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# The future of soils and land use in the UK: Soil systems for the provision of land-based ecosystem services☆

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A B S T R A C T

Historically, soils have always underpinned civilisation. Their role is fundamental to the provision of food and water, along with a wide range of ecosystem goods and services. Soils are arguably the most complex systems on Earth, and are intimately linked to human security and the integrity of the wider environment. In this paper we propose 18 ecosystem services that are critical for soils and land use in the UK. Soils are extremely heterogeneous and not all soils can fulfil the full spectrum of services required for the future of the UK, so there is a need to protect their multifunctional attributes in order to preserve national and international natural capital. There are concerns that anthropogenically induced changes in land use or management will result in soils not being utilised to provide the functions to which they are best suited. For example, soils primarily suited for food supply may be given over to provide a platform for construction. This is an all-pervading and recurring concern and highlights the importance of critical decisions, thresholds and potential 'tipping points'. Once critical soil functions are lost they are irrecoverable, potentially for millennia, representing a loss of resource that is fundamental to the UK's national livelihood and well-being. Pressures from changes in climate and to the Earth system will bring about complex and systematic change to soils and their abilities to provide essential functions. We therefore recommend national needs for ensuring the sustainability for soils and future land use in the UK. They are to maintain the long-term base for soil science through education and intellectual investment, including communication of the value of soils and land as natural capital; to manage soil resources so that multifunctionality prevails and critical tipping points are avoided; to audit the national soil resource through soil mapping; preparation of appropriate databases and provision of long-term monitoring networks and observatories; and to synthesise adaptable predictive frameworks for soil system science through integrated modelling.



## Introduction

Soils underpin our civilisation, providing a veneer to our Earth system and a common rendezvous-point for our activities. The global imperative for food, fibre and fuel production makes a myriad of benefits and problems manifest, and they all involve soils. Despite the link between the quality of the soil resource and the rise and fall of world civilisations that has been repeated throughout history, a recent international workshop concluded that soil remains an undervalued and underappreciated resource (National Research Council, 2009). In this paper we aim to provide a background to the nature and properties of soils, their history in the UK context, and how they underpin land use. More broadly, the paper will explain how soil systems underpin the delivery of a wide range of ecosystem goods and services and examine critical issues such as anthropogenic and climate pressures and the concepts of thresholds or tipping points. An understanding of these principles is fundamental to the effective analysis of present and future land use and to future management strategies for the UK landmass. The paper will conclude by identifying future threats to key soil functions and prescribing a number of national 'needs' to help protect these.

## Soil systems: a primer

Soils are arguably the most complex systems on Earth (Ritz, 2008), and are intimately linked to climate change, human security and the biodiversity and integrity of the wider environment

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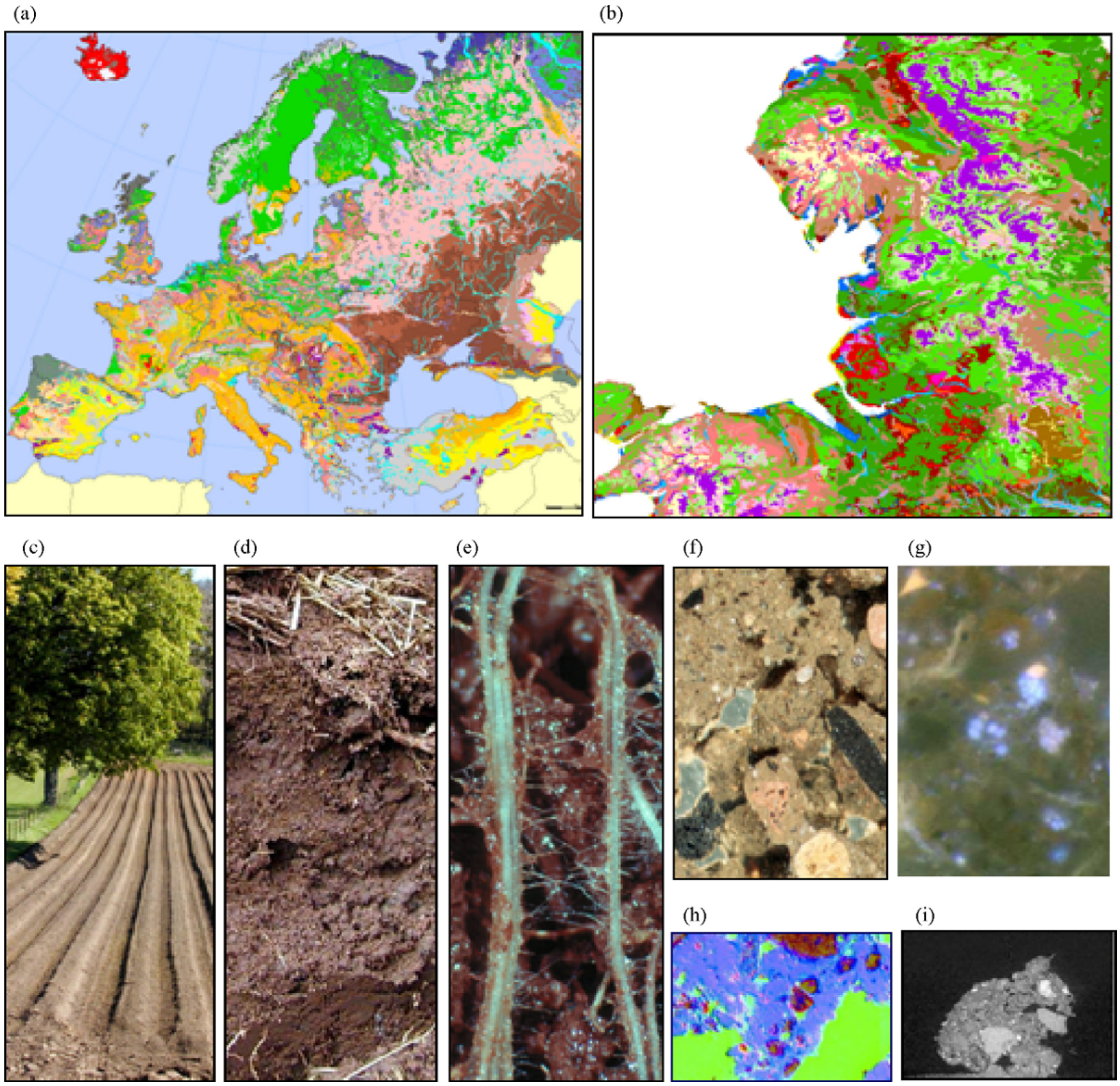


**Fig. 1.** Soil structure across nine orders of spatial magnitude. (a) Soil map of Europe; map width c. 3000 km. (b) Soil map of part of Wales, UK; map width c. 150 km. (c) Field-scale view of potato field and adjacent pasture; view width (front) c. 5 m. (d) Surface view of arable soil; image width c. 15 cm. (e) Magnified view of roots and bridging fungal hyphae in grassland soil; image width c. 15 mm. (f) Polished surface view of resin-impregnated block of undisturbed arable soil; image width c. 500 μm. (g) Bacterial cells in thin section of soil; image width c. 20 μm. (h) Thin section of mineral soil viewed with transmitted light, false colour; image width c. 10 μm. (i) X-ray computed tomographic image slice of soil aggregate; image width c. 3 mm, digital resolution = 4.4 μm. Sources: (a) Joint Research Centre, Ispra; (b) National Soil Resources Institute, Cranfield University; (c–i) Karl Ritz.

(Bardgett et al., 2005; Chapin et al., 2009; McNeill and Winiwarter, 2004). They show remarkable spatial heterogeneity across many orders of magnitude of scale (Fig. 1), and encompass biological, chemical and physical dynamics over timescales which range from seconds to millennia. Soils are essentially porous media that form a thin layer across the surface of the majority of the terrestrial landmass, and are comprised of a wide variety of solid, semi-solid, liquid and gaseous constituents (Brady and Weil, 2002). But such a clinical description belies the fact that soils are dynamic, reactive and remarkable entities teeming with a huge variety of life. They can be viewed as the 'biological engine of the Earth', driving many key processes that underpin the majority of soil functions.

The solid phases of soils are classed as inorganic ('mineral') or organic (containing carbon). The organic phase is made up of non-living or living matter (biota). The mineral phases of soils are fundamentally derived from the underlying geology, unless they have been modified by mineral supplements added by humans. The development of soils from such parent material is termed pedogenesis (Jenny, 2009). In some cases the upper layers are derived from other sources and are not connected directly to the bedrock in this manner but deposited superficially, for example as a result of glacial action.

Soils are produced by gradual processes of biogeochemical transformation including 'weathering', a range of erosive chemical, physical and biological mechanisms that produces a variably sized population of mineral particles. The small (nanometre), medium and large (millimetre) components are classified as the clay, silt and sand fractions. These mineral constituents eventually combine with organic components, predominantly originating from green plants, to form relatively thin 'topsoils'. Subsoil material, which occurs in the strata below, generally contains less organic material, and eventually connects to the bedrock. The variety of mineral components in soils can be very large, contingent on their associated geology and origin. They constitute a solid phase that not only