

Putting soil health on the agenda

With the SQUARE project, TEAGASC, UCD, UL and IT Sligo are identifying indicators of soil health in Ireland.

A precious resource

Soil is a precious resource that supports essential functions, including: food, feed and fibre production; nutrient cycling; carbon sequestration and climate regulation; water purification; and, as a habitat for biodiversity. The sustainable management of agricultural soils is critical for achieving the growth targets set out in Food Wise 2025, and for protecting soil resources (post 2020 EU-CAP). Grass-based animal production systems rely heavily on soil quality to deliver profitable and sustainable production. But what is soil quality or soil health?

Soil quality has been described as the soil's ability to provide ecosystem services through its capacity to perform the functions mentioned above under changing management and climatic conditions (Toth *et al.*, 2007). Recently this term has been replaced by 'soil health', which really focuses more on the soil biological community as a key driver of soil functionality. In light of this, monitoring of soil health is required to better manage and protect our agricultural soils and their viability for future generations.

SQUARE

The Soil Quality Assessment and Research (SQUARE) project, funded by the Department of Agriculture, Food and the Marine (DAFM) from 2014 to 2018, was a collaboration between Teagasc, University College Dublin, the University of Limerick, and IT Sligo. Within SQUARE, an initial assessment of soil quality for 180 grassland farms in Ireland was completed.

The sites were geographically distributed across the five major agro-climatic regions of Ireland and classified into two soil drainage classes according to the Irish Soil Information System. SQUARE identified a selection of suitable indicators for assessing soil quality and health.

A key challenge for SQUARE was to identify soil health indicators that could sufficiently account for differences in: (i) intrinsic soil characteristics; (ii) spatial/climatic conditions; and, (iii) grassland management type and intensity. In addition to soil survey and pedological description, each farmer completed a detailed questionnaire in order to collect soil and grassland management information.

Selecting suitable soil health indicators

Not all soil attributes are suitable indicators of soil health. However, certain soil properties play a major role in maintaining soil health, making them suitable indicators. A final matrix of key indicators of soil functionality was compiled for Irish grassland soils, including their ability to inform the delivery/supply of at least two out of five soil functions. Three classes of indicators (physical, chemical, and biological) were identified to provide holistic assessment of soil health (Table 1) (Bünemann *et al.*, 2018).

What soil quality indicators are important for grassland soils?

Of the physical indicators identified, structure was considered a key factor that supports all soil functions. The decline in soil structural quality, which leads to soil degradation and compaction, is often the consequence of more intensive management practices. The chemical indicators provide much information in relation to nutrient cycling, primary production and carbon sequestration functions in soils. In particular, soil pH and soil organic matter were identified as key factors, which regulate nutrient availability in soil, and were considered highly relevant in the delivery of all the different soil functions, including carbon sequestration and macro/micronutrient cycling. The biological indicators provide the greatest information on the delivery/supply of all soil functions. This indicates that soil biodiversity and the soil microbiome is at the centre of soil functioning. However, some biological indicators were more difficult to measure and were impractical for soil health assessments.

Are Irish grassland soils healthy?

Overall, the health status of Irish grassland soils is relatively good; however, we identified potential weaknesses under certain soils by weather or management situations where soil health may be negatively impacted. Our assessment of physical, chemical and biological indicators of soil health across grassland soils identified differences in the delivery of soil functions according to soil type, climatic region and grassland management system (i.e., grazing vs silage). While all soils have the capacity to deliver all functions, some soils were better at delivering particular functions compared to others. We found that well-drained soils were more resilient in terms of soil compaction and had high capacity to support the primary production function once balanced nutrition was supplied. However, these soils presented higher risk in terms of water purification and

Table 1: Soil health key indicators selection. Indicator categorisation matrix and evaluation of their explanatory power for each soil function.

Key indicators	1. Type		2. Suitability of indicator across different scales			3. Feasibility of indicator measurement			4. Relevance to delivery of soil functions*				
	Static	Dynamic	Soil pedon/ biota	Field	Landscape	Logistic	Extrapolation potential	Sensitivity	PP	WP	CS	BIO	NC
Physical indicators													
Soil texture	√		√				√	√	High	Low	High	Low	Low
Soil structure		√	√	√	√	√	√	√	High	High	High	High	High
Bulk density		√	√	√			√	√	High	High	Low	Low	Low
Hydraulic conductivity		√		√	√	√	√	√	High	High	Low	Low	Low
Chemical indicators													
pH		√	√	√		√	√	√	High	High	High	High	High
Macro/micronutrients		√	√	√		√	√	√	High	Low	High	Low	High
Soil organic matter		√	√	√		√	√	√	High	Low	High	High	High
Soil carbon fractions		√	√	√			√	√	High	Low	High	High	High
Biological indicators													
Earthworm abundance		√	√					√	Low	Low	High	High	High
Microbial biomass		√	√	√		√	√	√	High	High	High	High	High
Rooting type, depth and abundance		√	√	√		√	√	√	High	High	High	High	High
Botanical composition		√		√	√	√	√	√	High	High	High	High	High
Bacterial and fungal communities	√		√					√	Low	Low	High	High	High
Enzyme activity		√	√				√	√	Low	Low	High	High	High

*Soil functions: PP = primary productivity; WP = water purification; CS = carbon sequestration; BIO = biodiversity; NC = nutrient cycling.

climate regulation. In contrast, poorly drained soils were more prone to structural compaction and less resilient for production, especially with high trafficking intensity. On the other hand, these soils have high capacity to sequester carbon, to provide a habitat for an active microbiome under low to moderate management intensity.

What next?

Thus far the results of the SQUARE project have led to the production of on-farm tools for a first quick assessment of soil health (Bondi *et al.*, 2018; Emmet-Booth *et al.*, 2018). These tools can now be used by farmers and practitioners to check the health status of their land. In addition, we need a long-term soil quality monitoring network to detect changes in soil health over time, and further research to find practical management solutions for its protection. This knowledge can be integrated with knowledge transfer services to provide advice to farmers and farm advisors. We have made a start but we have a long way to go!

Acknowledgements

Funding from the DAFM, farmers for providing access to field sites across Ireland. We acknowledge Lillian O’Sullivan, Teagasc, Johnstown Castle, for GIS analysis for site selection, and the Teagasc laboratory and field staff.

References

Bondi, G., *et al.* (2018). ‘Using machine learning to predict soil bulk density on the basis of visual parameters: Tools for in-field and post-field evaluation.’ *Geoderma*, 318: 137-147.
 Bünemann, E.K., *et al.* (2018). ‘Soil quality – a critical review.’ *Soil Biology and Biochemistry*, 120: 105-125.

Emmet-Booth, J.P., *et al.* (2018). ‘Grass VESS: a modification of the visual evaluation of soil structure method for grasslands.’ *Soil Use and Management*, 34.1: 37-47.

Tóth, G., Stolbovoy, V. and Montanarella, L. (2007). ‘Soil quality and sustainability evaluation – an integrated approach to support soil-related policies of the European Union.’ EUR 22721 EN. 40 pp. Office for Official Publications of the European Communities, Luxembourg ISBN 978-92-79-05250-7.

Authors

Giulia Bondi
 Research Officer – Soil, Teagasc Crops, Environment and Land Use Programme, Johnstown Castle, Co. Wexford

Owen Fenton
 Principal Research Officer, Teagasc Crops, Environment and Land Use Programme, Johnstown Castle, Co. Wexford

Karen Daly
 Senior Research Officer, Teagasc Crops, Environment and Land Use Programme, Johnstown Castle, Co. Wexford

David Wall
 Senior Research Officer, Teagasc Crops, Environment and Land Use Programme, Johnstown Castle, Co. Wexford
 Correspondence: David.wall@teagasc.ie

