SoilBioHedge: harnessing hedgerow soil biodiversity for restoration of arable soil quality and resilience to climatic extremes and land use changes

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Only 30% of Earth's surface is land, only 9% is cultivated, and there is little scope for future expansion. The supply of water and nutrients from soil to crops in approximately 7800 km3 of topsoil (to 0.5 m) currently sustains 7 billion humans. This soil resource is the essential foundation of arable farming on which plant production for food, fibre and biofuels, and ultimately the entire global economy depends. How we manage this vital, life sustaining, resource will determine the quality of life and Earth's carrying capacity for future generations. SoilBioHedge addresses the central problem for soil security: continuous conventional arable cultivation depletes soil organic matter, degrades soil structure, reduces water drainage and water holding capacity, and increases the susceptibility of soil and crops to the impacts of climatic stress through decreased resilience to flood and drought conditions. We will test our central hypothesis: grass-clover leys sown into arable fields and connected to hedgerows and unploughed grassy margins enable key ecosystem-engineers (earthworms and mycorrhizal fungi) to recolonize the fields, restoring and improving soil quality compared to leys unconnected to field margins. We will determine for the first time the importance of connectivity from biodiversity refugia under hedgerows to arable fields via grass-clover leys in restoring functional biodiversity. We will quantify soil quality as functional benefits from soil-organism interactions: increases in soil organic matter, water-stable macroaggregates, water holding capacity, infiltration rates, drought and flood resilience, and resulting crop yields. We will quantify the operational temporal and spatial scales for ecosystem engineers (grass-clover roots, AM fungi, and earthworms) and soil functions to synergistically develop with land use and management change. We will transform mechanistic understanding of soil structure dynamics by combined metabolomics and metagenomic analyses tracking soil aggregate formation over 3 growing seasons. Our research design includes three nested scales of observation. 1) Hedge-to-Field Experiments at Leeds U. farm to quantify spatial/temporal changes in soil functions and biodiversity, arising from arable-to-ley conversion strips that are disconnected or connected to the field margin, and across a whole field converted to arable in 2012, and ley-to-arable conversion using conventional vs. minimal tillage strips and a field that converted to ley in 2009. Monolith mesocosm studies will use turf blocks removed from the experimental plots, treated with herbicide and direct drilled with wheat. We will compare crop yields between the field and monoliths maintained at near-ambient conditions, under simulated drought and excess rainfall causing flooding. The results will quantify soil quality and the resilience of the crop and soil organisms and functions to these stresses. 2) Landscape-Scale Hedge-to-Field Transects will quantify soil functional changes on long-term arable fields and pairs of arable fields converted to ley over 2 differing time scales. We will utilize our network of >100 farms that provide a range of soil types, and management (conventional, organic, and minimal tillage). 3) Field-to-Landscape Scale mathematical modelling to establish an integrative and predictive spatiotemporal model of soil quality change at field-to-landscape-scale, including the role of dispersal of hedgerow and field margin biodiversity into arable land resulting from land use

and management change involving leys. We will integrate mechanistic understanding of soil aggregation and carbon accumulation through the synergistic actions of roots, AM, and earthworms from our experiments and landscape-scale transect observations with existing Countryside Survey data and national digital soil map, to deliver a step-change in understanding for sustainable soil management policy and practice.