An assessment of soil organic matter thresholds for crop production in Europe

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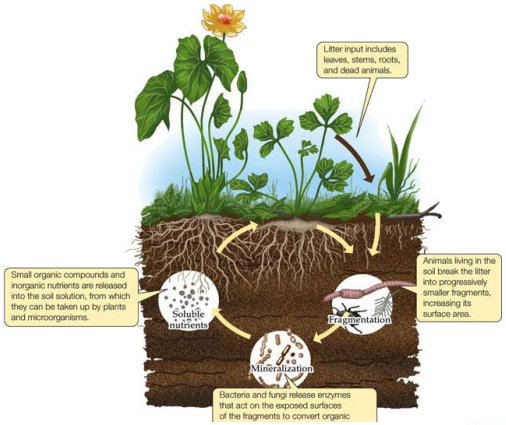
Role of soil organic matter (carbon)

Soil organic matter:

- organic fraction in soils
- derived from plant / animal material

Functions:

- Aggregate stability
- water storage capacity and infiltration rate
- C sequestration
- nutrient supply
- soil biodiversity
- degradation of pesticides and retention of pollutants



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Why soil organic matter thresholds?

- Potential public and private benefits

→ *Monitoring of policy success needs target values*

- Targets to increase soil organic matter can either focus on:
    - Annual increase (*e.g.* the 4‰ initiative at COP Paris)
    - Absolute values (*e.g. 2%* SOC)

SOM threshold values (for productivity) found in literature

Proposed value (% SOM)	Region	Based on:	Reference
1-2	US & Canada	Aggregate stability	Kemper and Koch (1966)
Sand: 1.0-2.2 Loam: 1.3-3.5	Europe	crop yields in field experiments	Körschens et al (1998)
± 1.7 (very tentatively)	Temperate	Literature review	Loveland and Webb (2003)
± 1.7 (very tentatively)	Denmark	Crop yields in field experiments	Oelofse et al (2015)
1.9	Tropics	crop yields in field experiments	Aune and Lal (1997)
3.4	UK	Aggregate stability	Greenland et al (1975)
3.4	Global	crop yields in field experiments	Oldfield et al (2019)
3.4-5.1	New Zealand	Expert panel	Sparling et al (2003)

Assumed: 1% SOC ≈ 1.7% SOM

Examples of threshold values found in literature

→ What about farmers' perceptions?

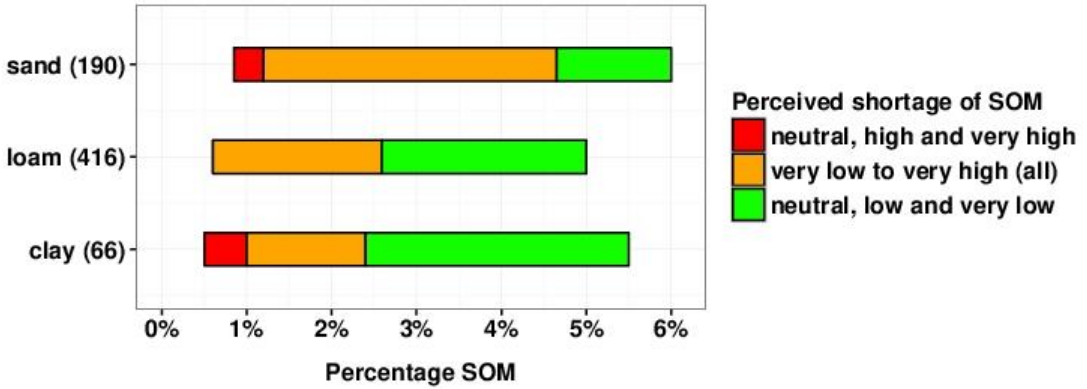
CATCH-C farm survey in 2013

- More than 1500 farmers in 5 European countries (Belgium, Austria, Germany, Italy and Spain)
- Questions on:
    - Slope, soil texture, crops cultivated
    - Average percentage of SOM
    - Perceived deficiency of SOM (1 = very low, 5 = very high)

→ 672 farmers reported both SOM content and perceived deficiency

CATCH-C farm survey: SOM thresholds per soil texture based on farmers perceptions

- Sand: 1.2 – 4.7%
- Loam: 0.6-2.6%
- Clay: 1.0-2.4



→ *Which European soils fall in the red and orange areas?*

→ *What about impact of climate*?

→ *Validation?*

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Hijbeek, R., Cormont, A., Hazeu, G., Bechini, L., Zavattaro, L., Janssen, B., Werner, M., S Bijttebier, J., Pronk, A.A., van Eupen, M., van Ittersum, M.K., 2017. Do farmers perceive organic matter? A European and farm level analysis. Ecological Indicators 83, 390-403.

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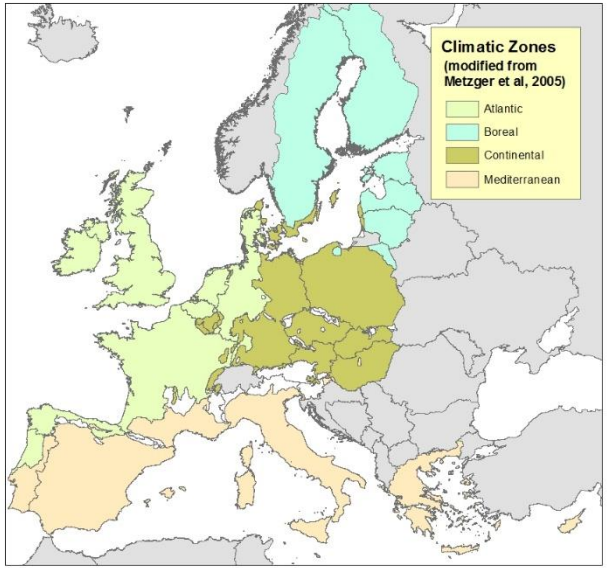
Research questions

1. Can thresholds further be specified per climate zone?
2. Which agricultural soils in Europe have a SOM content below these thresholds?
3. Validation: Are observed crop yields lower when SOM is below thresholds?

Methodology

1. Further specification of CATCH-C farm survey data per climate zone
2. Spatial comparison of current SOM levels (Ballabio et al, 2016) with thresholds
3. Comparison of remote sensing biomass data (EEA) on agricultural fields with SOM content below and above thresholds

Results 1: # farmers per climate X soil texture in CATCH-C survey

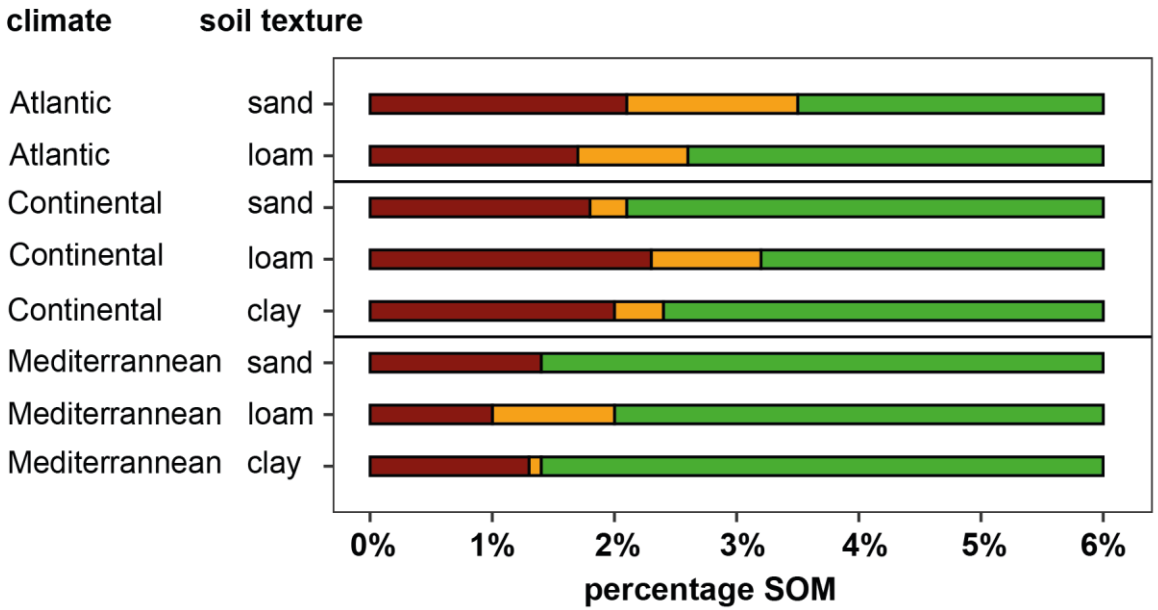


climate

Soil texture

	Sand	Loam	Clay
Atlantic	101	251	4
Continental	55	68	43
Mediterranean	8	86	16

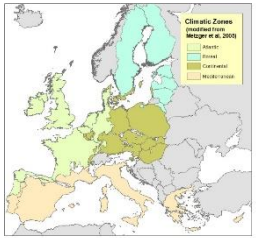
Results 1: thresholds per climate X soil texture combination



Ranges (% SOM)
2.1-3.5
1.7-2.6
1.8-2.1
2.3-3.2
2.0-2.4
1.4
1.0-2.0
1.3-1.4

Boreal climate (Soinne *et al*. 2016*)*:

- Finer soils (clay): 6.88% SOM (4% SOC)
- Coarser soils (sand): 3.44% SOM (2% SOC)



perceived deficiency of SOM

- neutral, high and very high
- very low to very high (all)
- neutral, low and very low

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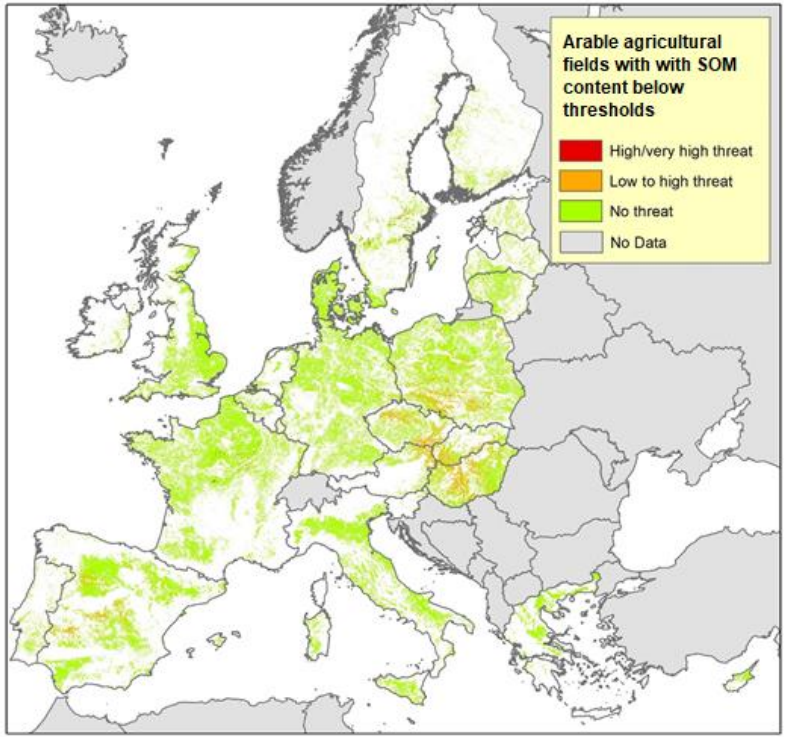
Results 2: agricultural areas with SOM content below thresholds



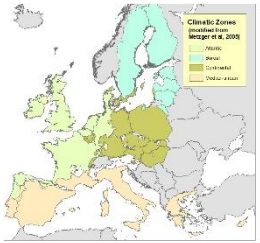
Results 2: percentages per country

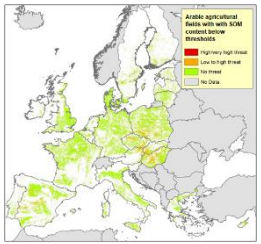
Country	Low to high threat (orange)	Very high threat (red)
Denmark	0.0%	0.0%
Estonia	0.0%	0.1%
Finland	0.0%	0.8%
Ireland	0.0%	0.0%
Lithuania	0.0%	0.2%
Latvia	0.0%	0.0%
Sweden	0.0%	3.3%
United Kingdom	0.0%	0.0%
Netherlands	0.0%	0.0%
Italy	0.0%	0.0%
Belgium	0.1%	0.0%
Cyprus	0.1%	0.0%
Slovenia	0.1%	0.0%
Luxembourg	0.3%	0.0%
France	0.4%	0.4%
Germany	1.1%	0.0%
Greece	1.6%	0.0%
Portugal	8.9%	0.1%
Spain	9.1%	0.0%
Malta	11.1%	0.0%
Poland	12.0%	0.4%
Austria	29.6%	0.0%
Czech Republic	30.1%	0.0%
Hungary	30.8%	0.0%
Slovakia	34.4%	0.0%

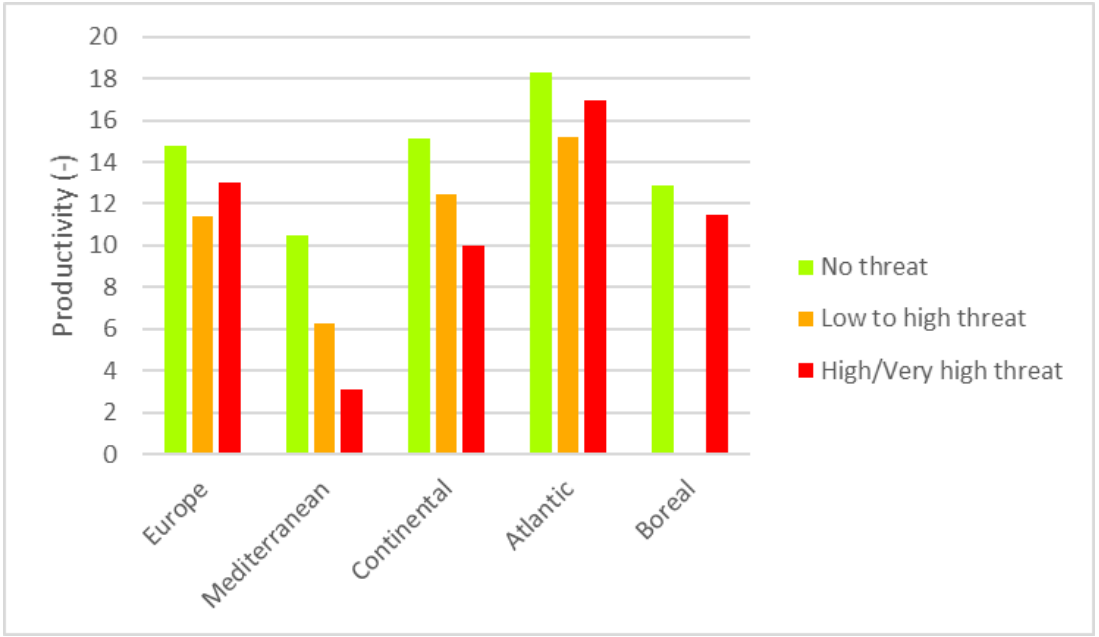
Results 3: Remote sensing observations of biomass in arable fields above and below thresholds

- All comparisons $P < 0.01$
- Productivity is on average lower in areas at risk that in areas not at risk

→ What about other factors?







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Discussion

- Current sample size of farm survey data is too small. Need for a larger farm survey?
- Agricultural area at risk seems overall small but substantial in specific southern and eastern European countries
- First assessment of relations with crop biomass are significant
- -> Need for policy incentives?

Further research

- On setting SOM thresholds:
  - More intensified sampling
  - Cross validation with thresholds from other data sources (*e.g.* at regional level)
- On correlations with observed biomass:
  - Inclusion of crop type, N input or other climatic variables

Acknowledgements

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Supplement: # farmers

climate zone	soil texture	ranges	number of farmers with a low or very low perceived SOM deficiency	number of farmers with a high or very high perceived SOM deficiency
Atlantic	coarse	2.1-3.5	54	19
Atlantic	medium	1.7-2.6	99	67
Atlantic	medium fine	NA	2	NA
Continental	coarse	1.8-2.1	23	10
Continental	medium	2.3-3.2	47	3
Continental	medium fine	2.0-2.4	31	2
Mediterrannean	coarse	1.4	3	1
Mediterrannean	medium	1.0-2.0	48	18
Mediterrannean	medium fine	1.3-1.4	6	4

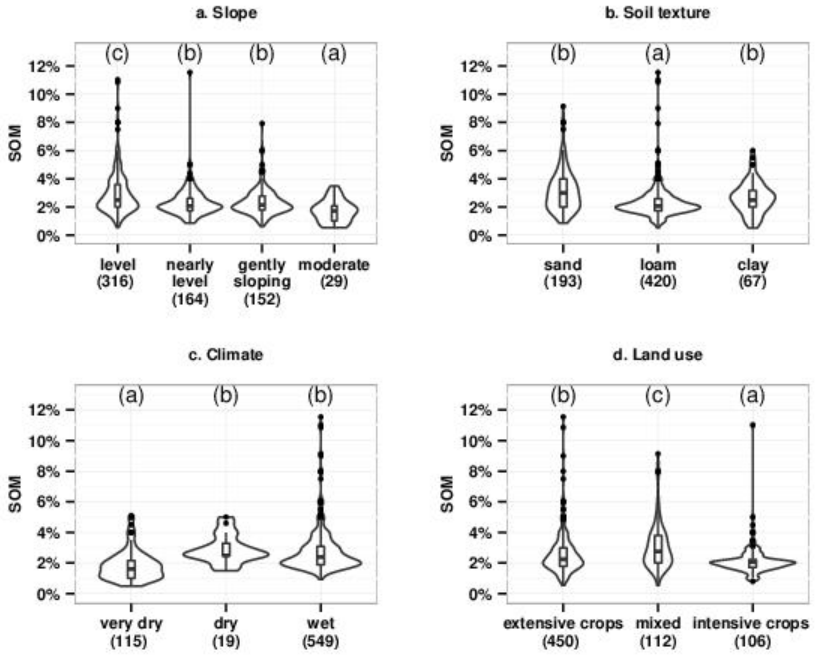
Supplement: # farmers

	Total (n)	Farmers providing average SOM content (n)	Farmers providing perceived shortage of SOM (n)	Farmers providing average SOM content and perceived shortage of SOM (n)
Farmers with information on slope	1447	665	1402	657
Farmers with information on soil texture	1481	680	1433	672
Farmers with an aridity index calculated	1542	683	1469	675
Farmers with information on land use	1466	668	1411	660
Farmers for which risk indicator can be calculated	1371	648	1331	640

Supplement: Limitations of study

- Percentages of SOM are reported by farmers, some degree of error
- Perceived shortage of SOM by farmers is measured holistically, many different underlying factors (soil structure, water, erosion, nutrients)

Supplement: SOM contents



Supplement: One extreme condition overrides interactions