Institution: Cranfield University

Unit of Assessment: UoA 6

Title of case study: Improved national soil policies and local soil management based on geospatial data and modelling

Period when the underpinning research was undertaken: 2000–2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr Pat H Bellamy	Senior Research Fellow in Statistics	1993–2012
Dr Anil Graves	Senior Lecturer in Land Use Systems	2002–present
Dr Jacqueline A Hannam	Senior Research Fellow in Pedology	2004–present
Prof Jim A Harris	Professor of Environmental Technology	2002–present
Prof Guy JD Kirk	Professor of Soil Systems	2003–present
Prof Paul Leinster	Professor of Environmental Assessment	2015–2020
Prof Jane Rickson	Professor of Soil Erosion and Conservation	1985–present
Prof Joe Morris	Professor in Resource Economics and Management	1973 - 2010
Dr Rob W Simmons	Reader in Sustainable Soil Management	2008–present
Caroline Keay	Senior Information Scientist	1988- present

Period when the claimed impact occurred: 2013–2020

Is this case study continued from a case study submitted in 2014? Y/N No

1. Summary of the impact (indicative maximum 100 words)

Cranfield's work on large-scale soil and environmental data has driven policy debates on the protection of national soil resources, culminating in a Parliamentary inquiry into soil health and inclusion of soil protection measures in Defra's 25 Year Environment Plan which underpins the new Agriculture Act and Environment Bill.

Research into spatial soil data and information systems has saved the Welsh Government an estimated £100 million, and 10 to 20 years of resources.

The impact of the geospatial data research on sustainable use of natural resources in the UK and worldwide was recognised by the award of the Queen's Anniversary Prize in 2017.

2. Underpinning research (indicative maximum 500 words)

Cranfield has been at the forefront of the debate on the state and protection of the national soil resources for more than 40 years. The research is strongly interdisciplinary, combining understanding of the goods and services provided by soils; the physics, chemistry, and biology of soil processes; geo-spatial statistics and modelling; life-cycle assessment; and the socioeconomics of land use and management. We have quantified national, regional, and sub-regional scale changes in soil resources in response to decadal changes in land management

and environmental conditions. We have linked these changes to underlying causes and demonstrated the consequences for delivery of national goods and services. Examples of the research are as follows.

The National Soil Inventory (NSI) data for England and Wales is held by Cranfield. It was first sampled in 1978 to 1983 and re-sampled up to 20 years later. Our research showed losses of carbon from all soils across England and Wales between the samplings of the NSI [R1]: the first national-scale evidence, anywhere in the world, for an anticipated feedback loop between climate change and soil carbon emissions. This is a globally unique example of soil system change at national scale, in response to multiple stressors, clearly shown by monitoring. It is still widely cited (756 citations in WoS [18/09/20]).

Research led to the development of methods to quantify the economic value of soil resources, linked to geospatial soil information, and understanding of soil-derived goods and services [R2]. We have shown that the annual costs of soil degradation in the UK – such as by loss of carbon and erosion – exceed £1.2 billion at 2010 prices [R2]. This includes both on-site impacts on soil fertility and crop production, and off-site costs of carbon emissions and water treatment. Linked to this, we have devised methods for quantifying acceptable rates of soil erosion based on rates of soil formation versus erosion by known erosion types and used these to quantify tolerable and actual rates of erosion across Europe [R3]. This showed that rates of erosion in parts of the UK exceed tolerable levels by several fold. The work led to evidence-based recommendations to correct soil degradation from the bottom up, based on local priority areas for soil protection that are finer than the scales of administrative districts or landscapes [R4]. Working with farmers, we demonstrated that erosion control measures can significantly reduce field soil losses by 53% to 72% compared with previous practice [R5]. We have developed land information systems providing soil and land quality data at such scales – for example, for RoI and Wales – using digital soil mapping techniques [R6].

3. References to the research (indicative maximum of six references)

[R1] Bellamy PH, Loveland PJ, Bradley RI, Lark RM & Kirk GJD (2005) Carbon losses from all soils across England and Wales 1978–2003. *Nature* **437,** 245–248. https://doi.org/10.1038/nature04038

[R2] Graves AR, Morris J, Deeks LK, Rickson RJ, Kibblewhite MG, Harris JA, Farewell TS & Truckell I (2015) The total costs of soil degradation in England and Wales. *Ecological Economics* **119,** 399–413. https://doi.org/10.1016/j.ecolecon.2015.07.026

[R3] Verheijen FGA, Jones RJA, Rickson RJ & Smith CJ (2009) Tolerable versus actual soil erosion rates in Europe. *Earth-Science Reviews* **94,** 23–38. https://doi.org/10.1016/j.earscirev.2009.02.003

[R4] Kibblewhite MG, Bellamy PH, Brewer TR, Graves AR, Dawson CA, Rickson RJ, Truckell I & Stuart J (2014) An exploration of spatial risk assessment for soil protection: Estimating risk and establishing priority areas for soil protection. *Science of the Total Environment* **473-474,** 692-701. https://doi.org/10.1016/j.scitotenv.2013.12.086

[R5] Niziolomski, J. C., Simmons, R. W., Rickson, R. J. and Hann, M. J. (2020) 'Efficacy of mulch and tillage options to reduce runoff and soil loss from asparagus interrows', Catena, 191, p. 104557. https://doi.org/10.1016/j.catena.2020.104557

[R6] Hallett SH, Sakrabani R, Keay CA & Hannam JA (2017) Developments in land information systems: examples demonstrating land resource management capabilities and options. Soil Use & Management 33, 514–529. https://doi.org/10.1111/sum.12380

4. Details of the impact (indicative maximum 750 words)

An estimated 94% of all food supplies rely on healthy soils. Soils store huge amounts of carbon, protect communities from flooding and drought, and are the root of many industry supply chains, for fibres, fodders, and biofuels.

Much of Cranfield's soils research is done in close collaboration with government agencies and departments (Defra, Environment Agency, Natural England, and Welsh Government), industry (agricultural and horticultural production, food processing, and retail) and civil society (Agriculture Horticulture Development Board (AHDB), National Farmers Union (NFU), Waste Resources Action Programme (WRAP), Linking Environment And Farming (LEAF)). This ensures research has clear routes to impact.

1) *Influencing national soil policy and debate*

Our research on long-term changes in national soil resources has stimulated public and policy debate, including providing evidence for international negotiations within the EU Soil Framework Directive in 2014 and ongoing since shaping the Soil Strategy for England in 2011 [S1]. Our evaluation of the total economic costs of soil degradation at GBP1,200,000,000 a year was cited in the National Audit Office's briefing on environmental protection to the House of Commons Environmental Audit Committee [S2]. Combined with research by other groups we collaborate with, this culminated in the Environmental Audit Committee's Soil Health Inquiry in 2016, whose report [S3] specifically cites our research in the text (and in the footnote), including the losses of soil carbon since 1978 found in the National Soil Inventory [R1], the economic costs of soil degradation [R2] and assessments of contaminated land. Following the Inquiry, our work continued to inform the implementation of the 25 Year Environment Plan and the development of a 'Healthy Soils' indicator framework [S1]. This is also demonstrated in a 2018 letter from George Eustice, then Minister of State for Agriculture, Fisheries and Food [S4], and mentioned in a 2018 House of Commons speech by Eustice [S5]. In addition, Cranfield staff are on the scientific panel of the Sustainable Soils Alliance (Rickson), advising Defra on the design and implementation of the new Environmental Land Management scheme (ELMS) [S6] and the Natural Capital Committees (Leinster), advising government on the sustainable use of natural capital [S7a&b].

2) *Tools for regional-scale land assessment*

Our research on spatial soil data and information systems [R6] has been crucial in the establishment of the freely available Predictive Agricultural Land Classification map for the Welsh Government (launched in 2017). This predictive map allows unprecedented land assessment at 50m resolution – a scale readily adopted by land managers and planners – and identifies for the first-time subclasses for land classification, allowing it to be linked to land quality assessment required in planning policy. For the Welsh Government [S8] and local planning authorities, this has been a real game-changer, increasing the credibility and early consideration of agricultural land quality in national and local planning policy. Using the predictive mapping approach, instead of obtaining the data through a detailed national field survey, has saved the Welsh Government an estimated GBP100,000,000 and 10 to 20 years of resources [S8]. It is one of the most downloaded datasets offered by the Welsh Government (>16,000 downloads since 2018), reducing manual calculations by the Welsh Government from 2000 sites per year to zero.

3) *Local impact on sustainable farm practices*

We have worked with government agencies and farmers to develop field-scale advisory tools based on the national soil data, publicly available through Landis (www.landis.org.uk). For example, soil-erosion prediction models developed at Cranfield to predict vulnerability to erosion have been used by Natural England and the EA to identify risk and make land use recommendations. National soil data has also been used by land managers to avoid soil compaction, only accessing the land during suitable 'workability' windows, determined by soil

properties and weather conditions. AHDB's unique, on-line Soil Management Information System (SMIS), developed by Cranfield, draws together soils and agronomic data, which is interrogated to provide evidence-based information on soil management to farmers and advisors[S9]. In areas vulnerable to soil degradation, national soil maps (at 1:50k and 1:25k) are used to design in-field soil protection practices [R6]. For example, the dimensions of hydraulic structures for controlling excessive runoff and soil erosion (grass waterways) are based on soil properties, which determine the maximum permissible flow velocities of non-eroding channel. This approach has been used by farmers in conjunction with Cranfield staff to design and implement >18 km of grassed waterways, >65 km of vegetated buffer strips and >850 ha of reoriented field layouts in the UK. Before these measures were adopted, farmers were fined for breaches of the Water Framework Directive. John Chinn, owner of Cobrey Farms (>1,500 ha) [S10] states,

> *"What we and others have seen, is what a difference the advice from Cranfield is making*".

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1] Letter from Head of Evidence, Soils and Peatlands, Landscapes, Peatlands and Soils Team, Natural Environment, Trees & Landscapes Directorate, DEFRA

[S2] Reference to Cranfield's Defra sponsored project on the total costs of soil degradation **P26, 2.29.**
https://www.nao.org.uk/wp-content/uploads/2014/06/Environmental-Protection-briefing.pdf

[S3] Written [Hannam] and oral [Harris] evidence to Environmental Audit Committee's Soil Health Inquiry (2016). **P5, 22, 24, 30, 41, 42 & 43:**
https://publications.parliament.uk/pa/cm201617/cmselect/cmenvaud/180/180.pdf

[S4] Letter from Minister of State for Agriculture, Fisheries and Food, June 2018.

[S5] Mention in House of Commons speech by Minster for Agriculture, **P.232,Column 246** (https://hansard.parliament.uk/Commons/2018-10-10/debates/2827A5E3-DF64-49EE-8CF9-60F44889E5B9/AgricultureBill?highlight=cranfield#contribution-3E2FBD34-C581-4581-AECD-C12674A0C1FD]

[S6] Sustainable Soils Alliance (SSA) science panel member [Rickson] https://sustainablesoils.org/science-panel and (R2) was presented [Morris] at the SSA Parliamentary debate: The Economics of Soil: Private Asset or Public Good? attended by Rt Hon Elizabeth Truss MP, Chief Secretary to the Treasury; Rt Hon Greg Clark, Secretary of State for BEIS; Emma Howard Boyd, Chair of the Environment Agency; Dr Toby Willison, Environment Agency; Sue Pritchard, Food Farming & Countryside Commission. Portcullis House, Westminster, March 2019
https://sustainablesoils.org/the-economics-of-soil

[S7a&b] (a) Cranfield's work on the extent and costs of soil degradation (R2), and cost effectiveness of soil conservation measures is cited in the Natural Capital Committee's Advice on Soil Management (May 2019): **P3, P4.**
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/909069/ncc-advice-soil-management.pdf
(b) Membership of Natural Capital Committee [Prof P Leinster, Cranfield University]
https://www.gov.uk/government/groups/natural-capital-committee

[S8] Letter from Policy Lead, Soil Policy & Agricultural Land Use Planning Unit, Department for Environment, Energy & Rural Affairs. Welsh Government.

[S9]	Testimonial from Head of AHDB's crop nutrition, soil and growing media teams. See also: https://ahdb.org.uk/knowledge-library/smis-data-driven-soil-coalition
[S10]	Testimonial from Cobrey Farms - economic benefit and reduction in erosion incidents following soil management advice from Cranfield University https://www.youtube.com/watch?v=0Z6bKH_o1N0&t=2s **(@ 25:00 mins).**