Institution: 10007822

Unit of Assessment: 6

Title of case study: Improved Soil Management Planning through Enhanced Spatial Information

1. Summary of the impact

Cranfield's research on improved soil management planning through enhanced spatial information has influenced policy development, allowed the adoption of new approaches to soil mapping, and enhanced the management of strategically important land assets. The research has provided key input to policy development nationally, within the European Union and across the globe. It has developed new technologies which have been used to survey soils at the scale of complete countries, saving significant cost and survey time compared to conventional methods. Cranfield's modelling has also supported the management of strategic land assets such as military training areas, and soil-related geohazards related to road networks and other linear infrastructure at the regional and national levels.

2. Underpinning research

Historically, spatial information on soils could only be collected by expensive ground-based surveys. This relied on experienced surveyors' knowledge of soil-landscape relationships creating paper maps and associated monographs. By the mid-1990s, Mayr and others at Cranfield and other centres concluded that inference engines, combined with emerging geographic information systems (GIS) and increasing access to remote-sensed and other environmental data could be used to support predictive modelling of soil properties, classes and functions [1].

The outputs of this research were spatial databases of soil properties with quantitative estimates of soil function and, critically, the associated uncertainty. The research group at Cranfield, established under the leadership of Mayr, with Corstanje, Hannam and others, developed and further expanded these insights [2,3].

A particular research contribution of this group in the late 1990s was the insight that high fidelity soil landscape models could only be achieved if the form and density of predictions were varied for and matched to different landscape categories (strata) [3]. An important output from this work has been the development of meaningful strata for categorisation of soil-landscapes ('soilscapes').

Mayr and colleagues implemented this new understanding through the application of Bayesian rule-based methods in a sequence of exercises starting with small scale trials, moving on to larger prototype exercises and, most recently, through the completion of a new digital soil map for a complete country. In collaboration with the British Geological Survey, Macaulay Land Use Research Institute (now the James Hutton Institute) and CEH, these methods have been used to successfully predict soil types for 50 m^2 pixels in two contrasting English landscapes [4]. In 2006, Cranfield and Teagasc (Ireland) formed a partnership to deliver a new soil map and an operational spatial database of soil properties for the whole of the Republic of Ireland. Cranfield developed the predictive modelling (Mayr, Hannam and Corstanje) with Teagasc conducting field surveys and providing data. The approach built strongly on previous projects, with rigorous comparison of inference models based on field observations. Predictions were made and validated for large areas that had not been mapped or had been mapped inconsistently.

Building on this capability, Cranfield (represented by Mayr), the European Commission JRC and Cranfield Visiting Professor Alex McBratney, achieved a significant theoretical advancement [5], '*digital soil assessment*', in which the Cranfield contribution is a set of models that are used to map soil multi-functionality based on the now exhaustive and robust databases of predicted soil information. Mayr then led a full-scale prototype exercise with the completion of a soil properties and functions database for 10,000 km^2 of central England, demonstrating the feasibility of generating continuous spatial datasets for soil properties in areas with sparse field measurements. This was developed further by Mayr, in collaboration with the Macaulay Institute and the Centre for Ecology and Hydrology to predict soil hydrological and other functions, as well as soil properties for two river catchments [6].

Key staff	Post	Dates	Research
Dr Thomas Mayr	Principal Research Fellow, Head of NSRI	1992–present	Digital mapping of soil properties and functions, crop modelling, precision farming.
Dr Ronald Corstanje	Senior Lecturer	2008–present	Geostatistics, scaling and scale behaviour, digital mapping of soil properties and functions, modelling soil functions and ecosystem goods and services.
Dr Jacqueline Littler (Hannam)	Senior Research Fellow	2004–present	Pedology, soil magnetics, digital soil mapping.

3. References to the research

1. Mayr, T. and Palmer, B. (2007) Digital Soil Mapping: An England and Wales perspective. In: Lagacherie, P., McBratney, A., and Voltz, M. (Eds): Digital soil mapping – an introductory perspective. *Developments in Soil Science*, Volume 31. Elsevier, Oxford
2. Cavazzi, S., Corstanje R., Mayr T., Hannam J. and Fealy R. (2013). Are fine resolution digital elevation models always the best choice in digital soil mapping? *Geoderma*, 195–196: 111-121. doi: 10.1016/j.geoderma.2012.11.020
3. Taalab, K.P., Corstanje, R., Creamer, R. and Whelan, M.J. (2013) Modelling soil bulk density at the landscape scale and its contributions to C stock uncertainty. *Biogeosciences,* 4691-4704. doi: 10.5194/bg-10-4691-2013.
4. Mayr, T.R., Palmer, R., Lawley, R. and Fletcher, P. (2001) New methods of soil mapping. SR0120 Final report to the Department for the Environment, Food and Rural Affairs (DEFRA). http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=8966.
5. Carré F., McBratney A., Mayr T. and Montanarella L. (2007) Digital soil assessments: Beyond DSM, *Geoderma*, 142 69-79. doi: 10.1016/j.geoderma.2007.08.015
6. Mayr, T.R., Palmer, R.C. and Cooke, H.J. (2008) Digital soil mapping using legacy data in the Eden valley, UK. In: Hartemink, A.E., McBratney, A., Mendonça-Santos, M.L. (Eds), Digital soil mapping with limited data. Springer

4. Details of the impact

Cranfield’s research on improved soil management planning through enhanced spatial information has informed policy development related to soils at national, European and international levels, allowing nations to adopt new approaches for the soil mapping of their land mass, and more effective management of strategically important land assets.

Policy Development

Cranfield’s research on soil assessment is supporting decision makers at the European and global levels, and has been widely recognised. At the European scale, it has been described as “*a major step towards a better understanding of the soils of Europe and their diversity, thus fostering and strengthening the commitment of the European Union to protect and preserve our soil”* by Janez Potocnik, Commissioner for Science and Research (EC 2005) and Stavros Dimas, Commissioner for Environment (EC 2005) [1].

Cranfield’s work on the soil atlas of Africa has also been described by Maire Geoghegan-Quinn as *“raising public awareness on the importance and the key role of soil in Africa as a non-renewable resource essential to human existence. In doing so, it supports the development of protective measures to safeguard soils for future generations”* and by Professor José Graziano da Silva, Director-General of the UN FAO as “*perfectly supporting the ideals of the FAO-led ‘Global Soil Partnership’”.* [2]

In carrying out underpinning research for such initiatives, Cranfield has applied its landscape models to pilot areas in SE England, Central Europe, Hungary and Morocco. Such technologies have now been adopted by the European Union, Global Earth Observation System of Systems (GEOSS) and FAO [3] for global soil terrain assessment, and are currently being applied in high resolution mapping of soil properties in Africa.

Cranfield's research on digital soil assessment has also informed policy for Defra and the Scottish Executive Environment and Rural Affairs Department (SEERAD), where this functional based approach to soil has demonstrated that it can be used to assist decision-making for a particular catchment level [4]. This method, developed further with the Macaulay Institute [5], now forms the basis of the current Scottish Soil Framework [6].

National Soil Surveys

Cranfield has developed and assisted in the implementation of the Irish National Soil Survey Scheme. This is based on our soil-landscape modelling framework. It has created a new soil map and spatial database of soil properties for the whole of the Republic of Ireland. This has benefited the Irish Environmental Protection Agency by providing high quality soils data for the whole of the Country, saving approximately €50 million and has allowed delivery within five years compared to 25 years by conventional methods [7].

Management of Strategically Important Land Assets

Cranfield's multi-functional soil landscape modelling has been used by the UK Ministry of Defence to predict soil physical conditions, in particular soil moisture, on a daily basis. Combining soil landscape modelling with real-time soil moisture monitoring has allowed Defence Estates to improve the usage of military training grounds covering more than 300 km^2, whilst ensuring that ecological and soil integrity is maintained in these areas.

The Infrastructure Transactions Research Consortium (ITRC), Infrastructure UK (IUK), Defra and Infrastructure Operators in the UK, have also used a similar digital soil assessment approach based on Cranfield's work to determine the vulnerability of infrastructure to soil geohazards (e.g. erosion, subsidence, shrink / swell) under current conditions and future climate scenarios. In this work a probabilistic soil model was superimposed on the critical infrastructure network of the UK at 25x25 km grid resolution, and in specific case studies at 5x5 km grid resolution [8]. In a parallel project a similar probabilistic soil landscape model was used by Lincolnshire County Council to determine soil-related geohazards to roadways and other linear infrastructure to prioritise roads at risk from environmental conditions.

5. Sources to corroborate the impact

1. Soil Atlas of Europe, European Soil Bureau Network European Commission, 2005, 128 pp. Office for Official Publications of the European Communities, L-2995 Luxembourg.
2. Soil Atlas of Africa, European Soil Bureau Network European Commission, 2013, 176 pp. Office for Official Publications of the European Communities, L-2995 Luxembourg.
3. Towards global soil information: activities within the geo task global soil data. Workshop Report, FAO Headquarters, 20-23 March 2012, Rome. http://www.fao.org/fileadmin/templates/GSP/downloads/GSP_SoilInformation_WorkshopReport.pdf
4. Mayr, T., Black, H., Towers, W., Palmer, R. Cooke, H., Freeman, M., Wood, C., Wright, S.,Lilly, A., Jones, M., DeGroote, J., and Hornung, M. (2006) Novel methods for spatial prediction of soil functions within landscapes. Final Report to the Department for the Environment, Food and Rural Affairs (DEFRA) and the Scottish Executive Environment and Rural Affairs Department (SEERAD) http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=11504
5. Towers, W., Bradley R.I., Mayr, T., Feeney, I. & Bruneau P.M.C. (2008). Nature conservation value of soils: bringing functionality into practice. SNH commissioned research report 281. http://www.snh.org.uk/pdfs/publications/commissioned_reports/Report%20No228.pdf
6. Scottish Soil Framework: http://www.scotland.gov.uk/Publications/2009/05/20145602/13
7. Irish Soil Information System, Teagasc. http://www.teagasc.ie/environment/soil/

8. Defra. 2013. The National Adaptation Programme: Making the country resilient to a changing climate. July 2013. The Stationery Office, London.; www.itrc.org.uk