, and shows some dependence on soil texture for primary tillage. Therefore information on the soil texture, organic matter content, surface temperature, land use and crop modelling should be important inputs to the success of retrieving soil moisture at the field scale.

Keywords: soil moisture; SAR; remote sensing; soil texture

Variability of gas diffusion in soils

Lewis Rose[a*], George Shaw[a], Neil Crout[a], & Andy Tye[b]

[a]*University of Nottingham*
[b]*British Geological Survey*

Soil gas is a mixture different to that in the atmosphere. It controls many processes throughout ecosystems, including transport of pollutants.

Part of this mixture is radon: a naturally-occurring, radioactive element from the uranium decay series. It is possible to accurately measure radon concentrations and obtain information about its movement through the soil profile. This information can be used feed computer models of the soil system.

Soil gas transport models have varying levels of applicability, and some measurement techniques for radon gas can be expensive and/or laborious. A technique to make field measurement quicker and cheaper, with high spatial and temporal resolution, will be developed.

One issue with the use of commonly studied gases such as CO2 and CH4 is that their production and destruction is dynamic both spatially and temporally. The use of radon as a tracer enables soil gas concentrations due to physical processes only to be determined, as its production and destruction are much more easily predicted.

Radon gas is collected from soil using steel-tipped "probes" and analysed using known techniques. This not only enables quick and cheap analysis, it also minimises the disturbance to the soils being studied.

It is hoped that more accurate estimations of soil gas diffusion coefficients will be generated for undisturbed soils, and tracking changes will assist in evaluating the physical condition of soils change over time. As radon is a leading cause of cancer, accurate prediction of its movement, done much more cheaply than is often seen in literature studies, would assist in mapping efforts around the world.

These experiments are a starting point for future applications predicting the movement of other gases through soil. Prediction of the behaviour of contaminants which may be released during human activity, or as a result of changing climate, may ultimately be possible.

Keywords: gas diffusion, computer models, radon-222, minimally invasive, undisturbed soils

Zero-tillage could offer a long term strategy to mitigate climate change

Hannah Cooper[a*], Sacha Mooney[a], Sofie Sjogersten[a], & Murray Lark[a]

[a]*University of Nottingham*

A change in the management of agricultural soils can affect their role as a source or sink in the global carbon cycle, and the size and composition of their greenhouse gas emissions. Conversion from conventional management by ploughing to zero-tillage can reduce soil erosion and increase biological activity, and is now practised on 7.9% of arable land globally (111 million ha). However, there is conflicting evidence on the effect of such a conversion on carbon storage and greenhouse gas emissions. Here we present a study to examine the effect of zero-tillage on both carbon storage and greenhouse gas release at a regional scale, in this case the East Midlands of England. We examined sites where zero-tillage had been implemented for different periods of time, and each zero-tilled site had an adjacent paired site under conventional management. We recorded a significantly higher net global warming potential under conventional tillage systems (30% larger than zero-tillage systems) due to the emission rates of different greenhouse gases, and provide evidence that the net global warming potential of zero-tillage systems decreases further over time (assessment was up to 15 years post conversion). When modelling regional estimates of global warming potential, conventionally tilled soils were more spatially uniform than zero-tilled soils (650-700 compared to 200-800 mg CO2 eq. m-2 h-1 respectively) which were more spatially variable. Simultaneously, in zero-till systems, carbon stocks increased with time under management and a similar pattern emerged from the prediction of carbon stocks across the region with zero-tilled soils showing a larger variation in carbon stocks compared to conventionally tilled soils. In addition, changes in organic carbon chemistry indicated an increase in the proportion of sequestered recalcitrant carbon compared to conventionally tilled soils. Further research investigating the seasonal impact is imperative, but our work highlights the importance of the temporal effect of agricultural conversion and indicates that zero-tillage could play a significant role in reducing greenhouse gas emissions whilst increasing carbon stocks that may be enhanced over time.

Keywords: modelling, climate change, greenhouse gas emissions, agriculture

The impact of soil and plant diversity upon soil microbial diversity

Fiona Seaton[a*], Davey L. Jones[b], Si Creer[b], Paul B.L. George[b], Inma Lebron[a], Bridget Emmett[a], & David A. Robinson[a]

[a]*Centre for Ecology & Hydrology*
[b]*Bangor University*

Soil microbial diversity is incredibly high and as yet the factors driving this are not fully realised. The heterogeneity of the soil environment is often cited as a potential driver of high microbial diversity. Not only is there a highly heterogeneous variety of soil physical particles but the influence of plant roots and larger soil organisms can dramatically alter the soil structural environment. Here we will discuss the use of statistical modelling to evaluate the impact of soil textural heterogeneity and plant diversity upon soil bacterial and fungal diversities across a variety of habitats.

The Welsh national field survey GMEP created a powerful dataset that includes information on plant communities and soil properties. Over 1300 sites were examined for a range of soil properties and for a subset of these samples the soil fungal and bacterial communities were characterised using DNA metabarcoding. Soil texture of many of these samples was measured through laser granulometry, enabling detailed description of soil textural heterogeneity. Statistical techniques including structural equation modelling were used to model the complex interactions driving the accumulation of soil microbial diversity.

We have found that the factors influencing microbial diversity differ by the microbial group, yet strong links between the diversity of microbial groups can obscure these underlying physicochemical drivers. The extent to which microbial diversity is controlled by the soil structural environment is moderated by their life history strategies, ability to navigate the soil environment, and the influence of other biological groups in moderating soil structural influences.

Keywords: bacteria, fungi, biodiversity, texture

Oral presentations: Session 3: Understanding the soil-root interface

Does root architecture influence the formation of rhizosheath?

Emma Burak[a*], Ian Dodd[a], & John Quinton[a]

[a]*Lancaster University*

With the ever increasing global population, the agricultural sector is put under increasing pressure to intensify crop production, causing widespread soil degradation that ultimately decreases productivity. Enhancing the interaction between crops and the soil may improve resource acquisition. Fine roots are believed to be of most importance in acquiring water and nutrients, but their functional complexity is often veiled by an arbitrary diameter classification. The rhizosheath is the part of soil that is most strongly bound to the roots. While root hairs appear to be critical in promoting rhizosheath development, the role of fine roots has attracted little attention.

This study used two root hairless mutants, barley brb and maize rth3 and their respective wild types (WT), to assess the capacity of different root types to bind soil particles to the root system (assessed as rhizosheath weight). The plants were grown in a sandy loam and periodically harvested during vegetative development. Rhizosheath weight was the dried weight of the soil adhering to the whole root system after being excavated from the soil. Axile and lateral roots were classified according to their distinctive diameters and linear regressions assessed which root types best explained the variance in rhizosheath weight.

When standardised by root length, the WT genotypes formed considerably more rhizosheath (4-fold in barley, 3-fold in maize) than the mutant genotypes lacking root hairs. However, pooling the data from all harvests demonstrates that the length of lateral and axile roots outweighed the influence of root hairs. For barley, lateral root length explained the most variance in the rhizosheath data whereas axile length was the best indicator for maize. It is not yet clear why root type has varying effects on rhizosheath formation in the two species. Although root hairs are important in rhizosheath formation, other root types also need to be considered.

Keywords: rhizosheath, roots, root hairs

Can roots influence soil structure via reorganisation of the rhizosphere?

Jasmine Burr-Hersey[a*] Karl Ritz[a], Sacha Mooney[a], & Glyn Bengough[b]

[a]*University of Nottingham*
[b]*The James Hutton Institute*

Soil compaction is a form of degradation that affects agricultural land on a global scale. Primarily caused by the passage of heavy farm machinery, soil compaction can result in the reduction and loss of the soil macropore network, leading to poor aeration, nutrient depletion and reduced permeability of water and penetration of roots into the soil. The compressive effects on soils can be persistent and difficult to alleviate. Currently deep-tillage practices are used as a short-term solution to lessen soil compaction however this intensifies the risk of permanent subsoil compaction. We hypothesise that plant species that are able to grow in heavily compacted soil may increase the number and size of pores helping to positively alter the structure of degraded soils. Hence plants may offer a simple means to improve a compacted soil via localised structural remediation, particularly in and around the rhizosphere. We analysed the root growth patterns of three non-cultivated plant species often found occurring naturally on compacted soils, suggesting they have an intrinsic ability to grow effectively under such circumstances. Ribwort plantain (*Plantago lanceolata*), dandelion (*Taraxacum officinale*) and spear thistle (*Cirsium vulgare)* plants were grown for 28 days in a sandy-loam soil compacted to 1.8 g cm^{-3} with a penetration resistance of 1.55 MPa. X-ray Computed Tomography was used to observe root architecture *in situ* and visualise changes in rhizosphere porosity (resolution of 35 µm) at 14 and 28 days after sowing. Porosity of the soil was analysed within four incremental zones up to 420 µm from the root surface. In all species the porosity of the rhizosphere was greatest closest to the root and decreased with distance from the root surface. There were significant differences in the rhizosphere porosity between the three species, with spear thistle plants exhibiting the greatest structural genesis across all rhizosphere zones. This novel approach indicates that roots can have a localised effect in increasing the formation of pore space in the rhizosphere, counteracting any initial compression due to root penetration. The resulting structural alteration of the soil indicates the potential for roots to create and improve soil structure in heavily degraded soils. Further research will be pertinent in advancing our understanding of soil remediation potential by roots, especially at the root-soil interface.
Further research will investigate how specific roots traits that induce remedial structural changes could be applicable to the field scale restoration of sites damaged by modern day tillage practises.

Keywords: compaction, remediation, rhizosphere, porosity, x-ray computed tomography

Protein breakdown in soil along a grassland altitudinal gradient

Lucy M. Greenfield[a*], Paul W. Hill[a], Eric Paterson[b], Elizabeth M. Baggs[c], Fiona M. Seaton[a] & Davey L. Jones[a,d]

[a]*School of Natural Sciences, Bangor University, Gwynedd, LL57 2UW, UK*
[b]*The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH, UK*
[c]*The Royal (Dick) School of Veterinary Studies, University of Edinburgh, Easter Bush Campus, Midlothian, EH25 9RG, UK*
[d]*School of Agriculture and Environment, University of Western Australia, Crawley, WA 6009, Australia*

Protein represents a major input of organic matter to soil and is an important source of carbon (C) and nitrogen (N) for microorganisms. Therefore, the factors regulating breakdown of proteins in soil are key to understanding soil C and N cycling. We investigated how soil properties affect protein breakdown along a grassland altitudinal sequence that contained a gradient in soil type. Topsoil and subsoil were collected along a catena sequence. Rate of protein breakdown was determined by adding ^{14}C-labelled soluble plant protein and measuring $^{14}CO_2$ evolution over a two-month period. A conceptual framework of protein breakdown was created to determine the key soil parameters that influence protein breakdown (pH, ammonium, nitrate, microbial C, phenols, amino acids, protein, cation exchange capacity, N mineralisation). Linear mixed effect models were used to determine the relationship between rates of protein breakdown and soil parameters. Surprisingly, we found measured soil properties were not good predictors of protein breakdown rates. This indicates that the rate of N supply rather than N breakdown was the rate-limiting factor.

Keywords: soil organic matter, mineralisation, protease, carbon, nitrogen, amino acid

Measuring plant-driven soil carbon dynamics in field conditions

Chris McCloskey[a,b*], Guy Kirk[a], Wilfred Otten[a], & Eric Paterson[b]

[a]*Cranfield Soil and Agrifood Institute, Cranfield University, College Road, Cranfield, MK43 0AL*
[b]*The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH, UK*

Release of carbon (C) from plant roots can prime the mineralisation of soil organic matter (SOM) by stimulating the activity of soil microbial communities. The mechanisms behind priming and the factors that affect it, however, are not fully understood, and it is not represented in most models of soil C dynamics. This adds to uncertainties in our ability to predict how soil C dynamics will respond to climatic or land use changes. This is a significant problem as soils are the largest terrestrial C reservoir, and it is imperative that we understand all the factors that affect whether the land surface shifts from a net C sink to a source.

A major obstacle to developing a better understanding and improved models of plant-driven soil C dynamics is a lack of datasets representative of conditions in the field. Most studies assessing rhizosphere priming have been short-term and lab- or pot-based. We are measuring plant respiration and SOM mineralisation under field conditions over two growing seasons in large (0.8 m diameter, 1 m deep) lysimeters containing two C3 soils and sown with a C4 grass, using differences in the C isotope ratios of CO2 produced by C4 plant respiration and C3 SOM decomposition to partition net C fluxes. Previous studies under field conditions have struggled to separate these fluxes as differences between plant and SOM isotope ratios are small. Using a novel C3 to C4 plant change allows us to exploit differences in C isotope fractionation between these two photosynthetic pathways to create a larger distinction.

Gas flux measurements are made thrice daily from 24 planted lysimeters using cavity ring-down spectroscopy, along with near-continuous soil moisture and temperature measurements at multiple depths. We have successfully used this system to partition soil and plant C fluxes, demonstrating the viability of this method for measuring plant-soil C dynamics in the field. Coupling C flux data with measurements of soil moisture and temperature we have shown how SOM decomposition and plant respiration respond on both diurnal and seasonal timescales. Measurement and modelling of photosynthesis and grass sward productivity will allow us to model the relationship between plant productivity and SOM mineralisation across the soil-root interface. We will use the resulting datasets to assess whether inclusion of rhizosphere priming can improve models of SOM dynamics, potentially improving forecasts of soil responses to a changing environment.

Keywords: rhizosphere priming, soil carbon, carbon flux partitioning, cavity ring-down spectroscopy, C4 grass

The impacts of land management on beneficial Pseudomonad communities

Heather Ruscoe[a*], Tim Mauchline[a], Penny Hirsch[a], & Ian Dodd[b]

[a]*Rothamsted Research*
[b]*Lancaster University*

Agricultural practices have been found to impact soil microbial communities but how such practices affect plant beneficial microbes in the soil is not well understood. To investigate this, Pseudomonads were isolated from bulk soil, rhizosphere and root of the wheat Triticum aestivum grown in pot experiments utilising three soil managements-continuous grassland, arable and bare-fallow (sampled from the Highfield experiment-Rothamsted research). Pseudomonad community structure was assessed through sequencing of the gyrB gene followed by BLAST identification and phylogenetic tree construction. No significant differences were identified in Pseudomonad abundance across the land managements, however differences in diversity were detected. Wheat grown in arable and grassland managed soils were found to support a more diverse Pseudomonad community compared to the more degraded bare-fallow soil, which may provide a harsher environment for crop cultivation. To further investigate this result, the interaction between soil management, plant stress and Pseudomonad modulation of the plant phytohormone system proceeded. Various Pseudomonad strains can reduce levels of the plant hormone ethylene (stress hormone) through degradation of its precursor 1-aminocyclopropane-1-carboxylate (ACC), via the enzyme ACC deaminase (ACCd). The Pseudomonad isolates were therefore screened for the acdS gene (encoding for ACCd). A treatment effect was detected with the percentage abundance of the acdS gene at 28.8% in bare-fallow, 6.7% in arable followed by 4.6% in the grassland managed soil. This increase in gene abundance suggests that the wheat grown in bare-fallow soil may potentially exude more ACC due to harsher conditions, which could thereby attract more acdS Pseudomonads. Further studies will focus on field experiments of wheat grown in the reversion plots at the Highfield experiment. Microbial DNA/RNA will be extracted from bulk soil and rhizosphere to assess total community acdS gene abundance and expression, in attempt to correlate this with root ACC measurements in wheat grown in the different managed soils. In addition, full genome sequencing of the isolates positive for the acdS gene are being analysed to assess if the gene can be used as a proxy for the selection of other beneficial traits related to plant stress and identify potential candidates for microbial inoculants. Understanding and manipulation of Pseudomonad communities at the soil-root interface could provide a promising alternative to the use of synthetic pesticides and fertilizers, helping to move towards a more sustainable agricultural system.

Keywords: pseudomonads, PGPR, land management, ACC deaminase

In-soil trophic interactions between plants, rhizosphere bacteria and nematodes: Improving availability of soil organic phosphorus

Malika Mezeli[a*], Tim S. George[b], Roy Neilson[b], Martin S.A. Blackwell[c], & Phil M. Haygarth[a]

[a]*Lancaster Environment Centre, Lancaster University, Bailrigg, LA1 4YW*
[b]*Ecological Sciences, The James Hutton Institute, Dundee, DD4 5DA*
[c]*Sustainable Agricultural Systems, Rothamsted Research, North Wyke, EX20 2SB*

Significant disparities between phosphorus (P) fertiliser application and plant P uptake, is in part induced by the in-soil conversion of inorganic P (Pi) to organic P forms (Po), which are not readily plant available. Phytase enzymes released by certain plants, bacteria and fungi hydrolyse organic sources (eg: InsP1-6) to plant available forms. Recent experimental work and historical ecological observations has demonstrated that bacterivorous nematodes can be complementary to plant P uptake, indicative of beneficial trophic interactions. The project aim is to demonstrate this beneficial interaction in arable cropping systems at the soil-root interface by investigating two main questions: (1) Do nematodes increase plant acquisition of InsP6 hydrolysed by phytase producing bacteria in arable systems? and (2) What are the key mechanisms behind such plant responses? Barley plants were grown under sterile conditions in agar with three different P treatments (no P, Pi and InsP6), phytase producing bacteria (Pseudomonas sp., CCAR59) and bacterivorous nematodes (Caenorhabditis elegans). Biomass accumulation and plant P concentrations suggested that beneficial trophic interactions were induced only under significantly P deplete systems, however the data failed to provide statistically significant results.When repeated in grassland soil, with a low Pi and high Po profile, a significant effect of nematodes was observed in the +InsP6 treatment. The data from these trials suggest that although a P deplete system is required to observe beneficial trophic interactions, a baseline of P is required to kick-start these bio-chemical functions, provided here by the +InsP6. In addition, in the agar trials, plant roots were able to colonise the entirety of the substrate, thereby potentially masking treatment effects due to the possible role nematode mobility and exploration may play in such biochemical transformations and measured plant responses. Therefore, later trials were conducted in agar without plants and conversion rates of InsP6 to Pi per mm of nematode exploration was measured. Such studies will allow for a better understanding of the role nematodes have, as an additional trophic cascade, on the P cycle in arable systems and bring together ecological functions to improve agronomic practice.

Keywords: organic phosphorus, phytase, nematodes, phytate

Oral presentations: Session 4: Resilience and response of soil functions and global changes

Characterising shifts in the resistome and microbial community structure of cattle slurry fertilised agricultural soil

Alex Williams[a*], Dov Stekel[a], Jon Hobman[a], Helen West[a], Rupert Hough[b], & Lisa Avery[b]

[a]*The University of Nottingham*
[b]*The James Hutton Institute*

International and UK government reports have cited antibiotic use as a significant driver of antibiotic resistance (AR) in agricultural environments at the national and global scale. Un-metabolised antibiotics excreted in faeces and urine from treated livestock are often highlighted as a selection pressure for resistant bacteria in slurry tanks and fields fertilised with animal husbandry waste. In this way crops destined for human consumption could also become contaminated with antibiotic residues and/or with bacteria carrying AR genes. However, assessing the flow of antibiotic resistance within farm environments is challenging due to their complex, multi-compartmental nature. As a result, the resilience of soil microbial communities and the response of the soil resistome to slurry application remain poorly understood.

Our key aims are to characterise AR within cattle slurry amended soils and to identify major factors governing AR at the University of Nottingham Dairy Farm site over two seasons (2017/18). Specific objectives were to determine how AR profiles and community structure of soil bacteria respond to successive slurry applications, to establish a base-line for un-amended soils and to use the real-world data gathered to generate statistical models of AR in slurry amended field soils. By using a combination of classical culture and molecular techniques at both the mesocosm and field scale we sought to negate common issues of methodology bias. Over 300 isolates were tested for phenotypic resistance to a range antibiotics over the study period. At least 11% of these isolates were multi-drug resistant with resistance to select penicillins, 1st and 3rd generation cephalosporins, quinolones, phenicols and nitrofurans. Soil samples were subject to DNA extraction and metagenomic analysis to elucidate microbial community composition and the resistome. Both phenotypic and metagenomic data will be discussed and contextualised within the current understanding of AR in the environment and farm management practices, with suggestions for improving practice where relevant.

Keywords: field study; antibiotic resistance; antibiotic susceptibility testing; metagenomics; animal husbandry waste

Diverging trends of belowground richness but not beta diversity revealed within temperate ecosystems

Paul B. L. George[a*], Delphine Lallias[b], Simon Creer[a], Fiona M. Seaton[c], John G. Kenny[d], Richard M. Eccles[d], Robert I. Griffiths[e], Inma Lebron[c], Bridget A. Emmett[c], David A. Robinson[c], & Davey L. Jones[a]

[a]*School of Environment, Natural Resources & Geography, Bangor University*
[b]*GABI - Institut National de la Recherche Agronomique*
[c]*Centre for Ecology & Hydrology, Bangor*
[d]*Centre for Genomic Research, University of Liverpool*
[e]*Centre for Ecology & Hydrology, Wallingford*

Mounting evidence suggests that soil microbial communities do not conform to the conventional assemblage/diversity patterns of animal and plant communities across large geographic scales. Additionally, many surveys of soil biota across large scales have not included the breadth of soil microbial biota (i.e. bacteria, archaea, fungi, and protists) and only recently have attempts been made to integrate findings between microbial and faunal analyses. This is especially pertinent to discussions of how belowground communities change in response to increasing land use intensification. We conducted an exhaustive survey of soil communities at a national scale in the context of their ecology. Environmental DNA and soil properties were extracted from 436 co-located samples collected as part of the Glastir Monitoring and Evaluation Programme, which is responsible for the assessment of Glastir, Welsh Government's agri-environment scheme. High throughput sequencing of prokaryotic and eukaryotic communities was used to investigate how α- and β-diversity of soil life are influenced by land use and soil properties. We found evidence of both well-established and novel macroecological trends. We observed decoupling between microbial and animal communities, with land use driving animal communities, while soil properties drive microbial communities. Microbial α-diversity followed linear relationships across a productivity gradient of land use types. On the contrary, animal α-diversity showed a humped distribution along the productivity gradient, suggestive of strong influences of aboveground plant communities. Across all organisms, α- and β-diversity was most strongly influenced by pH, following established trends. Other interactions between diversity and soil properties are hard to disentangle. Our findings provide an important foundation for future research into the dynamics of soil microbes across multiple land uses. Our data supports recent challenges to the notion that microbes follow conventional macroecological paradigms.

Keywords: microbial diversity, soil fauna, protists, biogeography, land use

The effects of climatic conditions on (de)stabilising processes in aggregate microcosms

Emily Dowdeswell-Downey[a*], Robert Grabowski[a], & Jane Rickson[a]

[a]*Cranfield University*

Climate change will lead to increased global surface temperatures, more frequent extreme temperatures and heatwaves, and more frequent extreme precipitation events. These changes have been predicted to increase soil erosion rates, with major implications for food production, land management practices and off-site impacts, such as pollution of waterbodies. For effective soil management it is critical to recognise the processes responsible for erosion (and how they may change in the future). With this knowledge, the most suitable soil management plan can be implemented successfully, protecting soil health and function. Currently, estimates of future soil erosion rates consider the implications of increased climatic erosivity, caused by more frequent extreme precipitation events and higher rainfall intensities. However, the intrinsic properties of soil, such as soil structure, which affect soil erodibility have largely been overlooked. Soil erodibility is the susceptibility of soil to erosion and is controlled primarily by soil texture and structure. Soil structure is highly dependent on the stability of soil aggregates, which are formed through physical, chemical and biological processes.

Physical processes influencing aggregate stability, such as wetting and drying, are a direct result of changes in temperature and moisture content. Additionally, changes in temperature and moisture conditions could also affect aggregate stability by limiting or stimulating the microbial community, and therefore impacting the associated biological stabilising mechanisms (e.g. Extracellular polymeric substance production or fungal hyphal growth). Previous research has shown that fluctuations in climatic conditions can alter the microbial community composition, biomass and activity. However, more information is needed to understand how changes in the microbial community relate to changes in biological (de)stabilising processes and aggregate stability. This ongoing research investigates how changing climatic conditions alter soil aggregate stabilisation processes and the resulting impacts on aggregate stability, soil structure and erodibility. The experimental work presented here examines how temperature and moisture content affect aggregate stability using environmental chambers and rainfall simulation. Two soil types, a sandy loam and a clay loam, have been exposed to a 3x3 treatment design (3 levels of temperature and moisture content) for 1, 2 and 4 weeks. From the resulting 54 treatments, samples have been analysed for aggregate stability, microbial biomass carbon, microbial respiration rate and microbial community composition. Changes in the biological community within the aggregate microcosms have been investigated to explore the impact on the potential underlying mechanisms mediating aggregate stability dynamics.

Keywords: aggregate stability, climate change, bacteria, fungi, erodibility

High and dry: are oceanic-alpine ecosystems resilient to summer drought?

Rosanne C Broyd[a,b*], Robert T E Mills[a], Andrea J Britton[b], Andy F S Taylor[b], & Nicholas J Ostle[a]

[a]*Lancaster University*
[b]*The James Hutton Institute*

Oceanic-alpine ecosystems in the Scottish Highlands are potentially among the most carbon rich habitats globally, with snowbeds being particularly large stores of old carbon. Spring snow cover extent in the northern hemisphere has declined over recent decades and is expected to decline by up to a further 25% by 2100. Potentially this will reduce melt water input to snowbeds during summer, while dry periods between rain events are also expected to increase, raising the risk of summer drought. Snow cover has greater sensitivity to warming at lower than higher elevations. Low-middle oceanic-alpine ecosystems, such as those in Scotland, already experiencing variable snow cover year to year, are therefore likely to be more vulnerable to climate warming than higher elevation mountain systems. We compared the resistance and resilience of snowbed and non-snowbed communities to summer drought, hypothesising snowbeds would be less resistant and resilient to drought than *Racomitrium* heath communities. Here we present ecosystem respiration fluxes from snowbed and *Racomitrium* heath mesocosms from a 37-day drought experiment, and subsequent recovery phase. Ecosystem respiration decreased under drought from both the snowbed and *Racomitrium* heath, and returned quickly to control levels upon rewetting. These alpine ecosystems are sensitive to summer drought, and although they were not resistant, these ecosystems were resilient to one drought event.

Key words: mountain, snowbed, carbon, respiration.

Determining regional-scale carbon losses from tropical peatlands using InSAR

Martha Ledger[a*], Andrew Sowter[b], Chris Marshall[a], Keith Morrison[c], Chris Evans[d], David Large[a], & Sofie Sjogersten[a]

[a]*University of Nottingham*
[b]*Geomatic Ventures Limited*
[c]*University of Reading*
[d]*Centre for Ecology and Hydrology*

80% of peatlands in Indonesia and Malaysia (15% of Earth's soil carbon) are now drained for production of pulp wood and palm oil. Associated increases in peat decomposition and large scale forest fires are now significant contributors to global greenhouse gas emissions. However, carbon losses from these processes and the impact of peatland drainage remain poorly quantified across SE Asia because of the challenging scale and inaccessibility of dense tropical peatland forests.

Field-based subsidence measurements are therefore a spatially limited approach for assessing carbon losses from tropical peatlands. Space-based platforms offer the opportunity for regular and efficient pan-regional monitoring. A development in satellite interferometric synthetic aperture radar (InSAR), a technique that measures surface motion, has the potential to solve this problem. A new 'intermittent small baseline subset' (ISBAS) modelling technique, developed at the University of Nottingham, provides excellent coverage across almost all land surfaces irrespective of ground cover. This enables long term measurement of peatland surface motion across whole catchments, regions and countries. Importantly, the ISBAS technique is able to determine surface deformation under tropical forest canopy using C-band InSAR data, enabling continuous monitoring of surface motion ranging from 0.1 – 40 cm/yr at spatial scales ≥90x90m. Thus, space-based InSAR-derived motions should directly relate to tropical peatland carbon loss, allowing pan-regional assessment of carbon loss from otherwise inaccessible tropical peatlands. This is a novel approach as InSAR is yet to have been used to determine subsidence of tropical peatland sites.

This project aims to determine whether rate of subsidence of the peat surface measured by InSAR is a proxy for rate of carbon loss in tropical peatlands in SE Asia. InSAR and field measurements of subsidence will be combined with peat carbon stock data using statistical regression modelling techniques to validate the use of subsidence as a proxy for carbon loss.

Keywords: peatland, carbon, subsidence, radar, InSAR

Of moisture and microbes

Harry Barrat[a*], L. Cardenas, D.R. Chadwick, Alice F. Charteris, K. Le Cocq

[a]*Rothamsted Research*

Nitrous oxide (N2O) is a potent greenhouse gas and ozone depleter, and it is produced by microbes under varying oxygen levels, and therefore varying water levels. Anoxic conditions can result in large emissions of N2O, which is typically when the soil is very wet (Smith, 2010). However if the soil has been dry before it becomes wet the emissions can be magnitudes higher (Bergerstermann et al., 2013). It still isn't fully understood why this is case, and so this study induced a 14 day drought on soil cores, and then wetted them inside a closed incubation system where nitrogen gases can be measured (nitric oxide, N2O and nitrogen). A parallel system was set up which mimics the incubation conditions, but allows soil cores to be taken and destructively sampled for changes in microbiology and chemistry. The results indicate large differences between cores that were dry and then wetted, compared to cores that were wet and then further wetted. With more extreme weather such as droughts and storms expected due to climate change, this phenomenon could increase the N2O footprint of grassland soils.

Keywords: nitrous oxide, historical conditions, grassland

Bio-monitoring: monitoring fugitive methane emission using microbiology

Tom Bott[a,b*], Dr. Simon Gregory[a], & Prof. George Shaw[b]

[a]*British Geological Survey*
[b]*University of Nottingham*

With continued interest in hydraulic fracturing to release methane from shales (fracking), tools to monitor abandoned and orphaned wells are needed. Increased methane flux can be observed using changes in microbiological populations therefore development of these tools also provides insights into microbial methane oxidation, an important ecosystem service for mitigating methane fluxes (for example from landfill) and as a sink for atmospheric methane. Monitoring old well sites is important to ensure sealed wells are not emitting methane and to check that the barriers sealing the well are still intact. These tools will also enable the location and mitigation of sites where these barriers have failed or were never installed. Using changes in microbial populations as an indicator provides an advantage compared to discrete gas flux measurements by providing a time average assessment due to the slow rate of microbial population change. Furthermore, it may be possible to distinguish between biotic and abiotic sources of methane by monitoring the flux of longer alkanes using similar methods. Expected changes, as a result of increased alkane flux from subsurface sources, include perturbations in the diversity of soil communities, with a shift toward specialised alkane degraders, for example within the Actinobacteria phylum, alongside an increased prevalence of oxygenase genes, specific for methane and short chain alkanes. By understanding and exploiting microbial processes, methane emission can be monitored and limited, thus protecting both the health of human populations and reducing the release of a potent greenhouse gas. Here, an outline of the techniques and methods being developed and adapted are presented.

Keywords: methane, bio-monitoring, oil and gas wells

Combining X-ray and electrical resistivity tomography methods towards a new methodology of soil hydraulics properties assessment

Mihai Cimpoiasu[a,b*], Oliver Kuras [a], Sacha Mooney[b], & Tony Pridmore[b]

[a]*British Geological Survey*
[b]*University of Nottingham*

Developing a better understanding of soil hydraulic properties is of significant importance for such diverse fields as agriculture, soil and ecosystems management, civil engineering and geotechnics. Electrical Resistivity Tomography (ERT) and X-ray Computed Tomography (CT) are two state-of-the-art methodologies with great potential for applications in soil science. ERT allows time-lapse monitoring of solute transport. X-ray CT is sensitive to bulk density changes at high resolution. We obtained the functional dependence of soil electrical resistivity and x-ray absorption on moisture content in a laboratory controlled calibration experiment, therefore deriving the corresponding transfer functions. Experimental results were compared with existing models, such as Waxman-Smits and Bailly. The high degree of correlation ($R > 0.85$) and low misfit (%RMS < 12%) between measurements and model predictions confirmed the validity of these models, subsequently formulating a new property relationship linking x-ray absorption and electrical conductivity. Furthermore, we conducted a column experiment, which takes advantage of the specific strength of both tomography methods. It aimed to assess the effect of zero tillage (ZT) by monitoring a 0.05 M KCl solution infiltration. ZT soils exhibited a slow solution infiltration correlated to an undeveloped porosity network and a significant ion binding effect. Our methodology opens the door for future assessments of soil hydraulic properties using X-ray CT and ERT and may serve as reference for future calibration studies between electrical and structural properties of materials.

Keywords: hydraulic properties, pedotransfer model, zero-tillage, electrical resistivity tomography, x-ray computed tomography

Direct and indirect effects of drought and warming on nutrient availability in an upland grassland in the UK

James Edgerley[a*], Carly Stevens, Rob Mills, Anna Oliver, & Emma Sayer

[a]*Lancaster University*

For a quarter of a century, the Buxton Climate Change Impacts Study ("Buxton") has monitored changes in the plant community of an upland grassland in response to different climate treatments. Work at Buxton to date has identified shifts in both the abundance of individual species and the functional traits of the plant communities in different climate treatments. Furthermore, shifts in soil microbial communities have been linked to both the direct impact of the climate treatments and the changes in plant traits related to resource availability. My project investigates whether concerted changes in plant species, plant traits, and soil microbial communities affect plant-soil interactions and key ecosystem processes. I established experiments in plots subjected to summer drought, winter warming, and a combination of both treatments, and I timed my experiments to capture both the direct and legacy effects of the treatments. I conducted an experiment by installing resin exchange membranes to capture the seasonal resource changes in the soil.

Viromics detects long-term persistence of faecally associated viruses in biosolid amended soils

Luke Hillary[a*], Steve P. McGrath[b], Davey L. Jones[a], & James E. McDonald[a]

[a]*Bangor University*
[b]*Rothamsted Research*

Biosolids, the solid by-products from wastewater treatment, are regularly recycled as agricultural fertilisers. Whilst biosolids are treated to reduce the number of pathogenic E. coli and Salmonella spp., the efficacy of virus removal is not monitored, and potentially harmful viruses are able to persist through this process. Many viral diseases are spread via the faecal-oral route, and viral pathogens have been shown to persist in soil for months. At present, the ability of biosolid-amended soil to act as a reservoir for these viruses is unknown. In addition, the change in soil physicochemical properties, microbial host availability and activity, can also cause shifts in the native soil viral community (virome). The cumulative and historical effects of biosolid amendment on soils were investigated through a replicated long-term experiment established in 1994 and managed by Rothamsted Research. Viruses were eluted and concentrated from soil samples from four replicates of three treatments (control, historical amendment and long-term amendment) and a sample of biosolids used for amendments. Virome-associated DNA was used to construct sequencing libraries using the Swift-Biosciences Accel-NGS 1S Plus DNA Library Kit, which has been shown to evenly amplify single and double stranded viral DNA. Libraries were sequenced on one lane of a HiSeq 4000, quality controlled, and uploaded to the Onecodex server for taxonomic annotation. Faeces/ sewage associated viruses were detected in amended soils and biosolids, indicating that they can persist in these environments for decades, much longer than previously thought. This research has the potential to inform the development of novel molecular techniques for detecting biosolid and sewage contamination, assessment of the risk of continued biosolid application to public health, and increase our understanding of the understudied role that viruses have in soil microbial ecology.

Keywords: viruses, sewage sludge, metagenomics, soil DNA extraction

Dermal bioavailability of PAH: the route forward

Jack Lort[a,b*], C. Vane[a], Darren Beriro[a], Mark Cave[a], Russell Thomas[c], Chris Taylor[d], Matt Jones[b], & Paul Nathanail[e,a]

[a]*British Geological Survey,*[b]*University of Nottingham,* [c]*WSP*, [d]*National Grid Proprty,* [e]*LQM*

Polycyclic Aromatic Hydrocarbons (PAHs) are ubiquitous in the environment (Humel et al., 2017) and belong to a category of contaminants known as persistent organic pollutants (POPs) due to their recalcitrant nature and consequent long half lives in the environment (Zhang et al., 2010, Kim et al., 2017). Their persistence in the environment is a matter of great concern for human and environmental health, due to their carcinogenic, mutagenic, and genotoxic effects (Chen and Liao, 2006), and as a consequence many PAHs are listed by ATSDR (Agency for Toxic Substances and Disease Registry) as a priority pollutant (ATSDR, 2017).There are three main pathways for substances into the human body: inhalation, ingestion and dermal absorption. The human skin represents around 10% of total body mass and is the largest organ of the body, resulting in the absorption of contaminants through the skin being a major pathway into the body. The most utilised dermal absorption study is the Wester et al. (1990) in vivo study using Rhesus monkeys, with their calculated PAH dermal absorption value of 13% used in the CLEA (Contaminated Land Exposure Assessment) model designed by the Environment Agency (UK) to produce generic assessment criteria (GAC) to assess whether a site is suitable for domestic or industrial use (Nathanail et al., 2009); but at present, no recommended literature values are provided by the Environment Agency (UK) for the dermally absorbed fraction of PAHs from soils. Previous in vitro studies of dermal absorption of PAHs from soil have used human (Moody et al., 1995, Moody et al., 2011, Roy and Singh, 2001), rat (Moody et al., 1995, Yang et al., 1989), porcine (Abdel-Rahman et al., 2002, Moody et al., 1995) and guinea pig (Moody et al., 1995) skin. Due to the high cost and difficulty in acquiring animal/human skin, ethical restrictions, difficulty in storing tissue, poor correlation with in vivo studies, and variability between individual extracts of skin, the use of artificial membranes in absorption studies is to be explored. Although these membranes have been shown to underestimate or overestimate absorption in comparison to in vivo data for some compounds, there has been little to no work on the use of these artificial membranes involving PAHs. When measuring bioavailability, it is necessary to know the concentration that remains in the skin/membrane after the duration of the experiment, so that a complete mass balance can be carried out. For this reason, three commonly used extraction methods have been chosen (Accelerated Solvent Extraction, Soxhlet, and Saponification) for comparison of PAH recoveries from an artificial membrane with the same dosed PAH concentration.

Keywords: PAHs, bioavailability, soil, skin

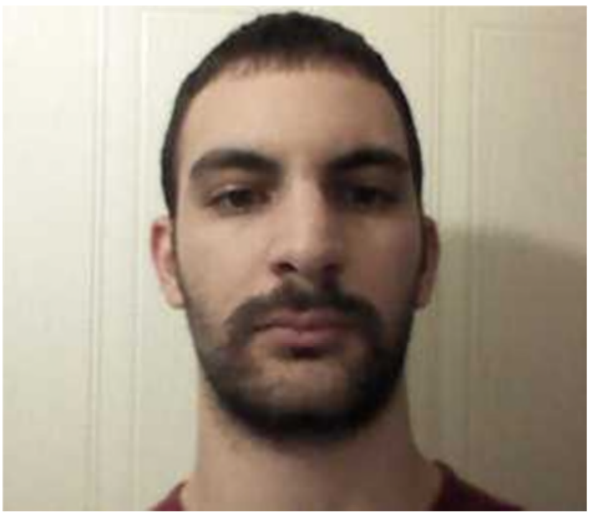
Modelling variety dependent least limiting water range: assessing the limits to root elongation in field soil

George Themistocleous[a*], Tracy Valentine, Blair McKenzie, & Sacha Mooney

[a]*The James Hutton Institute*

Agricultural research is primarily performed in order to derive more efficient ways to increase crop productivity. To that end, a variety of models are being employed that aim to integrate soil knowledge to express optimum conditions for plant growth. The "Least Limiting Water Range" (LLWR) is one such model that has been used to predict a desirable range of soil water concentration within which plants are believed to be least limited relative to various soil stress factors, which include soil strength, oxygen deficiency and drought. However, LLWR does not account for differential responses of plants species and uses specific cut off points e.g., at 2 MPa soil strength (root response), or the permanent wilting point (shoot response). Here, a methodology is described for adjusting the LLWR, aligning it more specifically to root responses. By utilizing a series of mini-rhizotron based experimental designs each soil stressor can be analysed as a continuous response instead of a cut off point while enabling measurements of plant root traits. In this way, it will be possible to integrate both soil and plant variables for different plant species and varieties into the reinvented model while remaining computationally feasible.

Keywords: soil root interactions



Estimation of carbon use efficiency (CUE) and CO2 production after application of digestate on grassland

Marta Cattin[a*], Kirk T. Semple[a], Marc Stutter[b], Chris Parry[c], & Ben W.J. Surridge[a]

[a]*Lancaster University*
[b]*James Hutton Institute, Aberdeen*
[c]*Cockerham Green Energy Ltd, Cockerham, Lancaster LA2 0DX*

Farmers have been widely encouraged to adopt on-farm anaerobic digestion (AD) for producing energy and heat. A range of digestor feedstocks (e.g. livestock manure, other agricultural and food wastes) are microbiologically decomposed in the AD process, producing biogas. The final residue, digestate, is increasing in abundance nationally. Digestate may be applied to agricultural soils as a replacement for inorganic fertilizer, but also as a soil conditioner with potential benefits for example in terms of soil organic matter levels. However, digestate application to agricultural soil can be detrimental to the environment through emission of greenhouse gases, leaching/runoff of nutrients and adverse impacts on the soil microbial community. There remain significant uncertainties surrounding the net effects of digestate application, processes of digestate application to agricultural soils and possible handling aspects (e.g. separation of liquid and solid fractions of digestate). In this context, the aim of this project is to understand how to manage digestate applications to maximize agricultural benefits while minimizing adverse environmental impacts. Using both laboratory-scale incubations and field trials, the research reported here examined:

(i) How the application of liquid and of solid fractions of digestate influences carbon use efficiency, CO2 emissions and soil organic matter levels under varying soil nutrient conditions in a grassland system;
(ii) How the application of liquid and of solid fractions of digestate influences the emission of greenhouse gases (CO2, N2O and CH4) from grassland soils;
(iii) How leaching and runoff of phosphorus from grassland soil is influenced by the application of digestate.

From this work we seek to identify the risks associated with sub-optimum management of digestate that increase the risk of soil, air and water pollution, in order to improve understanding of how digestate should be managed to maximise nutritional benefits within safe environmental limits.

Keywords: digestate, carbon use efficiency, greenhouse gases, leaching, runoff

Drivers of soil carbon changes in subtropical and tropical grasslands: a review

Rose Durcan[a*] & Mariana Rufino[a]

[a]*Lancaster University*

Soils are increasingly being recognised as important sinks for carbon, particularly the world's grassland ecosystems, which possess great potential to capture carbon and sequester it as organic matter. However, poor grazing management in grasslands is hindering this potential to store carbon, with high stocking densities and permanent grazing resulting in land degradation. Whilst the general effects of grazing on soil carbon dynamics are recognised, a lack of research focus has resulted in an array of knowledge gaps regarding the drivers of these effects. This review aims to explain and compare the key biotic and abiotic drivers of soil carbon changes in tropical and subtropical grasslands, alongside the identification of knowledge gaps upon which future research can address. A review and meta-analysis was conducted on 249 observations from 30 studies, covering 15 countries from both climatic zones. The effect of grazing on carbon stocks was calculated as a natural log response ratio, which was in turn used in statistical analyses. In both the subtropics and tropics, grazing at has had a negative effect on soil carbon stocks (-0.23 and -0.082 respectively). Preliminary statistical analysis found that in both climates grazing intensity and sampling depth had a significant effect on soil carbon dynamics. Photosynthetic pathway however, only had a significant effect in subtropical sample locations ($p = 0.086$). Furthermore, clay content (%) significantly affected soil carbon dynamics in tropical sample locations ($p = 2.79e-13$), likely due to the typically higher clay content of tropical soil. 98% of observations reported carbons stocks to a depth of 50cm or less, highlighting a lack of studies investigating deep soil carbon. Only 3 studies with 6 observations reported measurements of microbial biomass, all of which were from subtropical soils. The results suggest that more research should be undertaken into the links between grazing, soil carbon dynamics and microbial activity in these climatic zones in order to further explain drivers of soil carbon sequestration

Keywords: grazing, soil carbon, grasslands

Comparative metagenomics and GeoChip analysis reveals functional shifts in microbial community with soil carbon depletion

David Fidler[a*], James McDonald[a], & Davey Jones[a]

[a]*Bangor University*

Soils are Earth's largest store of terrestrial carbon, containing 1500 gigatonnes of soil organic carbon—predominantly in the form of decaying lignocellulosic plant material. Consequently, the microbial-mediated decomposition of lignocellulose in soils is a key feature of the global carbon cycle. However, the synergistic interactions between hydrolytic soil microorganisms, which drive the terrestrial carbon cycle, make them largely intractable to isolation and cultivation via traditional approaches. Our knowledge of the true diversity of the hydrolytic enzyme pool of biodegradative microbial communities in soils is therefore limited. To address this knowledge gap, a combination of techniques such as shotgun metagenomics, DNA microarray data, and in vitro tests on novel microorganisms for degradative abilities (combined with whole-genome sequencing) are required. Replicated shotgun metagenomes and GeoChip microarray results for soil samples from a long-term field experiment on carbon depletion were analysed. The experiment comprises field plots covered by opaque black sheeting ("blackout" treatments) for 10 years (n=3), and two years (n=4), and uncovered 'control' plots. Blackout plots experienced complete removal of plant cover, meaning labile carbon inputs from plant root-exudates, fine root-hairs, and were reduced, leaving recalcitrant carbon sources (e.g. lignocellulose) as the primary carbon source for microorganisms. Comparison of CAZyme profiles from assembled metagenomes (glycoside hydrolase (GH), auxiliary activity (AAs) and carbohydrate binding module (CBM) classifications) and GeoChips gave opposing results; the GeoChip indicated greater CAZyme abundance in control plots, whereas the metagenomes suggested greater CAZyme abundance in the blackout plots. Taxonomic annotation of the metagenome scaffolds which contained CAZymes was used to profile the microbial community involved in lignocellulose degradation. Establishing the taxonomic identity of the organisms which degrade lignocellulose in soils is important, as organisms from different taxa employ diverse strategies for lignocellulose degradation. Taxonomic and functional information may therefore be used in tandem to improve models of microbial carbon-utilization in soils responding to environmental changes.

Keywords: cellulose, hemicellulose, lignin, biofuels, dbCAN2

The impact of soil structure on microbial response to environmental change

Harry Harvey[a*]

[a]*University of Nottingham*

Environmental perturbation, anthropogenic or otherwise, can have a profound effect on soil microbiota and essential biogeochemical processes. The general resistance and adaptation of microorganisms to stressors has been well studied in vitro. However, the influence of key environmental variables, such as the soil structure (soil phenotype), on microbial response to perturbation, is very poorly understood. It has recently been established that phenotypic heterogeneity (i.e., variation between individual cells within genetically-uniform microbial populations) is an important parameter for microbial survival in soils during environmental perturbation, such as from pollutants. Using artificial structures to expose organisms to structure-specific stress, soil exo-endo aggregate microbial isolation, and microfluidic control in soil-micromodels, current work on this project is focused on disentangle the key parameters of a structured soil environment which may influence phenotypic heterogeneity as a microbial survival mechanism within soil ecosystems.

Keywords: structure, environmental, stress, microbial

Tracing the origin of sediments and C across the terrestrial-aquatic continuum: A holistic approach to assess climate change and water quality threats

Katy Wiltshire[a*], Jeroen Meersmans[a], Toby Waine[a], Miriam Glendell[b], Nikki Baggaley[b], & Fiona Napier[c]

[a]*Cranfield University*
[b] *James Hutton Institute*
[c] *SEPA*

On-site loss of sediments and soil organic carbon (SOC) across land-water interfaces has many impacts, not least of which are the loss of productive soils and the commensurate food security. Increased turbidity and nutrient enrichment of waterways impacted by this sediment flow and the corresponding degradation of water supplies constitute an equally important off-site impact. Detailed knowledge of the disposition and transport of SOC within the environment will not only facilitate sustainable management of water catchment areas but is essential if we are to better understand the potential of soils to act as sinks or sources of C in a changing climate.

It is increasingly important to (i) identify management practices that trigger SOC loss and (ii) to assess the impacts of land-use changes such as afforestation/deforestation and draining/reinstating wetlands on sediment fluxes to aid stakeholders in how to best employ resources to preserve terrestrial and aquatic assets. If we can identify the source of SOC deposited within catchment waterways, measures could be put in place to preserve fertile, productive soils in-situ and avoid costly remedial measures being required at a later date.

This catchment scale study will develop an holistic model with the aim of identifying the OC sediment sources for contrasting catchment areas in Scotland. To identify specific sources of aquatic OC within this study we need to (i) characterise the greatest contributor to the aquatic sediment in terms of land-use/vegetation type (e.g. grassland, forest, arable) and (ii) identify which areas of grassland/forest/arable within the catchment are most likely to be the source of this aquatic sediment (i.e. areas most prone to erosion).

We will combine use of existing land use, soil type/coverage, remote sensing, topography and aerial photographic databases, with fieldwork including soil, aquatic sediment and lake core sampling in order to both describe the landscape today and identify changes (e.g. land-use) through time. It will integrate (i) OC tracing techniques (stable isotope C, N; compound-specific-stable-isotope analysis of fatty acids; *n*-alkanes) identifying specific land-use/vegetation sources for the sediments with (ii) detailed modelling/mapping of SOC distribution, erosion and transport to characterise the C fluxes across the terrestrial-aquatic continuum.

Keywords: lateral carbon fluxes, sediment fingerprinting, land use, water quality, climate change

The role of soil fertility in the function of mycorrhizal associations

Leigh-Anne Kemp[a*], Alison Karley[a], Andy Taylor[a], Alison Bennett[b], Niall McNamara[c], & Emma Sayer[d]

[a]*James Hutton Institute*
[b]*The Ohio State University*
[c]*The Centre for Ecology and Hydrology*
[d]*Lancaster University*

Up to 90% of terrestrial plants form symbiotic associations with arbuscular mycorrhizal (AM) and ectomycorrhizal (ECM) fungi, exchanging carbon for nutrients. Research shows that the mutualistic relationship can shift to parasitic, depending on the ratio of carbon to nitrogen in the soil. However, much less is known about the role of mycorrhizal fungi in soil carbon dynamics. This is a major knowledge gap, because as much as 31% of soil respiration can be derived from mycorrhizal fungi and as much as 70% of soil carbon may be stored within the mycorrhizal hyphal network. Due to the higher turnover of AM fungi compared to ECM fungi, AM fungi are thought to promote the mineralization of soil organic carbon, whereas ECM fungi promote carbon storage. Importantly, we currently do not fully understand how soil fertility might influence whether mycorrhiza store or release carbon.

To address this gap, the present project examines the distinct responses of AM fungi and ECM fungi to changes in soil nutrient availability and assesses how this impacts plant – fungi relationships and soil carbon dynamics. The experiments use two tree species that associate with both mycorrhizal fungi types in a randomized block design with four fungal and four nutrient treatments replicated six times for each tree species. Measurements during two growing seasons will establish how soil nutrient availability influences: i) the plant – fungal relationship, ii) the soil fungal community, and iii) the transfer of carbon and nutrients by the different fungal types. The project not only represents the first empirical test of the carbon storage potential of distinct mycorrhizal fungi but will also provide important information on the mechanisms involved.

Keywords: carbon, mycorrhiza, nutrients, dynamics

Which grass species or mixture will stand the test of time with regards to soil erosion mitigation?

Corina Lees[a*]

[a]*Cranfield University*

Soil erosion is a global problem which is likely to be worsened by climate change in terms of increased intensity and frequency of rainfall events therefore needs to be mitigated against. One way in which soil erosion can be mitigated against is by using grassed water ways. The role of climate change and the effect it will have on soil loss will be investigated by using different scenarios, current summer, current winter and projected winter and projected summer. The temperature, humidity and carbon dioxide levels will be changed within these scenarios. For each scenario there will be three different water treatments, no water, normal water and excess water. Different species of grass/grass mixes will be grown under these different conditions and their plant above ground (plant height, plant percentage cover etc.) and below ground parameters (root length, root diameter etc.) relating to soil erosion mitigation will be measured.

Keywords: soil erosion, climate change, grass, grassed water ways, erosion mitigation

Fresh organic matter effects on carbon dioxide, methane and nitrous oxide emissions on cultivated peat

Samuel Musarika[a*]

[a]*Centre for Ecology and Hydrology, Bangor*

Peatlands cover an estimated area of approximately 400 Mha of the global land surface, which is a mere three percent. However, they play a significant role in carbon (C) sequestration as they store approximately 30% of the global C storage. Water saturation in peatlands eliminates oxygen leading to the natural accumulation of carbon derived from organic plant material. Due to agriculture, peatlands are drained to support horticultural production. It is estimated that agriculture exploits over 20% of peatlands worldwide. The exploited peatlands are no longer capable of storing C and thus have become significant emitters of carbon dioxide (CO2) and nitrous oxide (N2O) into the atmosphere. In Europe, agriculture is the second largest contributor of greenhouse gas (GHG) emissions. In addition to being large contributors of GHGs, we are fast losing productive peatlands; it is estimated that by 2050, a third of these productive peatlands will be lost. Loss of productive peatlands will affect productivity and food security. An increasing practise to preserve soil loss is crop residue management which involves crop residue from the previous growing season being left to provide cover then ploughing it in the next season. Alternatively, a specially selected cover crop can be grown to provide cover. Nevertheless, there is concern that the ploughed in fresh organic matter (FOM) can accelerate the decomposition of existing organic matter, especially in cultivated peat soils. This study aims to assess the effects FOM has on the emissions of GHGs such as CO2, methane (CH4) and N2O in currently cultivated peatlands. The experiment will be carried out on intact cores measuring 200 mm width by 500 mm depth and will use three different crop types commonly grown on peat soils in the UK, i) a root vegetable (carrot), ii) a salad crop (lettuce) and iii) a cereal crop (wheat). Samples of the FOM will be taken to measure their quality, nutrient content, moisture content and the C:N ratio. Furthermore, samples of the FOM will be analysed to ascertain relative decomposition rates by either using a litter bag technique, where mass loss is measured from the bags at various times or by assays of litter in petri dishes under controlled temperature and moisture conditions. The findings from this study will have implications on the future of FOM application and management of cultivated peatlands.

Keywords: peatlands, agriculture, sustainability, FOM

Acetamiprid transport and mobility within UK agricultural soils - A comparison of commercial mixtures under different soil organic matter treatments

Jessica Potts[a*], David Jones[a], & Andy Macdonald[b]

[a]*Bangor University*
[b]*Rothamsted Research*

Neonicotinoids are one of the most widely used insecticides on the current global market. Their systemic mechanisms allow for ease of application and relatively successful outcomes in controlling biting and sucking invertebrates, however neonicotinoids have been strongly associated with recent declines in various non-target organisms. The majority of neonicotinoids can be applied directly to the soil, either as a seed coating or as a soil drench in the form of water-dispersible granules. Despite these application methods there is relatively little research focusing on the movement, fate and interactions of these chemicals in British soils under general field management strategies, though current evidence suggests that practices such as the addition of soil bio-amendments can influence the mechanisms behind pesticide mobility.

The aims of this study were to i) assess the effect of soil organic matter level on Acetamiprid mobility and transport within soil, and to ii) assess the difference in active ingredient transport across different domestic pesticide mixtures. We used ^{14}C labelled Acetamiprid to track the degradation and movement of the domestic pesticide mixtures within soil. We chose to compare two commercially available Acetamiprid pesticide mixtures against the pure active ingredient. Most previous research has chosen to use just the pure active ingredient, however this isn't necessarily representative of true field scenarios. These spiked pesticides were then added to soils collected from the long term experimental site at Woburn, part of Rothamsted research. To assess the movement and behaviour of these pesticide mixtures we ran a range of leaching, sorption and mineralisation experiments.

The mineralisation of all three mixtures was shown to be very slow, with no more than 23% of any given chemical/SOM combination being mineralised over the 60 day experimental period. The highest mineralisation rates were found in the samples with the highest SOM level. Preliminary examination of the leaching data found that over 80% of each chemical passed through each soil sample during the experiment. This combined with the negligible sorption values collated from the initial sorption study plus the low rates of mineralisation imply that neonicotinoids are highly persistent within the environment. Further investigation is required to understand the implications of this in the context of larger agricultural and domestic garden systems.

Keywords: pesticide, neonicotinoid, transport, degradation

List of attendees

Simon Avery	University of Nottingham
Steven Banwart	University of Leeds
Richard Bardgett	University of Manchester
Harry Barrat	Rothamsted Research
John Beal	Cranfield University
Tom Bott	British Geological Survey
Rosanne Broyd	Lancaster University
Kate Buckeridge	University of Edinburgh
Bea Burak	Lancaster University
Jasmine Burr-Hersey	University of Nottingham
Laura Cardenas	Rothamsted Research
Marta Cattin	Lancaster University
Dave Chadwick	Bangor University
Mihai Cimpoiasu	British Geological Survey
Hannah Cooper	University of Nottingham
Ron Corstanje	Cranfield University
Paul Cross	Bangor University
Sarah De Baets	Cranfield University
Emily Dowdeswell	Cranfield University
Beckie Draper	University of Nottingham
James Edgerly	Lancaster University
Daniel Evans	Lancaster University
David Fidler	Bangor University
Paul George	Bangor University
Tim George	James Hutton Institute
Robert Grabowski	Cranfield University
Lucy Greenfield	Bangor University
Francesca Gregory	Edinburgh University
Simon Gregory	British Geological Survey
Harry Harvey	University of Nottingham
Phil Haygarth	Lancaster University
Paul Hill	Bangor University
Luke Hillary	Bangor University
Jane Ince	Food Standards Agency
Davey Jones	Bangor University
Anchen Kehler	University of Nottingham
Leigh-Anne Kemp	James Hutton Institute
Guy Kirk	Cranfield University
Oliver Kuras	British Geological Survey
Olivia Lawrenson	Lancaster University
Martha Ledger	University of Nottingham
Corina Lees	Cranfield University
Jack Lort	University of Nottingham

Tim Mauchline	Rothamsted Research
Chris McCloskey	Cranfield University
James McDonald	Bangor University
Steve McGrath	Rothamsted Research
Jeroen Meersmans	Cranfield University
Malika Mezeli	Lancaster University
Rob Mills	Lancaster University
Sacha Mooney	University of Nottingham
Sam Musarika	Centre for Ecology & Hydrology
Andrew Neal	Rothamsted Research
Roy Neilson	James Hutton Institute
Flora O'Brien	NIAB
Laura O'Keefe	Lancaster University
Nick Ostle	Lancaster University
Francis Parry Roberts	Bangor University
Eric Paterson	James Hutton Institute
Jessica Potts	Bangor University
John Quinton	Lancaster University
Sam Reynolds	Rothamsted Research
Karl Ritz	University of Nottingham
Lewis Rose	University of Nottingham
Mariana Rufino	Lancaster University
Ian Rugg	Welsh Government
Heather Ruscoe	Lancaster University
Emma Sayer	Lancaster University
Fiona Seaton	Centre for Ecology & Hydrology
George Shaw	University of Nottingham
Andrew Smith	Bangor University
Marc Stutter	James Hutton Institute
Ben Surridge	Lancaster University
Federica Tamburini	ETH Zürich
George Themistocleous	James Hutton Institute
Saoirse Tracy	University College Dublin
Andrew Tweedie	James Hutton Institute
Andrew Tye	British Geological Survey
Tracy Valentine	James Hutton Institute
Hans-Jörg Vogel	UFZ - Leipzig
Toby Waine	Cranfield University
Helen West	University of Nottingham
Alexander Williams	University of Nottingham
Catherine Wiltshire	Cranfield University