Modelling soil erosion and soil carbon dynamics in agricultural systems

Marcelo Galdos (SEE), Pippa Chapman (SoG)

Contact email: m.galdos@leeds.ac.uk

Besides supporting food, feed, fuel and fibre production, soils provide ecosystems services such as storing carbon, filtering water and maintaining biodiversity. Fertile soil is being lost at the rate faster than it can recover, primarily from inadequate agricultural management practices and by climate change. Soil carbon (C) content, one of the main indicators of soil quality and resilience, has declined globally, and Bellamy et al. (2005) estimated mean annual soil carbon losses of 0.6% across England and Wales over the period 1978-2003. Climate change is expected to increase the incidence of highly erosive precipitation events in the UK, according to high resolution weather forecast models (Kendon et al., 2014)

Soil conservation practices are a key aspect of the climate-smart approach to global warming mitigation and adaptation, and include reduced soil disturbance; maintenance of permanent soil cover; and increased crop diversity through rotations and intercropping. Process-based models integrate soil, crop and climate information to evaluate the impact of management systems on soil erosion and soil carbon dynamics (Fleskens et al., 2016, Galdos et al., 2009). Although most biogeochemical models represent soil C dynamics and erosion separately, there is a need to integrate those processes, including feedbacks and interactions (Chappell et al. 2015, Lugato et al. 2016). The omission of soil C erosion in crop models can lead to overestimations of C losses by decomposition, and in the potential for soil C sequestration in agricultural soils at regional and global scales.

The purpose of this PhD project is to assess the impact of soil conservation practices on soil carbon dynamics and erosion in selected catchments in Yorkshire using process-based models and climate scenarios, interacting with researchers from the UK Met Office, ICAS/SEE and the School of Geography. Specific objectives include:

1. Assessing soil losses by erosion and soil C dynamics in agricultural land in the River Ouse catchment.
2. Evaluating the impact of conservation management practices on reducing erosion and increasing soil C sequestration in agricultural land.
3. Estimating the effect of climate change on erosion and soil C cycling, including increased temperatures and the higher incidence of extreme precipitation events.
4. Contributing to the inclusion of SOC erosion processes in the improvement of Earth System Models (ESM) at the global scale.

The geographical scope for the project will be the River Ouse catchment in North Yorkshire, covering approximately 4,847 km^2. 95% of this catchment is comprised of agricultural land, with nearly 55% of that classified as excellent to moderate quality productive land.

For future climate scenarios, the student will use UK Climate Projections 2018 (UKCP18), developed by the Met Office Hadley Centre Climate Programme, specifically downscaled climate projections (at the 2.2km scale) using the IPCC Representative Concentration Pathway (RCP) 8.5.

The student will parameterize, calibrate and evaluate process-based models using existing datasets from the selected case studies, and will collect additional soil, climate, land use and

land management data as needed. The main models used in this project will be JULES-Crop (Osborne et al. 2015), Roth-C (Jenkinson, 1990) and Apex (Gassmann et al. 2009).

Fit to NERC Science

This project is aligned to NERC's 'Terrestrial & freshwater environments' research subject. Specifically the project aligns to the following NERC research areas: (1) **Biogeochemical cycles** – by considering the fluxes and cycling of soil carbon within and between the biosphere and the physical environment; (2) **Ecosystem-scale processes and land use** – through the focus on catchment-scale assessments of erosion and soil carbon dynamics, and the impacts of agricultural land use patterns; (3) **Land - atmosphere interactions** – through quantification of carbon fluxes and transformations between the land and the atmosphere, and the variability of these interaction in time and space; and (4) **Soil science** – by modelling physical, chemical and biological properties and processes in soils at different scales. The project is also linked to NERC's 'Climate & climate change' research theme, with the use of climate change scenarios and the assessment of the impact of extreme climate events; and the 'Plant & crop science' research theme, by including process-based crop modelling.

Potential for high impact outcome

The project will enable relevant advancements to be made in understanding the connection between erosion processes and soil C dynamics in agricultural land. This research has potential applications in catchment management, helping identify sustainable agricultural practices that can reduce the environmental impact of food production while maintaining or increasing yields. It will also contribute to adaptation strategies for climate change in the region, by modelling the impact of future climate scenarios on erosion and carbon cycling processes. Finally, it can help improve the understanding of the global carbon cycle through potential applications of the research outcomes in the improvement of Earth System Models.

The project will produce several outputs, including (i) 3–4 academic publications, at least one of which we anticipate being suitable for submission to a high-impact journal and (ii) policy briefing notes to inform farmers and other stakeholders about the potential benefits of conservation management practices in both current and future climates.

Training

The student will work under the supervision of Dr Marcelo Galdos (www.see.leeds.ac.uk/people/m.galdos) and Professor Pippa Chapman (www.geog.leeds.ac.uk/people/p.chapman), within the Faculty of Environment, University of Leeds. The successful candidate will develop a range of research skills, including modelling, field sampling, chemical analysis, statistical analysis and data interpretation, academic writing skills and giving presentations. Training will be provided in field/laboratory health and safety procedures and the use of field and analytical equipment. In addition, the candidate will develop their understanding of (i) land management, climate and soil aspects related to estimating soil erosion, (ii) soil processes and fluxes related to the cycling and storage of carbon in the soil, and (iii) soil modelling.

The student will be supported throughout the studentship by a comprehensive PGR skills training programme that follows the VITAE Research Development Framework and focuses on knowledge and intellectual abilities; personal effectiveness; research governance and organisation; and engagement, influence and impact. Training needs will be assessed at the beginning of the project and at key stages throughout the project and the student will be

encouraged to participate in the numerous training and development course that are run within the NERC DTP and the University of Leeds to support PGR students, including statistics training (e.g. R, SPSS), academic writing skills, grant writing etc (www.emeskillstraining.leeds.ac.uk). Supervision will involve regular meetings between all supervisors and further support of a research support group. The student will also be part of water@leeds – a major interdisciplinary water research centre at the University of Leeds - where there are over 180 PhD students studying water-related topics. That network will broaden the student experience and enhance the network of contacts.

Student profile:

The student should have a keen interest in soil processes and environmental issues with a strong background in one or more of physical geography, earth sciences, soil science, environmental sciences or related discipline. Strong analytical/statistical/fieldwork skills are desirable but not essential, as full training will be provided during the PhD.

References

Bellamy, P. H., Loveland, P. J., Bradley, R. I., Lark, R. M. & Kirk, G. J. D. 2005. Carbon losses from all soils across England and Wales 1978-2003. Nature, 437: 245-248.

Fleskens, L., Kirkby, M.J. and Irvine, B.J. 2016. The PESERA-DESMICE Modeling Framework for Spatial Assessment of the Physical Impact and Economic Viability of Land Degradation Mitigation Technologies. Frontiers in Environmental Science, 4. 31.

Galdos, M.V., Cerri, C.C., Cerri, C.E.P., Paustian, K. & van Antwerpen, R. 2009. Simulation of Soil Carbon Dynamics under Sugarcane with the CENTURY Model. Soil Science Society of America Journal, 73, 802.

Gassman, P.W., Williams, J.R., Wang, X., Saleh, A., Osei, E., Hauck, L.M., Izaurralde, R.C. and Flowers, J. 2009. The Agricultural Policy Environmental EXtender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses. CARD Technical Reports. 41.

Jenkinson, D. S. 1990. The turnover of organic carbon and nitrogen in soil. Phil.Trans. R. Soc. 329: 361-368.

Kendon, E.J., Roberts, N.M., Fowler, H.J., Roberts, M.J., Chan, S.C., Senior, C.A. Heavier summer downpours with climate change revelaed by weather forecast resolution model. 2014. Nature Climate Change 4: 570-576.

Chappell, A., Baldock, B., Sanderman, J. 2015. The global significance of omitting soil erosion from soil organic carbon cycling schemes. Nature Climate Change 6:187-191.

Lugato, E., Paustian, K., Panagos, P., Jones, A. & Borrelli, P. 2016. Quantifying the erosion effect on current carbon budget of European agricultural soils at high spatial resolution. Glob Chang Biol, 22, 1976-84.

Osborne, T., Gornall, J., Hooker, J., Williams, K., Wiltshire, A., Betts, R., Wheeler, T. 2015. JULES-Crop: a parametrization of crops in the joint UK Land Environment Simulator. Geosci. Model. Dev., 8:113901155.