University of Reading

Soils for Secure and Sustainable Societies

1st Soil Research Centre Annual Stakeholder Event

Wednesday 10th December 2014

Palmer Building, 12:30-18:00

'Research Highlights' Presentation Abstracts

Contents

Soil & Food Security

Soil Service: managing nutrients, organic matter and biodiversity for sustainable agriculture

Reading Scientists (main contact e-mail): Simon Mortimer (s.r.mortimer@reading.ac.uk)

Collaborators: Lancaster University, Lund University, Swedish University of Agricultural Sciences, University of Copenhagen, University of Helsinki, Netherlands Institute of Ecology, Wageningen University, Justus-Liebig-University of Giessen, Biology Centre of the Academy of Sciences, Czech Republic, Aristotle University of Thessaloniki

Overview: Soils and their biodiversity form the basis of agricultural production systems and generate a range of fundamental ecosystem services. Yet soil degradation is widespread in the EU: erosion, loss of soil organic matter and compaction are some of the degradation processes that are threatening soil fertility. The SOILSERVICE project has quantified the negative impacts of intensive arable cropping systems on soil ecosystem services due to loss of soil organic matter and soil biodiversity. SOILSERVICE has also analysed how soils can be better managed to mitigate climate change and reduce nutrient and chemical inputs, and, ultimately, improve the long-term incomes of European farmers. This goes hand in hand with conserving soil biodiversity, the natural capital that generates ecosystem services.

Key findings to date: Bacteria and fungi, nematodes, microarthropods and protozoa, and their complex interactions with each other and with plants, perform many important functions that underpin the delivery of ecosystem services. Short rotations of annual crops, high rates of fertiliser and chemical application, and absence of organic amendments (manure, grass break crops, straw, etc.) result in degradation of soil biodiversity and declining soil organic carbon content. Although impacts of land use changes may vary with regional differences in climate and soil characteristics, SOILSERVICE shows that the decrease in the abundance and biomass of most groups of soil organisms as a consequence of intensification of agriculture is general across Europe.

Current arable farming practices in the EU imply that soil biodiversity will continue to decline and consequently maximum yields will be lower than if biodiversity was well-maintained. Currently, inorganic fertilisers cannot substitute fully for soil services and a shift towards management that builds up soil carbon will both improve the sustainability of food production and farmers' incomes. In the four arable regions of Europe studied in the project, farmers' maximum income will increase in the future if soil carbon content—which is a good proxy for soil natural capital—is optimised. Not only do farmers benefit from higher yields but also from lower costs of inputs that are replaced by soil ecosystem services (i.e. improved fertility).

Key papers:

De Vries *et al.* (2013) *Proceedings of the National Academy of Sciences*, 110: 14296-14301
http://centaur.reading.ac.uk/33768/
Tsiafouli *et al.* (2015) *Global Change Biology*, 21: 973-985

Web: http://www.reading.ac.uk/apd/staff/s-r-mortimer.aspx

How to increase carbon sequestration on soft fruit farm

Reading Scientists (main contact e-mail): Martin Lukac (m.lukac@reading.ac.uk), Simon G. Potts

Collaborators: Waitrose Plc, Berry World Ltd, Hall Hunter Partnership Ltd

Overview: Current soft fruit production at Tuesley farm was put into place across the holding from 2003 onwards. Prior to this, the dominant land management practice on site was arable agriculture with focus on cereal production. Land use change from arable to a less intensive disturbance regime has very likely resulted in a build-up of carbon stock in the soils, and also in standing tree and shrub biomass present on the farm today. The main focus of this work was to assess carbon stocks in soils under several different soft fruit crops currently grown on the farm. Due to crop rotation, soft fruit crops have been growing in the same field for varying lengths of time, offering an opportunity to assess the speed of the change in carbon stocks. We present recommendations on how management practices at Tuesley could be modified to enhance longer-term carbon stock, and how our approach could be rolled out to other horticultural and agricultural production systems within the Waitrose supply chain.

Key findings to date: Based on the information on soil carbon content under various crops and ecosystems found on or in the vicinity of Tuesley farm, we recommend the following:

1. Maintain and where possible expand the grass strips between berry crops in order to maximise soil C sequestration.
2. Plant deeper rooting grass species mixed with species supporting nitrogen fixations (clovers) to further enhance soil C sequestration.
3. Maintain soil rooted berry shrubs in situ, unless detrimental to the productivity of the farm, as the deep rooting habit of these crops leads to C accumulation at depth.
4. Leave cuttings and waste biomass from main crops on the inter-row grass strips as this will benefit C accumulation in the soil below these strips.
5. Plan crop rotation on the farm with the aim to establish more row/inter-row strips which will remain in situ even if the main crop is replaced.
6. Grow crops in coir bags or pots where possible to facilitate the maintenance of inter-row strips as this will reduce the need to plough the soil – this practice leads to loss of soil C.
7. Utilise the biomass production of the existing windbreaks and hedges to harvest fuel for a biomass boiler. Heat generated from biomass accumulated on the farm will be C neutral and possibly C negative if soil C storage under permanent windbreaks and hedges is included.

Web: http://www.reading.ac.uk/apd/staff/m-lukac.aspx

Farmer attitudes to mitigation options to reduce soil and phosphorous loss

Reading Scientists: Alison Bailey (a.p.bailey@reading.ac.uk), Richard Tranter, Philip Jones

Collaborators: ADAS (Martyn Silgram), Lancaster University (John Quinton, Clare Deasy, Mary Ockenden)

Overview: Mitigation options for phosphorus and sediment (MOPS1 and MOPS2) were two collaborative research projects, funded by the Department for Environment, Food and Rural Affairs (Defra), to review and test the cost effectiveness of mitigation options to reduce losses of sediment and phosphorus from agricultural fields. MOPS1 focused on in-field mitigation options for winter cereals. MOPS2 focused on infield losses from spring grown crops (potatoes), and edge of field constructed wetlands. Alison was responsible for the financial analysis determining the costs associated with introducing and maintaining the mitigation practices and the effect of adopting mitigation options upon farm costs, and thus the potential for their uptake

Cost-effectiveness

Option	Effectiveness (%)	Impact (£/ha)
Winter wheat options trialled		
Tramline disruption	69-99%	- £2-£4
Minimum tillage	4-98%	+ £68-£78
Crop residues	24-50%	- £17-£19
Contour cultivate	45-79%	- £0-£5
Vegetative barrier	9-97%	- £2-£7
Potato options trialled		
Cover crop	n/a	- £120-£167
Tramline cultivation		- £2-£3
Stone row cultivation (rotary harrow, vertical and angled tines, tied ridger)		- £30-£60
Autumn cultivation (up/down, contour, wide and narrow)		- £19-£47
Sediment retention (t ha^{-1} yr^{-1})		Cost (£)
Field wetlands	0.01-6t	£280-£3100

Key Findings: Potential uptake of mitigation options

Four focus groups were conducted between 2012 and 2013 with 44 participants, the majority of whom were farmers (33), advisors (6) or both (3). These focus groups were followed by a postal survey to 1200 farmers, with a total of 119 completed questionnaires received representing a response rate of 10%. Soil erosion was perceived as an issue by many, with contributing factors being both the natural environment and farm practice. What was also evident is that a significant number of respondents were undertaking many mitigation practices as part of routine farming practice, particularly where they relate to cultivations and field management. Options linked to farm infrastructure, including the edge of field options, which require some form of investment are less likely to be adopted without an incentive, whether that be monetary or awareness creation. The more novel in-field options, disruption of tramlines (winter cereals) and stone rows (potatoes), both have the potential for adoption particularly in the latter case where cost savings linked to water retention could be realised. The barriers to adoption relate to practicality and timing issues, alongside availability of the right staff and machinery to do the job. Incentives may be necessary in some cases, not necessarily through the current agri-environment scheme set-up, but with options and incentives more tailored to each individual situation.

Web: https://www.reading.ac.uk/apd/staff/a-p-bailey.aspx

Dissecting the soil microbial biomass black box to inform manipulation of soil function

Reading Scientists: Liz Shaw (e.j.shaw@reading.ac.uk), Christos Gougoulias, Antia Villada

Collaborators: University of Aberdeen (Liz Baggs), UFZ Leipzig (Annelie Wendeberg)

Overview: A central goal in soil microbial ecology is to link biogeochemical processes to specific microbial taxa *in situ*. A suite of cultivation-independent methods has been developed in the last decade in order achieve this goal. Although very powerful, none of these techniques offer the opportunity to understand the quantitative role that any taxonomic unit within microbial communities plays in a particular process or the opportunity to quantify the role of functional groups in linking component assimilatory and dissimilatory processes of biogeochemical cycles of different elements. We describe the development of a new methodological approach that links isotopic labelling, Fluorescence In Situ Hybridisation (FISH) and Fluorescence-Activated Cell Sorting (FACS) in order to quantitatively track the fate of a model plant root exudate into a targeted taxonomic bacterial group.

Key findings to date: Using the isotope-FISH-FACS approach, we have shown that pseudomonads are competitive for salicylic acid utilization in rhizosphere soil, increasing their abundance from 1.5% to 10% of the total flow-cytometry-detected population and incorporating up to 47% of spiked salicylate ^{14}C (50 µg g^{-1} soil) into their biomass. We are now seeking to extend our approach to incorporate mRNA-FISH to target a functionally active (nitrous oxide-reducing) bacterial population and test the hypothesis that the competitiveness of this population for C will depend on the carbon source (glucose, succinate, cysteine or salicyclic acid) and be represented by a lowered denitrification ^{15}N-(N_2O-to-N_2) product ratio.

Key papers:

Gougoulias & Shaw (2012). Systematic and Applied Microbiology, 35: 533-540
http://centaur.reading.ac.uk/24954/
Gougoulias et al (2014). Journal of the Science of Food and Agriculture, 94: 2362-2371
http://centaur.reading.ac.uk/36353/

Web: http://www.reading.ac.uk/ges/aboutus/staff/e-j-shaw.aspx

Use of beneficial microbes to improve plant health by reducing the impact of pests and disease

Reading Scientists (main contact e-mail): Rob Jackson r.w.jackson@reading.ac.uk, Liz Shaw, Louise Johnson, Simon Andrews, Carol Wagstaff

Collaborators: Rothamsted Research (Chris Bass, Penny Hirsch, Tim Mauchline), East Malling Research (Richard Harrison, Robert Saville), UMass Dartmouth, USA (Mark Silby)

Overview: Plants depend on beneficial microbes to protect them from pests and diseases and to improve their health, although many microbes can attack plants to cause disease. Understanding how disease occurs and how beneficial microbes protect plants are key areas of research. We use a range of microbiology and molecular techniques to examine bacterial performance. This is to examine direct improvement of plant growth, protection of plants from fungal and oomycete pathogens, and killing of aphid pests.

Key findings to date: We have identified a range of bacteria that kill aphid pests and recently demonstrated that the bacteria sprayed on plants can reduce aphid colonisation. We have also found that bacteria living around plant roots require two key movement systems, including a soap-like surfactant that also has antimicrobial properties. A recent major breakthrough was demonstration that the bacteria can rapidly evolve to overcome catastrophic mutations – this has implications for understanding resilience of the bacteria when living in their natural environment.

Key paper:
Taylor et al. (2015) Science, 347: 1014-1017
http://centaur.reading.ac.uk/39447/

Web: http://www.reading.ac.uk/biologicalsciences/about/staff/r-w-jackson.aspx

Investigating phosphate cycling in agricultural soils

Reading Scientists: John Hammond (j.p.hammond@reading.ac.uk), Mark Tibbett

Collaborators: University of Warwick (Liz Wellington, Gary Bending, Dave Scanlan, Jonathan Moore, Alex Jones)

Overview: Phosphorus (P) is an essential nutrient required by crops to ensure good growth and yields. Crops get their P from the soil via their roots in the form of phosphate (Pi). The availability of Pi for the crop in the soil depends on the soil type, its pH, the growth of bacteria and fungi in the soil and the amount of Pi the crop takes up. The project will investigate how bacteria living near to the root recycle Pi and make it available to the crop and the role of carbon released from the root in encouraging these bacteria to grow.

Intended outcomes: The project will identify 1) the key functional microbes driving phosphate (Pi) cycling in the soil near the root, 2) the role of carbon from the plant in encouraging these microbes to grow, and 3) how these processes change during seasons. Improving our understanding of these processes will allow us to ensure we provide the optimal root environment for our crops to maximise their use of Pi in the soil and potentially reduce fertiliser Pi inputs. It will also provide targets for breeding crops that are more efficient at acquiring Pi from the soil, either by themselves, or with help from some soil bacteria and biotechnology based applications for microbes and enzymes identified during the project.

Web: http://www.reading.ac.uk/apd/staff/j-p-hammond.aspx

LIBERATION: linking farmland biodiversity to ecosystem services for effective ecological intensification (contact Simon Potts)

Reading Scientists: Simon Potts (s.g.potts@reading.ac.uk), Alison Bailey, Michael Garratt, Sam Leigh, Erika Degani

Collaborators: Wageningen University, Netherlands Institute of Ecology, Lund University, Swedish University of Agricultural Science, University of Wuerzburg, University of Bayreuth, Hungarian Academy of Science, University of Padova, University of Poznan, Food and Agriculture Organisation

Overview: The LIBERATION project is an EU FP7 funded project. Its aims are to provide the evidence-base for the potential of ecological intensification to sustainably enhance food security with minimal negative impacts on the environment. This requires a basic insight in how biodiversity contributes to various ecosystem services and subsequently how ecosystem services contribute to yield and farm income. Landscape and farm management can then be adapted to improve the contribution made by farmland biodiversity to crop production improving sustainability.

Research at Reading involves a number of soil biodiversity focussed studies:

1. A pan European field trial in wheat crops across seven EU countries quantifying the relationship between **soil management**, **semi-natural habitats** and multiple **ecosystem services** delivered by **soil biodiversity.**
2. A UK based study assessing the impacts of field boundary management for promoting **above-** and **below-ground** ecosystem services including **pollination**, **pest regulation** and **soil services**.
3. A review identifying relationships between **semi-natural habitats**, **on-farm management** and **below-ground biodiversity** in European cropping systems.

Web: http://www.fp7liberation.eu/TheLIBERATIONproject
http://www.reading.ac.uk/caer/staff_simon_potts.html

Soil & Built Environment

Exposure assessment and remediation of pollutants

Reading Scientists: Chris Collins (c.d.collins@reading.ac.uk) Tom Sizmur, Adrian Williams

Collaborators: Environment Agency, Defra, British Geological Survey, Institute of Occupational Medicine, Firth Consultants, Syngenta, Birmingham University, Stockholm University, University of Antwerp.

Overview: We are developing a number of screening tools to fine tune the risk assessment process to a range of indoor (e.g. flame retardants) and outdoor (e.g. pesticides) pollutants. This will enable regulators to balance the potential negative effects of these chemicals against the positive outcomes they can provide for society. The results of our research findings can be used in the assessment of contaminated land, during the registration process of chemicals and to determine if the use of certain chemicals should be restricted.

Key findings to date:

- In association with our project partners we have developed a screening methodology (CEPBET) which mimics the human gut to assess the release of pollutants from ingested materials.
- We have tested a number of methodologies for predicting the uptake of pollutants into crops and other foodstuffs.
- Exposure models have been tested and validated against independent data sets to determine the most important factors in the uptake of pollutants by livestock

Key paper:
Tilston et al (2011) *Environmental Science & Technology*, 45: 5301-5308
http://centaur.reading.ac.uk/20809/

Web: http://www.reading.ac.uk/ges/aboutus/staff/c-d-collins.aspx

Biochar for remediation of contaminated soils

Reading Scientists (main contact e-mail): Tom Sizmur (t.sizmur@reading.ac.uk), Chris Collins

Collaborators: University of York (Mark Hodson), Jose Gomez-Eyles (Integral Consulting Inc, Seattle)

Overview: Biochar is produced from burning organic material in the absence of oxygen. Any organic material can be used such as wood, grass, or waste products like nut shells or orange pulp. Biochars possess a number of remarkable properties that make them suitable for the remediation of contaminated soils, including a high internal surface area, negative charge and resistance to degradation. Biochars are therefore able to immobilise organic and inorganic toxic contaminants in soils. We thoroughly reviewed the literature on the capability of biochar to reduce the bioavailablity of organic and inorganic contaminants. We then carried out experiments to investigate the interactions between biochars, contaminants, and earthworms.

Key findings to date:

1. Application of biochar to contaminated soils reduced the mobility of organic and inorganic contaminants.
2. The mechanisms of immobilisation include sorption to biochar surface and increase in soil pH.
3. Biochar reduced the uptake of contaminants by plants and earthworms.
4. Earthworms did not re-mobilise contaminants previously immobilised by biochar

Web: https://sites.google.com/site/tomsizmur/home/photos

Bio-waste re-use

Reading Scientists (main contact e-mail): Steve Robinson (j.s.robinson@reading.ac.uk)

Collaborators: Terra Humana Clean Technology Development (Sweden), Plant Research International (Netherlands), University of Rostock (Germany), Gottfried Wilhelm Leibniz Universitaet (Germany), Helmholtz Zentrum für Umweltforschung – UFZ (Germany), University of Turin (Italy), Migal Galilee Technologies Ltd (Israel), Consejo Superior de Investigaciones Certificas (Spain), Sonac Vuren BVB.V (SOBEL Group) (Netherlands), ARPAD Agrar Plc (Hungary)

Overview: Diminishing reserves of economically recoverable phosphate rock demand research and development into alternative and renewable sources of phosphorus (P) fertilizer. Heat-treated animal bone char (ABC) was evaluated for its potential both as a phosphorus (P) fertilizer and biological pest control agent. Phosphorus-solubilising microbial strains were tested for their compatibility with the ABC and positive biocontrol effects in amended soils. Inoculated ABC test materials were also compared with reactive phosphate rocks (RPR) and triple superphosphate (TSP) fertilizer for their dissolution kinetics and agronomic effectiveness (key results below).

Key findings to date:

- The most important soil properties determining P dissolution from ABC were pH and P sorption. These two soil parameters could be combined in multiple regression equations that use readily measured soil properties to predict the potential for ABC dissolution in a soil.
- In comparison with RPR, ABC was a better source of plant available P.
- ABC is a P fertilizer of solubility intermediate between RPR and TSP

Web: http://www.reading.ac.uk/ges/Aboutus/Staff/j-s-robinson.aspx

Quantifying ecosystem services provision by (garden) plants

Reading Scientists: Tijana Blanusa (t.blanusa@reading.ac.uk)

Collaborators: RHS (Royal Horticultural Society), Sutton Griffin Architects

Overview: Tijana's research interests are in understanding the interaction between the plants and the environment: how the changing environment (such as drying soil and elevated temperatures) affects plants, but also how plants moderate the environment around them. She currently runs several projects investigating the contribution of green roofs, green walls, garden hedges and other forms of green infrastructure to the moderation of air temperatures, rainwater capture and aerial pollutants.

Key findings to date: Plant species differ greatly in the extent of the provision of various ecosystem services; the understanding of the ranges of those differences is the key to choosing the right species for a particular environment.

Web: https://www.rhs.org.uk/science/meet-the-team/Tijana-Blanusa

Soil sealing and carbon emissions from urban areas

Reading Scientists: C. Sue Grimmond (c.s.grimmond@reading.ac.uk), Helen Ward; Simone Kotthaus

Collaborators: CEH Wallingford, Forest Research

Overview: Over 70% of global greenhouse gas emissions are from urban areas. While a large number of studies have documented the seasonal dynamics of carbon fluxes of vegetated ecosystems, comparable measurements from urban areas remain relatively limited especially over extended periods. We have been undertaking long term direct measurements of carbon dioxide fluxes, using eddy covariance techniques, in two contrasting urban environments - central London and a suburb of Swindon. These are compared with a proximal woodland site to isolate the effect of soil sealing and vegetation cover on carbon exchanges.

Key findings to date: Similarities in surface–atmosphere exchange of CO_2 are seen between suburban and woodland sites during summer, when photosynthesis and respiration determine the diurnal pattern of the CO_2 flux. In winter, emissions from human activities dominate urban and suburban fluxes; building emissions increase during cold weather, while traffic is a major component of CO_2 emissions all year round. Observed CO_2 fluxes reflect diurnal traffic patterns (busy throughout the day (urban); rush-hour peaks (suburban)) and vary between working days and non-working days, except at the woodland site. Suburban vegetation offsets some anthropogenic emissions, but 24-h CO_2 fluxes are usually positive even during summer. Annual CO_2 exchanges are significantly different between sites, demonstrating the impacts of increasing urban density/soil sealing (and decreasing vegetation fraction) on the CO_2 flux to the atmosphere.

Web: http://www.met.reading.ac.uk/micromet/
http://www.met.reading.ac.uk/users/users/1968

Soil & Climate

GROMIT: Ground source heat pumps

Reading Scientists: Anne Verhoef (a.verhoef@reading.ac.uk); Pier Luigi Vidale

Collaborators: Nottingham University, British Geological Survey, CEH-Wallingford, Earth Energy

Overview: Alternative low-carbon technologies such as Ground Coupled Heat Pumps (GCHPs) can help reduce anthropogenic CO_2 emissions. A research project (NE/F020368/1; 2009-2012) ran to assess the mitigation potential of horizontal GCHPs in the UK. Effects of environment dynamics and GCHP properties on GCHP performance were assessed using simulation models and a field experiment. Model investigations were conducted for a range of slinky loop spacings, loop diameters, and soil thermal properties. Heat transfer rate and installation costs for a horizontal slinky-loop HE were calculated. We also combined a land surface model with the horizontal GCHP model, to analyse UK multi-year dynamic GCHP-environment interactions (climate, soil type, slinky configuration).

Key findings to date: Model results indicated that GCHP technical parameters have a significant effect on the thermal performance of the system. The maximum difference in the thermal performance between vertical and horizontal slinky-loop heat exchangers with the same loop diameter and loop spacing is less than 5%. Heat pump performance does not remain constant, and will depend considerably on the installation depth and operating characteristics, as well as on the changing climatological conditions. For the field experiment, the slinky influenced the surrounding soil by significantly decreasing nearby soil temperatures. Also, soil moisture contents were lower for the soil profile in the vicinity of the GCHP, affecting soil thermal properties.

Key Papers:
Chong et al. (2013) *Applied Energy*, 104: 603-610
http://centaur.reading.ac.uk/31166/
Garcia-Gonzalez et al. (2012) *Renewable Energy*, 44: 141-153
http://centaur.reading.ac.uk/26597/
Wu et al. (2011) *International Journal of Low-Carbon Technology*. 6: 261-269
http://centaur.reading.ac.uk/23394/

Web: http://www.met.reading.ac.uk/~ass98av/Site/Home.html
https://www.reading.ac.uk/geographyandenvironmentalscience/About/Staff/a-verhoef.aspx

SWELTER-21: Interactions between heatwaves and soils

Reading Scientists: Pier Luigi Vidale (p.l.vidale@reading.ac.uk), Anne Verhoef (a.verhoef@reading.ac.uk)

Collaborators: CEH-Wallingford (Chris Taylor, lead), University of Leicester, UK Meteorological Office

Overview: The research project (SWELTER-21; Soil Water – Climate Feedbacks in Europe in the 21st Century, 2011-2015) was funded by the NERC "Changing Water Cycle" (CWC) programme. It focussed on processes that control the feedback between land surface and atmosphere, and their contribution to the reinforcement of persistent warm and dry anomalies. Tools used were state-of-the-art models, re-analyses and remote sensing data.

Intended outcomes: Initial stages of the UoR project focussed on improving the water balance of UK land surface model, JULES. Later analyses involved detailed model studies of the chain of mechanisms involved in the initiation of heatwaves, and factors that perpetuate them. Complex interactions between atmospheric and land surface variables (in particular soil moisture content) can explain most of the recent heatwave events over Europe.

Key Papers:
Van den Hoof et al (2013) *Agricultural and Forest Meteorology*, 181: 108–124
http://centaur.reading.ac.uk/34276/

Web: http://www.bgs.ac.uk/changingwatercycle/swelter21.html
http://www.met.reading.ac.uk/~vidale/

IMPETUS: Improving drought predictions for decision making

Reading Scientists: Len Shaffrey (lead), Rowan Sutton, Pier Luigi Vidale, Anne Verhoef (a.verhoef@reading.ac.uk), Hannah Cloke, Nigel Arnell, Ben Lloyd-Hughes, Liz Stephens

Collaborators: Oxford, Newcastle, and Southampton Universities; the Centre of Ecology and Hydrology; the British Geological Survey, as well as various private sector partners.

Overview: Droughts have severe impacts on societies, economies, agriculture and ecosystems. The 1975-76 UK drought had a devastating effect on the UK economy causing loss to agriculture, subsidence damage to buildings and a large cost to the water industry Forward planning is critical for managing the impacts of drought, since early warning enables stakeholders to curb demand and to effectively manage diminishing water resources. Improved forecasts on drought management (monthly to seasonal) and planning timescales (seasonal to decadal) would be exceptionally valuable for effective drought management and for minimising the negative impacts of droughts.

Intended outcomes: IMPETUS (2014-2018) is an interdisciplinary project that brings together scientists from the meteorological, land surface, surface water and groundwater communities and social scientists from the water demand and forecast usability communities. IMPETUS aims to improve the forecasting of UK drought on monthly to decadal timescales, which will lead to the development of improved decision-making processes. This will be achieved by improving meteorological, hydrological and water demand forecasts, and how they are combined to produce drought forecasts. This will be done with stakeholders to ensure that drought forecasts are relevant for decision-making.

Web: http://www.nerc.ac.uk/research/funded/programmes/droughts/droughts-shaffrey/

SINATRA: Susceptibility of flooding from intense rainfall

Reading Scientists: Hannah Cloke (h.l.cloke@reading.ac.uk), Anne Verhoef, Richard Allen, David Mason, Sarah Dance, Javier Garcia-Pintado, Adrian Champion, Anna Mueller

Collaborators: Newcastle University, University of Bristol, University of Exeter, King's College London, University of Hull, British Geological Survey (BGS)

Overview: Extreme rainfall events may only last for a few hours at most, but can generate terrifying and destructive floods. Their impact can be affected by a wide range factors (or processes) such as the location and intensity of the rainfall, the shape and steepness of the catchment it falls on, how much sediment is moved by the water and the vulnerability of the communities in the flood's path. Furthermore, Flooding from Intense Rainfall (FFIR) are by their nature rapid, making it very difficult for researchers to 'capture' measurements during events. The complexity, speed and lack of field measurements on FFIR make it difficult to create computer models to predict flooding and often we are uncertain as to their accuracy. In addition there is no consensus on how to identify how particular catchments may be vulnerable to FFIR, due to factors such as catchment area, shape, geology and soil type as well as land-use. Additionally, the catchments most susceptible to FFIR are often small and un-gauged.

Erosion and deposition derived from before and after LiDAR images from the Cockermouth floods

Project aims and intended outcomes:
(1) Increase our understanding of **what factors cause FFIR** and gathering new, high resolution measurements of FFIR by: assembling an archive of past FFIR events in Britain and their impacts, as a prerequisite for improving our ability to predict future occurrences of FFIR; making real time observations of flooding during flood events as well as post-event surveys and historical event reconstruction, using fieldwork and crowd-sourcing methods; and characterizing the physical drivers for UK summer flooding events by identifying the large-scale atmospheric conditions associated with FFIR events, and linking them to catchment type.

(2) Use this new understanding and data to **improve models of FFIR** so we can predict where they may happen nationwide by: employing an integrated catchment/urban scale modelling approach to FFIR at high spatial and temporal scales, modelling rapid catchment response to flash floods and their impacts in urban areas; scaling up to larger catchments by improving the representation of fast riverine and surface water flooding and hydromorphic change (including debris flow) in regional scale models of FFIR; improving the representation of FFIR in the JULES land surface model by integrating river routing and fast runoff processes, and performing assimilation of soil moisture and river discharge into the model run

(3) Use these new findings and predictions to provide the Environment Agency and other professionals with information and software they can use to **manage FFIR**, reducing their damage and impact to communities by: developing tools to enable prediction of future FFIR impacts to support the Flood Forecasting Centre in issuing new 'impacts-based' warnings about their occurrence; developing a FFIR analysis tool to assess risks associated with rare events in complex situations involving incomplete knowledge, analogous to those developed for safety assessment in radioactive waste management.

Web: http://www.met.reading.ac.uk/flooding/

http://www.reading.ac.uk/h-l-cloke.aspx

Remote sensing soil moisture for flood forecasting

Reading Scientists: David Mason (d.c.mason@reading.ac.uk), Javier Garcia-Pintado, Hannah Cloke, Sarah Dance

Collaborators: NERC Flooding from Intense Rainfall SINATRA consortium project, involving Reading, Newcastle, Bristol, Hull, King's College London and Exeter Universities, British Geological Survey, Met Office, Environment Agency.

Overview: One factor that affects the susceptibility of a catchment to flooding is its soil moisture condition prior to an extreme rainfall event. The improved representation of antecedent soil moisture conditions in a hydrologic model should improve its prediction of runoff. We are investigating whether the low spatial resolution of the remotely sensed soil moisture data used in many previous studies has been a factor limiting their success. A higher resolution sensor might allow soil moisture variations within a small catchment to be detected, allowing a hydrologic model to take into account the spatial heterogeneity of hydrological processes.

Key findings to date: So far we have evidence that a weak topographic signal can be seen in high resolution remotely sensed surface soil moisture data, which is probably a necessary condition for a hydrologic model to be able to account for spatial heterogeneity in hydrological processes. Future work will involve selecting a suitable distributed hydrologic model and assimilation system, linking these, and assimilating the soil moisture data into the model to test whether the model runoff prediction can be improved.

Key papers:

Mason et al. (2015) *International Journal of Applied Earth Observation and Geoinformation*
http://centaur.reading.ac.uk/39370/
Garcia-Pintado et al. (2015) *Journal of Hydrology*, 523: 706-724.
http://centaur.reading.ac.uk/39388/

Web: http://www.met.reading.ac.uk/flooding/
http://www.reading.ac.uk/ges/Aboutus/Staff/d-c-mason.aspx

GloFAS: Global flood forecasting

Reading Scientists: Liz Stephens (elisabeth.stephens@reading.ac.uk), Hannah Cloke, Rebecca Emerton

Collaborators: European Centre for Medium-Range Weather Forecasts; Red Cross Red Crescent Climate Centre.

Overview: Scientists at Reading are carrying out research to support probabilistic global scale flood forecasting systems and working with humanitarian organisations to help implement these systems within disaster preparedness activities.

Key findings to date: The operational forecasting system can now be accessed through a web portal at www.globalfloods.eu. Future work will involve assessment of the drivers of global flood predictability.

Web: http://www.globalfloods.eu/
https://www.reading.ac.uk/geographyandenvironmentalscience/About/Staff/elisabeth-stephens.aspx

Peatland habitats as sources and controls of greenhouse gases

Reading Scientists: Alex Boon (alex.boon@reading.ac.uk), Steve Robinson, Anne Verhoef

Collaborators: Bangor University (David Chadwick), Rothamsted Research (Laura Cardenas)

Overview
Northern peatlands are globally valuable carbon stocks that can act as either sinks or sources of greenhouse gases (GHGs); carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). This research examined the effect of 'controls' such as water-table depth, soil moisture, temperature and cattle grazing on both the subsurface production and surface emission of GHGs. We focused on the autumn flooding and spring re-wetting periods on a seasonally flooded field site on the Somerset Levels and Moors and supplemented the field data with laboratory analyses of important physical and chemical variables.

Key Findings

- Water-table depth was the strongest 'control' on surface GHG emissions and subsurface concentrations.
- CO_2 emissions increased as the water-table lowered from the surface until 35cm, wherein CO_2 emissions began to decrease once more.
- Subsurface CO_2 concentrations increased as the water-table moved toward the surface.
- Both CH_4 emissions and subsurface concentrations showed an exponential relationship with water-table depth; increasing dramatically as the soil entered a flooded condition.
- Cattle grazing increased emissions and subsurface concentrations of N_2O, particularly at times of changing water-table depth.
- Further research into improved methods for accurate subsurface GHG measurement in waterlogged peat soils is needed.

Peatland management and drinking water provision

Reading Scientists: Joanna Clark (j.m.clark@reading.ac.uk), Mike Bell, Anne Verhoef

Collaborators: Imperial College London (Jonny Ritson (lead), Nigel Graham, Mike Templeton), Bangor University (Chris Freemen), University of Exeter (Richard Brazier), South West Water (David Smith), Welsh Water (Naomi Willis)

Overview: Climate change threatens the stability of peat soils by altering the biogeochemical cycles which control plant decay, lowering water tables so that oxic degradation can occur and by altering dominant vegetation types. One of the major fluxes of carbon from peatlands is dissolved organic carbon (DOC) in surface waters. As peatland areas are often used as source waters for drinking water supply this presents a problem as DOC must be effectively removed to meet regulatory standards. This project aims to characterise the sensitivity of different catchment sources of DOC to climate change and thus the impact on drinking water treatment.

Key findings to date: Work so far has highlighted the importance of the vegetative source of DOC in controlling both the quantity of DOC flux and its chemical character. Laboratory studies of vegetation decomposition and DOC production have suggested the current encroachment of grassland species into peatlands will cause a large increase in DOC flux from the litter layer. Experiments with peat soils have provided further evidence for the 'enzymatic latch' mechanism, whereby oxygenation of peat stimulates organic matter decomposition as normally oxygen limited enzymes increase in activity.

Key papers:
Ritson et al. (2014a) Water Research, 67: 66-76.
http://centaur.reading.ac.uk/37703/
Ritson et al. (2014b) Science of the Total Environment, 473-474: 714-730
http://centaur.reading.ac.uk/35680/

Web: http://www.imperial.ac.uk/people/j.ritson12
http://www.reading.ac.uk/ges/aboutus/staff/j-m-clark.aspx

Influence of soil type and tree species on forest soil carbon sequestration

Reading Scientists: Antia Villada, Liz Shaw (e.j.shaw@reading.ac.uk), Anne Verhoef

Collaborators: Forest Research (Elena Vanguelova), Forest & Landscape Denmark-University of Copenhagen (Per Gundersen, Lars Vesterdal)

Overview : Northern temperate forests have been identified as major contributors to the terrestrial C sink. Among the different land uses, afforestation and reforestation have been recommended as practices to mitigate climate change by promoting C storage in both soils and biomass but the main factors affecting long-term C stabilization in soils remain uncertain. This research investigated how different soil types and tree species affect the C sequestration potential of forest soils with respect to soil C quality and how soil properties and the activities of key enzymes may influence soil carbon transformation processes in topsoil (A and E) and subsoil (B) horizons. Chemical (cold and hot water extraction, acid hydrolysis extraction) and physical (density and particle size) based fractionation methods for measurement of soil C pools were applied to 18 UK forest soil plots and Common Garden Experiments (CGEs) in Frederiskborg and Ulborg (Denmark) in order to test tree species and soil type impact on SOC stability.

Key findings to date:
UK experiments: soil type (hydromorphic, podzol, cambisol) was a prevailing factor affecting the amount of C associated to the intra-aggregate fraction in subsoil horizons. There was no effect of soil type for other C fractions but positive and highly significant correlations were found between some fractions and soil properties across sites (e.g. Alox and Feox and the amount of silt- and clay associated C) which may suggest that soil chemical and physical properties are better predictors of soil C stability than soil taxonomic units.
Danish CGEs: tree species (beech, oak, Douglas-fir, Norway spruce and Sitka spruce) and forest type (conifers and broadleaves) clearly and consistently affected labile C pools with greater labile C pools found beneath conifers when compared to broadleaf species at both Ulborg (podzol) and Frederiskborg (luvisol) sites. Tree species and forest type did not consistently effect more stabilized C pools (non-hydrolysable C and silt- and clay associated C).
Overall: The interaction between soil type/ properties and tree species appears to be critical in determining the quality and potential stability of SOC in temperate forest soils.

Web: http://www.reading.ac.uk/ges/aboutus/staff/e-j-shaw.aspx

Soil & The Past

Peatlands in the UK and Ireland: archives of environmental change and human activities

Reading Scientists: Nicholas Branch (n.p.branch@reading.ac.uk), Stuart Black, Philip Stastney, Daniel Young, Rob Batchelor

Collaborators: Historic England, Natural England, Surrey Wildlife Trust, Bord na Mona, Irish Heritage Council

Overview: The overall aim of the project is reconstruct environmental change in the UK and Ireland from the end of the last glacial maximum (c. 20,000-18,000 years ago) to the present day. During this time, there have been significant, sometimes rapid, changes in wetland ecosystems, especially the vegetation cover and hydrology. At times, however, it remains unclear whether these changes occurred as a response to climate change, natural succession or human activities. Our research is attempting to evaluate the relative impact of climate change and human activities on the environment, and to advise various agencies on the environmental and cultural significance of, and threat to, wetland ecosystems.

Key findings to date: Our research in the UK and Ireland has identified –

- Major hydrological and vegetation changes in peatlands during the last 5000 years
- These changes have been attributed to periods of short term climate change at approximately 4200, 2700 and 1000 years before present
- Against this background of climate change, there is overwhelming evidence for the impact of farming on the environment, including deforestation and burning
- The results have revealed that heathland ecosystems are strongly associated with human activities, and that the plant diversity has changed considerably over time
- The studies have also provided records of environmental change in SE England towards the end of the last glaciation and at the beginning of the present interglacial; these records are unique and provide a valuable insight into the timing and nature of climate change and vegetation succession
- The findings are currently being evaluated to advise agencies on the potential threat, and significance, of the peatlands with respect to future conservation and management

Web: http://www.reading.ac.uk/archaeology/research/Projects/arch-NB-INSTAR.aspx
https://www.reading.ac.uk/sages/about/staff/n-p-branch.aspx

Climate and ancient human environmental impact in Amazonia

Reading Scientists: Frank Mayle (f.mayle@reading.ac.uk), John Carson

Collaborators: Jose Iriarte (University of Exeter), Bronwen Whitney (Northumbria University), Heiko Prümers (Deutsches Archäologisches Institut, Bonn, Germany), Museo de Historia Natural, Santa Cruz, Bolivia.

Overview: The overall aim of this project is to investigate how the vegetation of Amazonia has changed over recent millennia. The Amazon contains 50% of the world intact tropical rainforest. It is a centre of exceptional species diversity, a large terrestrial carbon sink, a key component of the continental hydrological cycle and provides many other ecosystem services. This globally important ecosystem faces considerable challenges over the coming century as the impacts of deforestation and climate change are felt. In order to better predict the response of rainforest ecosystem's to these growing pressures, we can look for analogues in the past.

Key findings to date: Our reconstructions of past environments in north-east Bolivia using microfossil remains has demonstrated that:

- Forest-savannah boundaries in parts of the southern Amazon have shifted in response to periods of drier climate in recent millennial.
- Ancient pre-European human impacts in this region were locally significant, but did not extend to the kind of landscape-scale deforestation practiced today
- There is a long history of human occupation in parts of these forests. These people may have had a lasting influence on the species composition of the forest, the hydrology of the landscape and the nature of the soils.

Key papers:

Carson et al. (2014) Proceedings of the National Academy of Sciences, 11: E3833
http://centaur.reading.ac.uk/37533/

Web: http://blogs.reading.ac.uk/tprg/home/

Early agricultural food security and built environments in the Middle East

Reading Scientists: Wendy Matthews (w.matthews@reading.ac.uk), Roger Matthews, Rob Batchelor, Robin Bendrey, Dominik Fleitmann, Gundula Mueldner, Amy Richardson

Collaborators: British Institute of Persian Studies, Bu Ali Sina University Iran, Iran's Cultural Heritage, Handicrafts and Tourism Organisation, Iranian Centre for Archaeological Research, Iraqi Institute for the Conservation of Antiquities and Heritage, NERC Life Sciences Mass Spectrometry Facility, Sulaimaniyah and Erbil Directorates of Antiquities and Heritage Iraq, State Board of Antiquities and Heritage Iraq, Sulaimaniyah Museum Iraq, University of Oxford, University of Bristol, University of Tehran, University College London

Overview: We are investigating the origins of two major transformations that underpin current global ecological and socio-economic strategies: the development of agriculture and built environments. We are conducting new interdisciplinary archaeological investigations in the Central Zagros, Iraq and Iran. Here many current global food resources were domesticated and managed-including goat and barley, and experiments in built environments conducted *c.*12,000-8,200BP.

We examine resource management and built environments on a highland-lowland transect through this region. The aim is to analyse the nature and sustainability of early agriculture and sedentism in different environments to study the diversity of strategies and options at the outset of the origins of agriculture.

Key findings: Microsopic and geochemical analyses of the materials and sediments within the settlements are providing new high-resolution insights into ecology and built environment. We have established that:

- Food security was sustained by: penning animals within settlements with a diet of reeds, grasses and tree/shrub leaf fodder; consumption of locally available biodiverse resources including snails, small game and predominantly goat in the highlands and sheep, pig and cattle in lowlands; nuts, cereals and pulses.
- Energy sources were diverse including early use of dung fuel, grasses, reeds and some trees/shrubs, and used initially sustainably in communal ovens
- Built environments were well-maintained and organized, with experimentation in architecture for storage, residence, ritual and burial.

Web: http://www.czap.org
https://www.reading.ac.uk/archaeology/about/staff/w-matthews.aspx