

Soil Security

1.1. Overview

The world's soils are critical to the well being of human societies because they deliver many ecosystem services that sustain life. Soils act as a medium for plant growth, a filter for water, and a major global sink of carbon, and are home to a vast diversity of organisms that drive the biogeochemical processes on which the functioning of the Earth depends. Despite their importance to mankind, our understanding of what regulates the ability of soils to perform these multiple functions in different contexts, and at different spatial scales, ranging from the soil profile to the Earth system scale, is severely limited, as is our knowledge of the controls over the ability of different soils to adapt and respond to land use and climate change. This represents a serious gap in knowledge given the rapid rate at which soils are being degraded worldwide and the urgent need to inform policy makers and land managers on the sustainable management of soils. **The high level goal of this TAP is to redress this gap in knowledge, by providing fundamental understanding of the factors that regulate the ability of soils to perform multiple functions, and its ability to adapt and respond to land use and climate change.** Ultimately, the scientific advances resulting from this TAP will underpin future decision making on the sustainable management of the world's soils. The proposed investment is a cross-theme action supported by the SUNR (£3m), BIO (£2m) and ESS (£0.5m) themes, with potential contributions from BBSRC, Defra, and other international funders.

1.2. Rationale

The soil system provides many essential ecosystem services that are crucial to food security, climate mitigation, and water cycling, and changes in the way we manage the land surface have resulted in widespread degradation of soils and their ability to deliver ecosystem services. For example, it has been estimated that currently 45% of European soils exhibit very low OM contents (0-2% organic C)¹ and degraded soils cover 15-17% of the world's land surface². There is an urgent need, therefore, for improved understanding of the factors that control: (1) how soils perform multiple functions and deliver a range of ecosystem services; and (2) their ability to resist and recover from global change, and hence continue to perform critical soil functions. Soils are highly complex; a range of physical, chemical, and biological factors interact to regulate their functioning, and their ability to resist and recover from perturbations, such as drought³. Moreover, these controls on soil functioning, and their response to perturbations, are likely to vary across different spatial and temporal scales⁴, and across different soil conditions and land types; in other words they are highly scale and context dependent. As an example, significant advances have been made in understanding the role of plant-soil interactions in driving processes of carbon and nitrogen cycling at local scales and in specific contexts, but very little is known

¹ Jones et al. 2012. State of Soil in Europe. JRC Reference Report 80pp.

² Staring Centrum Instituut voor Onderzoek van het Landelijk Gebied., Oldeman, L. R., United Nations Environment Programme. & International Soil Reference and Information Centre. (UNEP ;ISRIC., Nairobi, Kenya,Wageningen, Netherlands, 1991).

³ De Vries, et al. (2012). Land use alters the resistance and resilience of soil food webs to drought. *Nature Climate Change*, 2, 276-280..

⁴ Ettema, C. and D. A. Wardle. 2002. Spatial soil ecology. *Trends in Ecology and Evolution*, 17, 177-183.

about their role in driving these processes at the landscape and Earth system scale, and how these roles vary in different contexts⁵. A key challenge of this TAP, therefore, is to deliver, for the first time, a truly integrated, and multi-disciplinary understanding of the physical, chemical, and biological controls on soil functioning, and the relative importance of these factors for soil functioning at different spatial and temporal scales, and in different contexts. The TAP will focus on multiple soil functions, including nutrient and carbon cycling, soil stability, and water filtration, and, ultimately, knowledge gained will be used to inform future decisions on the future sustainable management of soils.

1.3. Objectives

The overarching goal of this TAP is to advance conceptual and mechanistic understanding of the factors that regulate the ability of soils to perform multiple functions in different contexts, and their ability to adapt and respond to perturbations, such as those caused by changes in land use and extreme weather events associated with climate change. Specifically, the TAP includes two, strongly linked scientific goals, namely to gain an integrated and predictive understanding of controls on:

- (1) The ability of soils to perform multiple functions in different contexts and at different scales, ranging from the field, to the landscape, and Earth system scale;
- (2) The ability of soils and their functions to resist, recover and ultimately adapt, to perturbations, such as those caused by land use change and extreme climatic events.

1.3. Approach

To achieve these goals there is a need for a new, multi-disciplinary approach to the study of soil, whereby soil physicists, chemists and biologists, work together to develop a more holistic understanding of soil. Moreover, it requires a multi-scale approach, whereby local, field scale understanding of soil functioning is linked to predictive models of soil functions, such as carbon and nutrient dynamics, at the landscape and, potentially, the Earth system scale. It also requires the use of novel tools for characterizing and quantifying the dynamics of soil functions at different spatial scales, including molecular tools for studying taxonomic and functional diversity of soil organism, high temporal resolution measurements of carbon and nutrient fluxes via sensors and stable isotopes, improved soil gas sampling, and in situ visualization of soil structures, roots and soil organisms, to improve understanding of soil functions and their response to perturbations across a hierarchy of scales and contexts. The TAP will require a combination of experimental manipulations, at the field and laboratory scale, established along relevant environmental gradients of management, soil conditions, and climates, combined with modeling in order to fully interrogate of soil functions and their controls at different scales and contexts.

1.4. Delivery

The TAP may take the form of consortia, which bring together scientists from a range of disciplines, including the plant, soil, microbial and modeling communities, to tackle the

⁵ Bardgett, R.D. and Wardle, D.A. (2010) Aboveground-Belowground Linkages: Biotic Interactions, Ecosystem Processes, and Global Change. Oxford University Press.

above listed scientific goals. Research will use selected, well characterized sites positioned along environmental gradients of management, soil conditions, and climate. We are exploring mutual interests with NSF, where joint funding could extend a portion of the funding for a joint UK-US study that uses broader environmental gradients delivered via their Critical Zone Observatory (CZO) sites in the USA. As mentioned, the delivery of the TAP will require the bringing together of scientists from different disciplines, which normally work in isolation, relevant to the study of soil. While these skills are already available in the UK to deliver the programme, there is an opportunity for the TAP to train a new generation of scientists who have the skills and knowledge needed to take a more multi-disciplinary approach to the study of soil, embracing new techniques and approaches from the physical, chemical and biological sciences. This will also ensure a legacy of this TAP, in that, through training of PhD and postdoctoral scientists, it will deliver a new generation of soil scientists with the ability to adopt new and innovative approaches to the future study of soil.

Partnership: There is much potential for the proposed action to form a joint research programme with BBSRC and Defra because complimentary science is evident in relation to the RCUK Global Food Security (GFS) programme and BBSRC's strategic priority in soil science and agri-system approaches. A joint a partnership in this area would ensure the relevant science disciplines are brought together to deliver the strategic science challenge(s) identified above and ensure that knowledge gained from the TAP would ultimately inform policy. We are also exploring the possibility of joint funding from NSF.

Impact: The potential global impact of this action is tremendous given the current scientific and political interest in managing soils sustainably for food security, water quality, and climate mitigation. The proposed action is timely because advancing our understanding of the soil system is a high priority for both LWEC and GFS, and the proposed EU Soil Framework Directive (COM(2012)46) remains "on the Council's table."⁶ The Soil Security research programme will deliver improved forecasts of the response of the soil system to changes in climate, vegetation or management at scales of analysis that match the scale of decision-making. Understanding this response will help guide institutional, economic and behavioral responses to the management of disruptive change. The impact of the TAP will be extended through links to existing programmes, such as NERC's Macronutrient Cycles programme, which includes study of N₂O emissions from agricultural soils, and through NERC's link to BBSRC's programme on rhizosphere processes (which NERC contributes to), and Defra's emerging programme on sustainable management of soils. Other initiatives that findings from the TAP will inform include the Global Soil Partnership (GSP); the FAO Soil Biodiversity Initiative; and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Recent global research infrastructure, primarily in Europe, US and China⁷ provide an experimental framework that could add value to the proposed investment.

Links to existing programmes: The proposed programme is distinct; there are no comparable research programmes worldwide that take such an integrated, science-driven approach to the study of soil and its function. Soils feature as a component of other NERC programmes, such as the Macronutrients, BESS, Tropical Forest, and Arctic TAP's, and there are potential links to these programmes through making available well-characterized study sites. However, there are no comparable programmes where there is an explicit focus on advancing understanding of the functioning of soil.

⁶ [Soil - Environment - European Commission](#)

⁷ e.g. NEON (National Ecological Observatory Network) Economist Aug 25th 2012 p64; Critical Zone Observatories see Banwart 2011 Save our Soils. Nature 474: 151-2.

Proposed spend profile: A 5-year, £5.5M investment from NERC is proposed to support the goals of this action. Additional support from potential partners is also being sought. The delivery of the TAP, and its two inter-related objectives, relies heavily on an integrated programme of research, which brings together scientists from various disciplines.