A soil health index based on organic carbon to clay ratio

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Healthy soils can be defined as those whose functions are duly and efficiently discharged.

But how do we measure soil health?

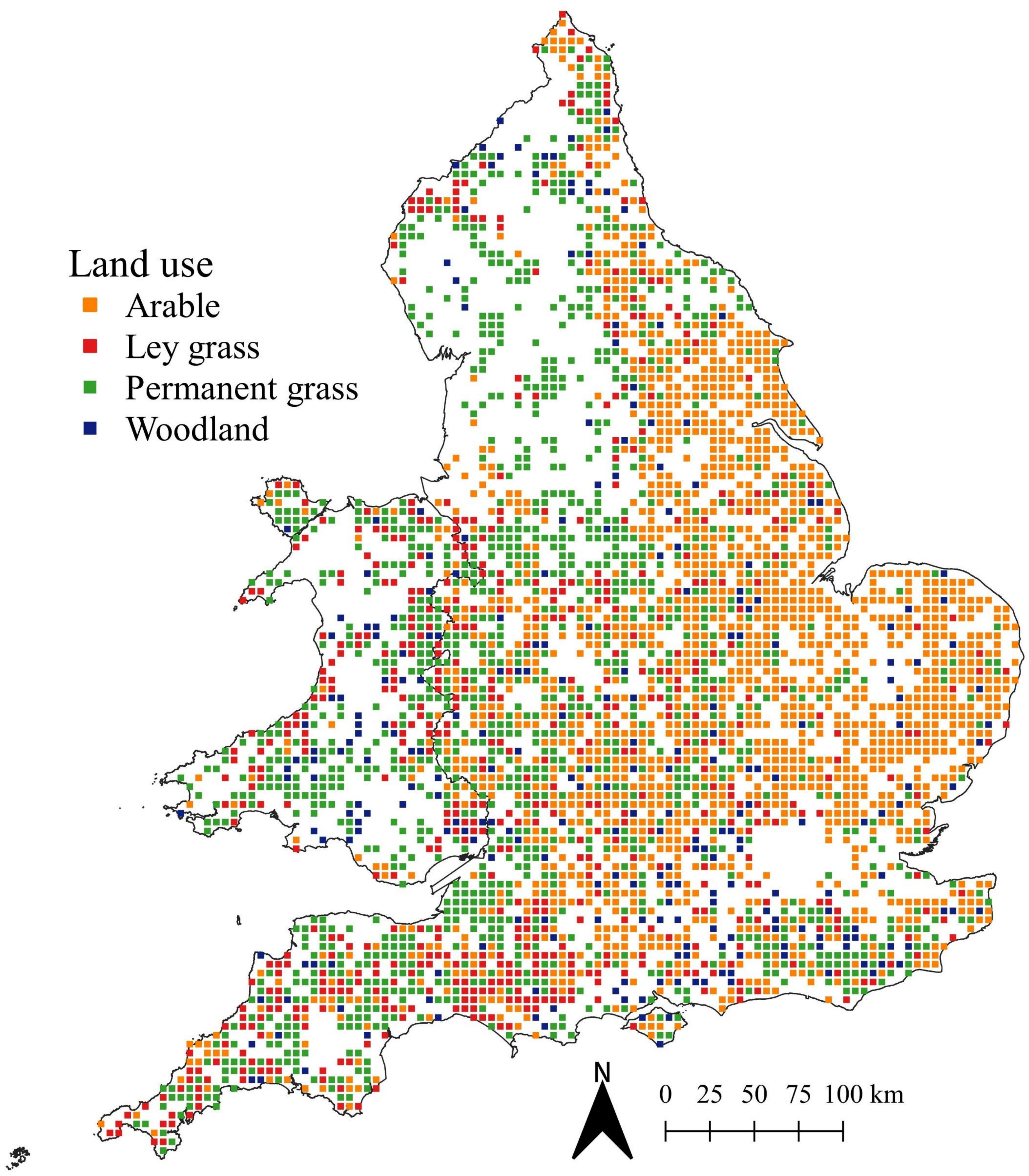
Soil organic carbon (SOC) influences a range of soil properties making it a central indicator of soil functions and therefore health. For example, SOC is closely related to soil structure, and a good soil structure is a basis for well functioning soils.

SOC/clay ratio has been proposed as an indicator linking SOC and soil structure.

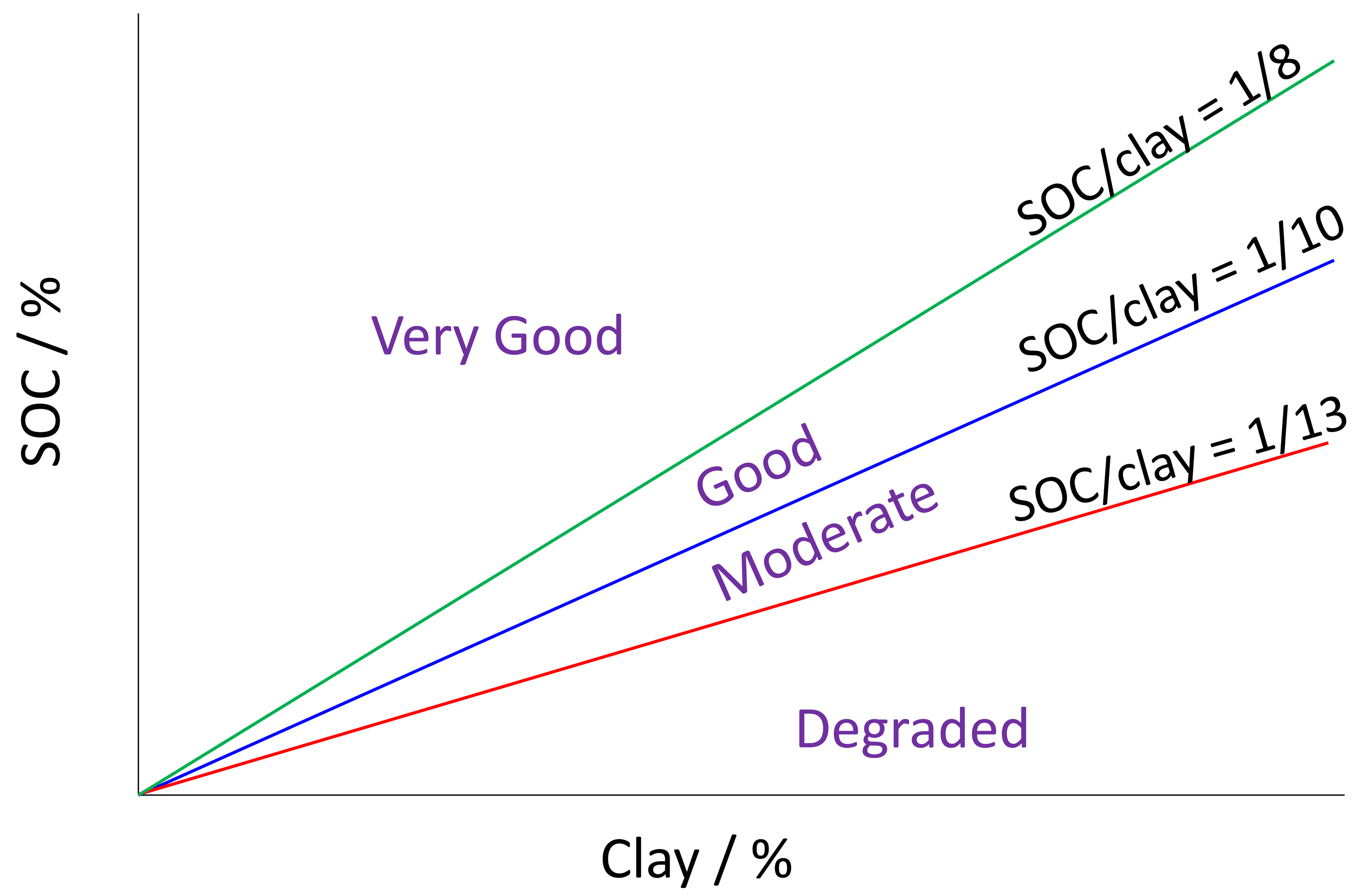
According to Dexter *et al.* (2008) a SOC/clay ratio of 1/10 is an approximate limit for SOC with clay particles (proposed using Polish and French soil datasets and tested on Danish soils (de Jonge *et al.*, 2009; Schjonning *et al.*, 2012) and also in England (Jensen *et al.*, 2019)).

SOC/clay ratios of 1/8, 1/10, and 1/13 indicate thresholds of structural condition (better with higher SOC/clay ratio), according to Johannes *et al.* (2017) who worked on Swiss soils.

We tested these thresholds using a subset of the National Soil Inventory of England and Wales (NSI):
5 x 5 km grid, topsoil (0-15 cm) samples.
This included 3809 samples selected under arable, ley grass, permanent grass, and woodland.



Prout *et al.* (2020) (submitted)



Aims:
1. To assess the variation in SOC/clay ratio and its drivers across the NSI dataset.
2. To test its ability to delineate soils of different structural quality.
3. To develop a single index for gauging SOC levels under different land managements and environmental conditions, based on SOC/clay ratios.

References

de Jonge, L.W., Moldrup, P. & Schjønning, P. (2009). Soil infrastructure, interfaces & translocation processes in inner space ("Soil-it-is"): Towards a road map for the constraints and crossroads of soil architecture and biophysical processes. *Hydrology and Earth System Sciences*, *13*, 1485–1502. DOI:10.5194/hess-13-1485-2009

Dexter, A. R., Richard, G., Arrouays, D., Czyz, E. A., Jolivet, C., & Duval, O. (2008). Complexed organic matter controls soil physical properties. *Geoderma*, *144*(3–4), 620–627. DOI:10.1016/j.geoderma.2008.01.022

Jensen, J. L., Schjønning, P., Watts, C. W., Christensen, B. T., Peltre, C., & Munkholm, L. J. (2019). Relating soil C and organic matter fractions to soil structural stability. *Geoderma*, *337*, 834–843. DOI:10.1016/j.geoderma.2018.10.034

Johannes, A., Matter, A., Schulin, R., Weisskopf, P., Baveye, P. C., & Boivin, P. (2017). Optimal organic carbon values for soil structure quality of arable soils. Does clay content matter? *Geoderma*, *302*, 111. DOI:10.1016/j.geoderma.2017.04.021

Schjønning, P., de Jonge, L.W., Munkholm, L. J., Moldrup, P., Christensen, B. T., & Olesen, J. E. (2012). Clay dispersibility and soil friability-testing the soil clay-to-carbon saturation concept. *Vadose Zone Journal*, *11*(1). DOI:10.2136/vzj2011.0067

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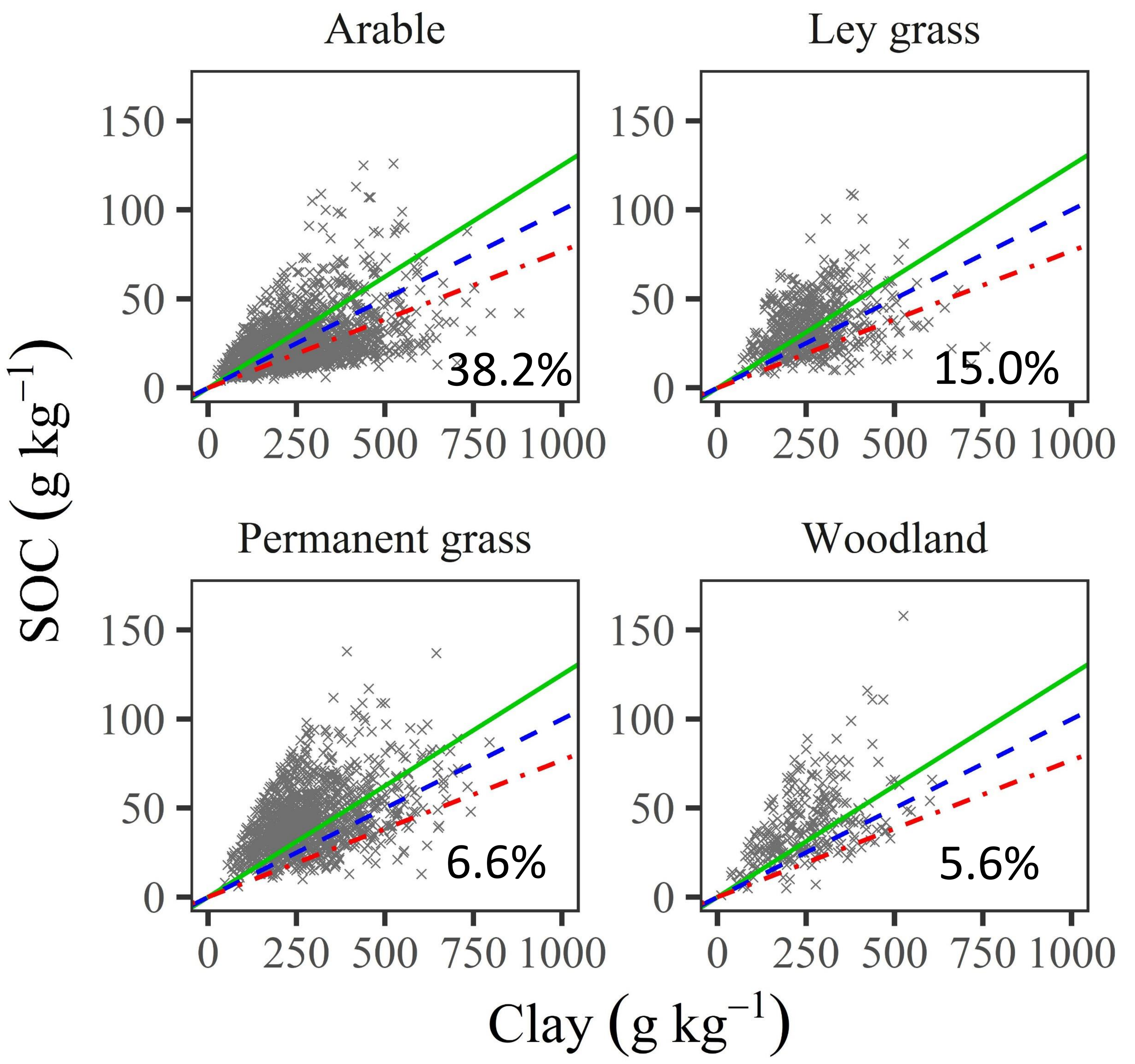
Aim 1 Variation in SOC/clay ratio

Random forest analysis explained 21% of the variance in SOC/clay ratio using the following variables:

	Increase of mean square error (%)	
Land use	32.7	39.8
Annual precipitation	28.0	26.0
Major soil group	26.4	20.3
pH	22.5	20.3
Depth of topsoil	10.4	
Carbonate score	10.0	
Risk of flooding	5.2	

Prout *et al.* (2020) (submitted)

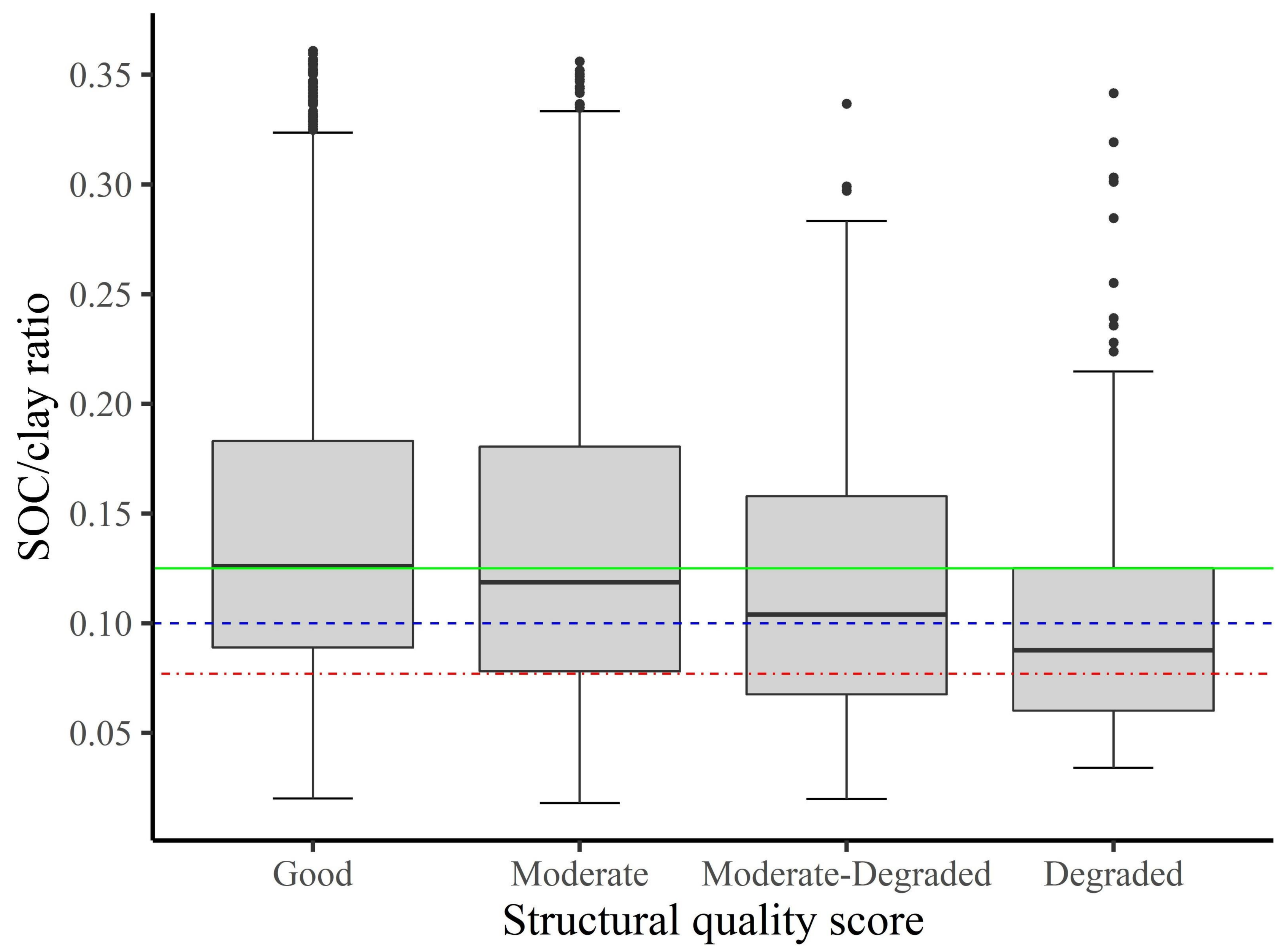


Prout *et al.* (2020) (submitted)

The increase of mean square error showed importance of variables. Using the top four variables highlighted the effect of land use.

Land use affected proportions of sites in each threshold range ($X^2(9) = 681.3$, $p < 0.001$). Arable has substantially more sites with low SOC/clay ratio than the other land uses.

Aim 2 Structural condition



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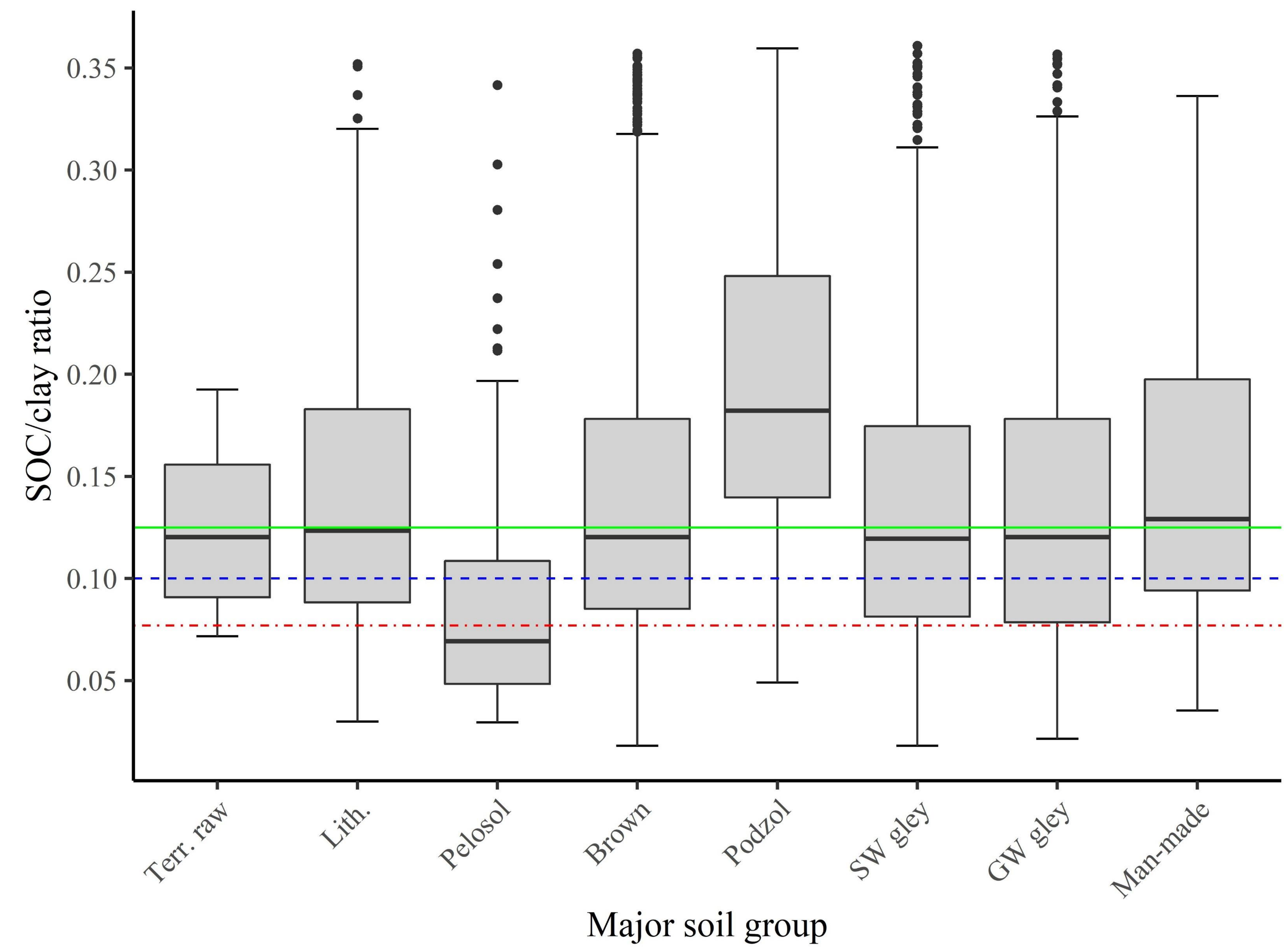
Structural scores were determined based on shape and size characteristics of structural description for different texture groups.
Structural score and SOC/clay ratio were not independent ($X^2(9) = 129.3$, $p < 0.001$)



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Major soil group was less important than land use. The variation in SOC/clay ratio was similar for lithomorphic, brown and gley soils (making up the majority of soils in the dataset).

These results suggested that the SOC/clay ratio thresholds identified for Polish, French and Swiss soils looked appropriate for use with a range of soils in England and Wales and that could extend to most soils in temperate-climate Europe.

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Aim 3 Index

We calculated an index using the thresholds to give an easy to communicate ascending scale of soil health based on SOC/clay ratio and indicated soil condition:

$$I = \frac{R - R_{\text{lower}}}{R_{\text{upper}} - R_{\text{lower}}}$$

Where:

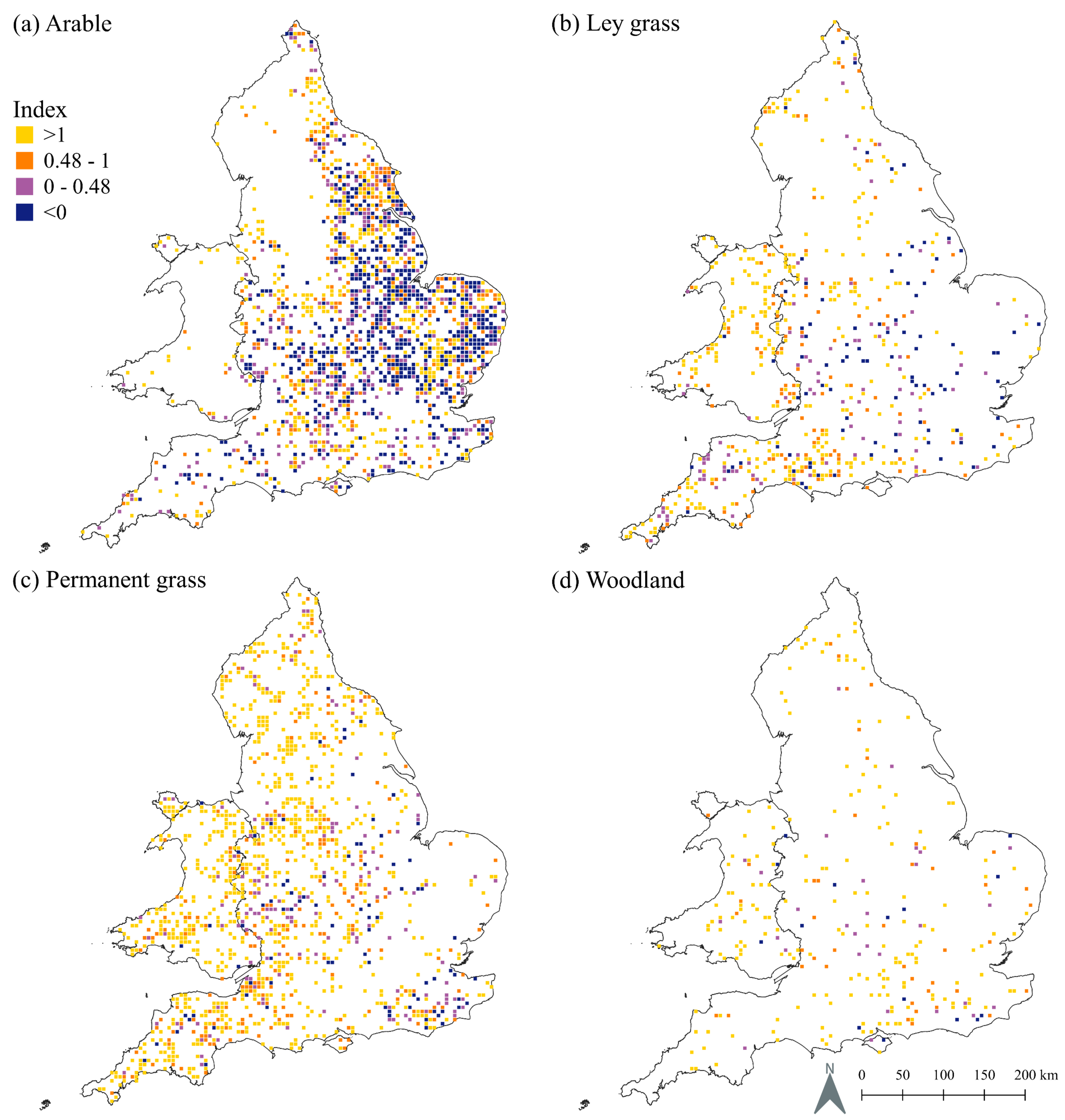
R = SOC/clay ratio

R_{lower} = 1/13

R_{upper} = 1/8

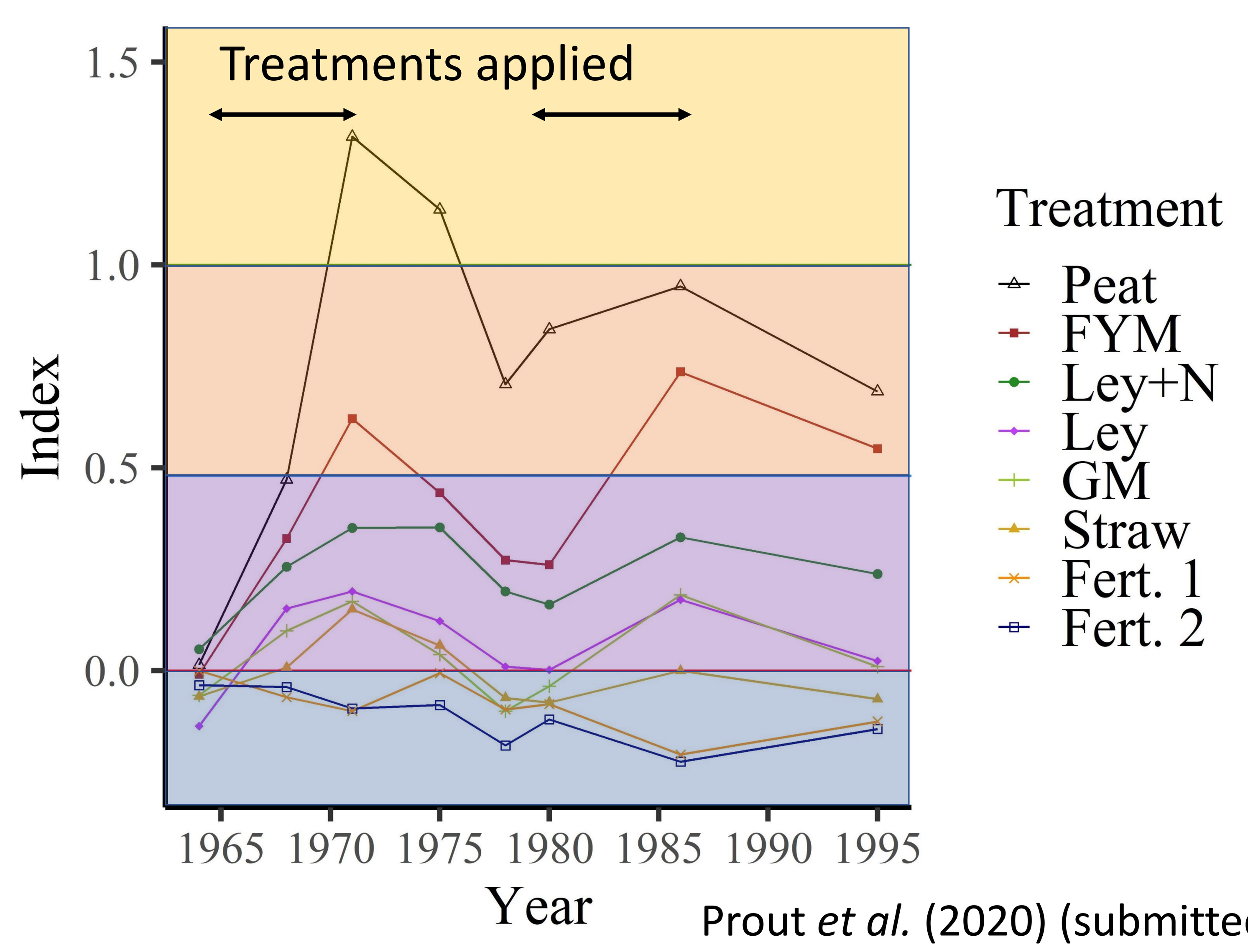
I = 0.48 → SOC/clay = 1/10

I	
≥ 1	Very good
0.48 – 1	Good
0 – 0.48	Moderate
< 0	Degraded



Prout *et al.* (2020) (submitted)

Woburn Organic Manuring Experiment



Prout *et al.* (2020) (submitted)

Treatment and experiment details see (Mattingly, 1974)
Sandy loam soil (clay content = 83 to 131 g kg^{-1})

Peat and grass manures (GM) were replaced with ley for second treatment cycle.

Reference
Mattingly, G.E.G. (1974). The Woburn Organic Manuring Experiment: I. Design, Crop Yields and Nutrient Balance, 1964-72. Rothamsted Experimental Station, Report for 1973, Part 2, 98-133. DOI:10.23637/ERADOC-1-8

Acknowledgements
We thank John Hollis, formerly of Cranfield University, for his advice on the structural quality assessment using the NSI dataset. We thank the e-RA data managers and Rothamsted Research for access to data and information on the Rothamsted Long-term Experiments. We also thank Paul Poulton and Andy Macdonald for their helpful comments and additional information. Mapping derived from soils data © Cranfield University (NSRI) and for the Controller of HMSO 2019.
Rothamsted Research receives grant aided support from the Biotechnology and Biological Sciences Research Council (BBSRC) of the United Kingdom. SPM and SMH are funded by the Institute Strategic Programme (ISP) grant "Soils to Nutrition" (BBS/E/C/000I0310). The Rothamsted Long-term Experiments National Capability (LTE-NC) is supported by BBSRC (BBS/E/C/000J0300) and the Lawes Agricultural Trust.