# The resilience of soil to biological and physical stresses

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The key to soil sustainability is an ability to resist and recover from the stresses imposed by man and nature. Measures of the stability of soil have therefore received considerable research interest, but measures of resilience are only just emerging. Little is known consequently about the soil properties that contribute to resilience or the influence of antecedent soil conditions on physical and biological responses to stress. A joint project between SCRI and Rothamsted Research has developed novel methods for assessing the biological and physical resilience of soils, which have allowed us to start to unravel the complex processes involved in the recovery of soils from stress.

There have been several stages to this research: (1) development of simple laboratory based resilience assays, (2) application to a wide range of Scottish soils, (3) controlled field experiments where the soil has been exposed to different physical stresses and (4) laboratory studies to investigate the role of different soil properties. Our biological stability and resilience indices examine shifts in the ability of soil organisms to decompose carbon. They are measured from the time-dependent effects of either (i) a transient stress (heating to 40 ºC for 18 hr) or (ii) a persistent stress (amendment with copper sulphate ($CuSO_4$)), on carbon decomposition of added plant residues. Our physical stability and resilience measures are: (i) compression and expansion indices of the soils to assess potential compaction impacts; and (ii) resistance of the pore structure to overburden stresses under prolonged wetting and structural regeneration through cycles of wetting and drying. By measuring both biological and physical resilience, we are able to investigate how soil organisms influence and stabilise the physical habitat in which they live.

A study of Scottish soils examined 26 different locations from the Central Belt to Shetland (Fig. 1). A wide range of biological and physical resilience responses were observed. Decomposition of plant residues following heat or copper stress after one month of recovery ranged from 23% to >100% that of the unperturbed soil. The air-filled pore space after the overburden stress ranged from 70% to >100% of the unperturbed soil. We were hoping that this survey of many soils would help us elucidate the major properties of soil that confer stability and resilience. The only trend observed was from the influence of carbon, which was related to the resilience to copper stress and both physical measures. The stability and resilience of these soils to compaction are illustrated in Fig. 2. Greater carbon has a negative impact on stability to compression and although carbon also increases resilience, very little recovery occurs following this stress. The persistence of soil compaction is often observed in arable soils.

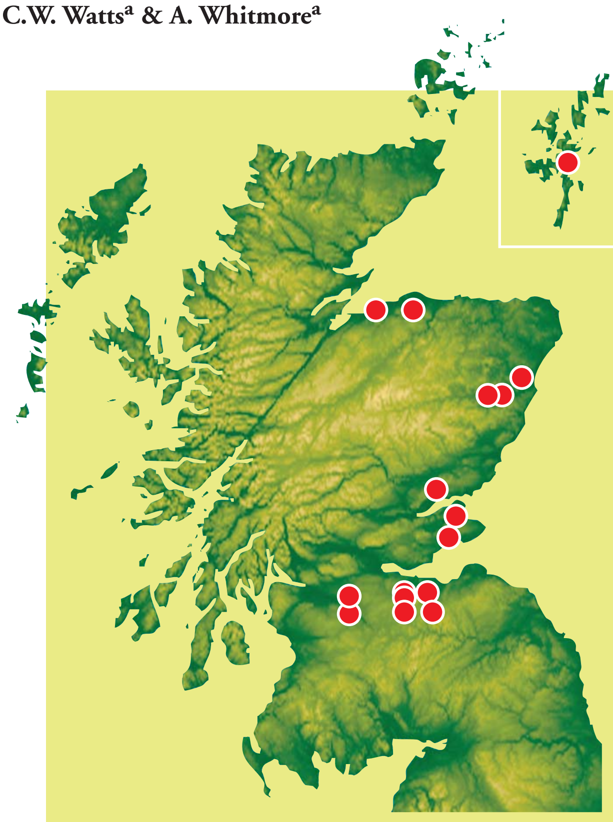

**Figure 1** Soil was sampled from 26 sites across Scotland on soils ranging from wind-blown sands (Aeolian) to upland peats.

This survey of Scottish soils included serpentine, aeolian sand, peat and arable mineral soils, so the inherent properties varied markedly. A more controlled field experiment, discussed in the preceding article by Wheatley R.E. *et al.*, investigated the impact of physical disturbance of one soil type through different forms of soil cultivation on biological resilience. Soils under minimum and zero tillage were less stable to the transient heat stress compared to ploughed, deep ploughed and ploughed-compacted soils, but recovered rapidly

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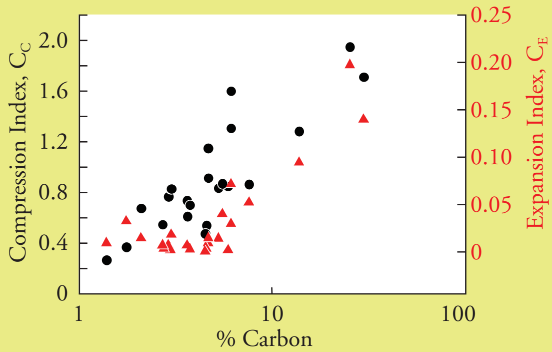


**Figure 2** Soil compresses and recovers more as the carbon content increases. The compression and expansion indices, $C_C$ and $C_E$ respectively, are related to the amount of pore space lost for a given level of compaction stress.

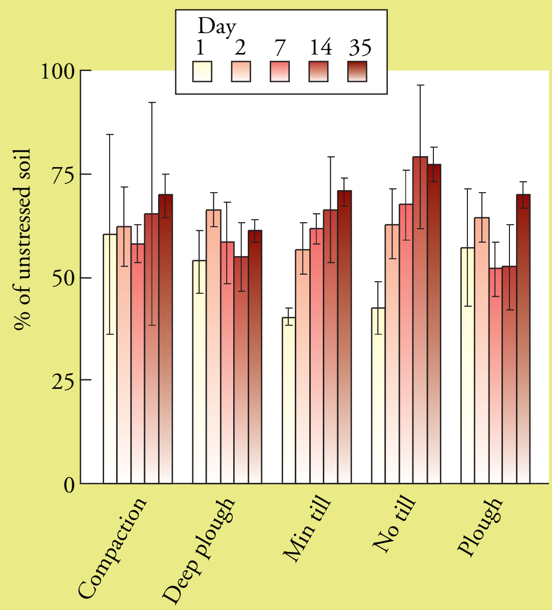


**Figure 3** Reducing physical disturbance by using minimum or zero tillage resulted in soil less stable but far more resilient to heat stress. The days since the stress was applied are indicated by the different coloured bars.

to much higher levels (Fig. 3). Less clear trends were found for the persistent copper stress, although the most physically disturbed deep ploughed and ploughed-compacted soils continued to degrade with time, whereas the other soils stayed static or showed signs of recovery. This study suggests benefits to biological resilience by reducing physical disturbance through cultivation. We are beginning to investigate if changes to the microbial community or soil physical structure are driving these changes. An on-going study of the stability and resilience of Rothamsted Research's long-term experimental plots, some dating back to 1843, will give greater evidence of the role of soil management.

By manipulating soil properties in the laboratory, we have isolated some of the dominant properties of soil that control its stability and resilience to stress. An experiment where the microbial communities were 'swapped' between two physically different soils showed the large impact of the pore space and particle surface area on the microbial community that develops and its subsequent stability and resilience to stresses. The physical condition of the soil when a stress is applied is also extremely important. Water potential and the habitable pore space for microbes have a major impact.

Our stability and resilience assays have provided useful indicators of soil quality. Massive differences in soil resilience were found across Scotland, which could not have been predicted using data available in existing soil surveys. Current changes in soil cultivation practices towards reduced tillage may help improve the resilience of our arable soils. It does appear that improving the physical stability and resilience of soil has positive implications to biological processes.