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Do farmers perceive a deficiency of soil organic matter? A European and farm level analysis

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ABSTRACT

Agricultural soils with too little soil organic matter (SOM) content are characterized by fertility problems. A number of authors have tried to specify threshold values for SOM content to indicate what is ‘too little’, ranging from 1 to 5%, below which yields may be affected. How much SOM content is sufficient, however, depends on a number of environmental factors. In addition, up to date farmers' perceptions were not included when developing thresholds. Therefore, this study focuses on the following three objectives: (1) to identify a risk indicator on SOM deficiency based on environmental factors and agricultural land use; (2) to test the risk indicator using farmers' perceptions and (3) to establish threshold values for SOM content based on farmers' perceptions.

For objective 1, literature was reviewed on effects of environmental factors and land use on SOM deficiency. Findings were combined into nine options for a risk indicator on SOM deficiency, mapped at European scale. For objective 2, a farm survey was done among 1452 arable farmers in five European countries (Belgium, Germany, Austria, Spain and Italy). Associations between perceived deficiency of SOM by farmers and environmental factors, land use and the risk indicator were investigated. For objective 3, farmers' perceptions on SOM deficiency were related to the average SOM content of their fields.

Mapping the risk indicator at European scale gives a high to very high risk of SOM deficiency for 7 to 37% of European agricultural land, mainly located in Southern and Eastern Europe. Of the farmers in our survey, 18% perceived a high to very high SOM deficiency. A weak correlation was found between the risk indicator and farmers' perceptions of SOM deficiency (0.15-0.18, Spearman's rank correlation). Stronger relations were found between separate environmental factors and perceived SOM deficiency. Apparently, having a more extreme environmental condition for one factor gives a higher chance of perceiving a deficiency of SOM than a combination of moderate environmental conditions. Based on farmers' perceptions threshold intervals for SOM content were established (sand: 1.2–4.7%, loam: 0.6–2.6% and clay: 1.0–2.4%).

If policies on SOM management want to include benefits for productive capacity, targeting areas with a relatively high risk of SOM deficiency, more extreme environmental conditions or with very low SOM contents (below the given threshold intervals) seems most promising.

Abbreviations: IQR, inter-quartile range; L, lower extreme: lowest point observed within Q1–(1.5*IQR) and Q3 + (1.5*IQR); L_L, lower extreme for the range of SOM contents of farmers with a low perceived deficiency of SOM; L_{VL}, lower extreme for the range of SOM contents of farmers with a very low perceived deficiency of SOM; Q1, first quartile; Q3, third quartile; SOM, soil organic matter; U, upper extreme: highest point observed within Q1–(1.5*IQR) and Q3 + (1.5*IQR); U_H, upper extreme of the range of SOM contents of farmers with a high perceived deficiency of SOM; U_{VH}, upper extremes of the range of SOM content of farmers with a very high perceived deficiency of SOM

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1. Introduction

Percentages of soil organic matter (SOM) in soils vary widely, from below 1% for some sandy soils, to almost 100% for certain peat soils (Loveland and Webb, 2003). When pastures or forests are converted to arable land, SOM content decreases often to less than 10% SOM, depending on soil texture, climate, land use and management (Verheijen et al., 2005). This decrease in SOM also reduces the global carbon stock (Smith, 2004), which could be an incentive to maintain or increase SOM content in arable soils above certain levels, especially if this improves productive capacity.

SOM improves a number of soil properties relevant for productive capacity such as soil structure, water holding capacity and buffering of nutrients (Hudson, 1994; Johnston et al., 2009; Oades, 1984). Farming on soils with a loose soil structure, low water holding capacity or low availability of nutrients can generate less profit, which would be an incentive for farmers to maintain SOM content above certain threshold values (Gardner and Barrows, 1985; Kimetu et al., 2008; Scrimgeour and Shepherd, 1998). At the same time, demands for organic inputs (such as straw) are increasing with new markets for bio-energy and renewable materials emerging (Nicholson et al., 2014).

With a decrease in SOM content, most soil properties change along a continuum (Karlen et al., 2001), making it difficult to define a critical or desirable C content for farmers (Sparling et al., 2003). Even so, for the percentage of SOM to be a useful indicator for productive capacity, target values need to be specified. Sparling et al. (2003) argue in favour of a minimum or threshold soil C value: *"below which there would be loss of desirable soil characteristics, productive capacity and ecological functions that were not readily restored within an acceptable timeframe".* This study follows this definition, focussing mainly on the relevance for productive capacity.

Threshold values for SOM to sustain productive capacity can be argued in relation to supply of nutrients and/or stability of soil structure. With insufficient external inputs of nutrients, the threshold value for SOM will mostly depend on nutrient supply from SOM (Tiessen et al., 1994). With sufficient supply of external inputs or when target yields are low, threshold values will mostly depend on the contribution of SOM to stability of soil structure and related ease of cultivation (Janssen and De Willigen, 2006). Setting threshold values can be an important guide for farmers to improve their management and for policy makers when providing farm subsidies.

A number of authors have tried to specify minimum or threshold values for SOM for crop production (also called critical levels), using a range of approaches such as information from soil surveys, literature reviews, soil organic carbon modelling, expert opinions or a combination of these. Table 1 shows a summary of these threshold values. Often, values mentioned by authors are very tentative. When based on experiments, threshold values are often related to observed losses in aggregate stability or direct losses in yield.

When threshold values depend on soil texture, typically higher values are given for soils with more clay or fine silt particles. How much SOM is needed however will probably not only depend on soil texture, but also on other environmental factors (such as slope or climate) and land use (types of crops cultivated). Furthermore, none of the studies asked farmers for their views whilst farmers are the group of stakeholders with the longest and most practical exposure to SOM of their fields.

For targeted and effective policies on SOM management, more insight is needed under which circumstances increases in SOM content benefit the productive capacity of soils. It is hereby imperative to base this insight not only on results from experimental fields, but also on farmers' knowledge and perceptions. Currently, it is unclear which areas have a high risk of SOM deficiency for productive capacity and farmers' knowledge has not been included when proposing thresholds for SOM content in agricultural soils. Therefore, this study focuses on the following three research objectives:

1. To identify a risk indicator on SOM deficiency based on environmental factors and land use.
2. To test the risk indicator using farmers' perceptions.
3. To establish threshold values for SOM content based on farmers' perceptions.

Objectives 1 and 3 give insight where policies on SOM management can increase productive capacities of soils, whilst objective 2 brings together farmers' knowledge and existing scientific evidence.

2. Methodology

For objective 1, literature was reviewed on the influence of different environmental factors and land use on the relationship between SOM content and productive capacity. Effects of environmental factors and land use were combined into an aggregated risk indicator on SOM deficiency, mapped at European scale (Section 2.1).

For objectives 2 and 3, a farm survey was conducted to estimate farmers' perceptions on SOM deficiency of their fields. Following, farmers' perceptions were related to environmental factors, land use, the combined risk indicator and the average SOM content of farmers' fields (Section 2.2).

2.1. Developing a risk indicator on SOM deficiency

In this study, a higher risk of SOM deficiency indicates that with similar soil management, a farmer has an increased chance of perceiving a reduction in productive capacity due to low SOM contents compared to a farmer with a lower risk of SOM deficiency. A reduction in productive capacity might be observed directly (*e.g.* lower yields) or indirectly (reduced workability of the soil). From this definition it follows that specific problems perceived by the farmer due to SOM deficiency (*e.g.* concerning soil structure) can be solved by increasing SOM content. The risk of SOM deficiency for the productive capacity of agricultural soils depends on environmental conditions and land use. In this paper, we aim to define a risk indicator on SOM deficiency with a scale from 1 to 5.

To develop a risk indicator on SOM deficiency (objective 1), a number of consecutive steps were followed. First scientific literature was reviewed to find effects of environmental factors and land use on the risk of SOM deficiency (Section 2.1.1). Following, findings were used to define a risk indicator on SOM deficiency (Section 2.1.2). Finally, the risk indicator on SOM deficiency was mapped at European scale (Section 2.1.3).

2.1.1. Literature review on effects of environmental factors and land use on SOM and risk of SOM deficiency

Relevant environmental factors for SOM deficiency were identified based on three criteria: 1) The factor is not changed by human management (therefore shaping the context in which farmers have to operate); 2) Datasets have to be available at European scale; 3) Literature has to be available on how the environmental factor influences the relation between SOM content and productive capacity. Following these criteria, the following three environmental factors were selected: land slope, soil texture, and climate.

Soil texture was chosen to describe soil types instead of soil taxonomy classes for a number of reasons: 1) Soil classifications schemes such as the World Reference Base for Soil Resources (ISSS Working Group RB, 1998) have many taxonomy classes (WRB has 32 main groups) which makes statistical analyses difficult. 2) We wanted to compare the risk indicator with farmers' perceptions in which case we relied on farmers' descriptions of soils. Farmers are more aware of their soil texture than of the scientific names given to their soil profiles. 3) Soil textures have more easily understandable relations with aggregate stability, water holding capacity and productive capacity than do soil classifications.