Soil & Tillage Research 145 (2015) 29–36

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Overall assessment of soil quality on humid sandy loams: Effects of location, rotation and tillage

Lotfollah Abdollahi[a,b,*], E.M. Hansen[a], R.J. Rickson[c], L.J. Munkholm[a]

[a] Department of Agroecology, Aarhus University, Research Centre Foulum, P.O. Box 50, DK-8830 Tjele, Denmark
[b] Faculty of Agriculture, Payame Noor University (PNU), P.O. Box 19395-3697, Tehran, Iran
[c] Cranfield Soil and AgriFood Institute, Department of Environmental Science and Technology, School of Applied Sciences, Cranfield University, MK43 0AL, United Kingdom

ARTICLE INFO

Article history:
Received 3 May 2014
Received in revised form 12 August 2014
Accepted 16 August 2014

Keywords:
Crop yield potential
Rotation
Tillage
Muencheberg soil quality rating
Soil structure

ABSTRACT

Conservation tillage and diversified crop rotations have been suggested as appropriate alternative soil management systems to sustain soil quality. The purpose of this study was to quantify the effect of implementing three crop rotations (R2–R4) on soil structural changes and the "productivity function" of soil. R2 is a winter-dominated crop rotation (winter wheat was the main crop) with straw residues incorporated. R3 is a mix of winter and spring crops with straw residues removed. R4 is the same mix of crops as in R3, but with straw residues incorporated. Three tillage systems were used for each rotation: mouldboard ploughing to a depth of 20 cm (MP); harrowing to a depth of 8–10 cm (H); and direct drilling (D) at two experimental sites with a sandy loam soil and different water budgets in Denmark. The Muencheberg soil quality rating (M-SQR) method and simpler soil quality indices (i.e. visual evaluation of soil structure (VESS), overall visual structure (OVS) and overall soil structure (OSS)) were employed to differentiate the effects of these alternative management practices on soil structural quality and relative crop yield (RY). A Pearson correlation was also employed to find the correlation between the soil quality indices and relative crop yield. Relevant soil properties for calculating the soil quality indices were measured or obtained from previous publications. Crop rotation affected the soil structure and RY. The winter-dominated crop rotation (R2) resulted in the poorest soil structural quality and produced the lowest RY compared to the mixed rotations (R3 and R4). Tillage systems clearly influenced the soil quality and RY. The MP resulted in the best soil structural quality, and consequently the highest RY compared with both the reduced tillage treatments. Significant correlations were found in most cases between soil quality indices (including M-SQR) and RY. This highlights the influence of soil quality (as measured by the selected indicators) – and soil structure in particular – on crop yield potential.

1. Introduction

Soil performance plays a crucial role for the survival and development of civilisations by providing food, fibre and essential goods for an ever-increasing world population (Hillel, 2009). The production of food and fibre is based on the soil "productivity function" and is considered one of the main soil functions (Blum, 1993; EC, 2006). Recent studies show that food production is not keeping pace with the increasing demand for food (Cassman et al., 2003; Richter et al., 2007) and suggest a sustainable soil system (Jones et al., 2009; Lal, 2008, 2009) to avoid soil degradation and thereby maintain yield (Lal, 2008, 2009; Oldeman, 1998). Conservation agriculture (Torres et al., 2001) including conservation tillage and diversified crop rotations (Zentner et al., 2002) has been suggested as an appropriate alternative soil management system to achieve sustainable agriculture (Hatfield and Karlen, 1994). These tillage and cropping systems must be economically viable and adapted to the soil and climatic conditions of the arable area, whilst ensuring the quality and quantity of yield production (Campbell et al., 1995; Zentner et al., 2002). Development of such alternative management strategies has necessitated an assessment of their direct and indirect effects. Hence, the concept of "soil quality" has been used to evaluate the impacts of different soil management strategies on soil quality indicators. This will help to develop new management systems to improve the quality and sustainability of the soil system (Doran, 2002; Karlen et al., 1992, 1997).

* Corresponding author at: Department of Agroecology, Aarhus University, Research Centre Foulum, P.O. Box 50, DK-8830 Tjele, Denmark. Tel.: +45 8715 1191.
E-mail addresses: lotfollah.abdollahi@yahoo.com, lotfollah.abdollahi@agrsci.dk (L. Abdollahi).

http://dx.doi.org/10.1016/j.still.2014.08.009
0167-1987/

There is no direct way of measuring soil quality. However, measuring and monitoring the changes in soil quality indicators following the application of a specific management strategy would be a useful approach to infer the current quality status of a soil (Sharma et al., 2008). Indexing soil quality has been proposed as an efficient tool to combine soil information that can be used in decision-making activities at different scales and consequently at different accuracies (Andrews et al., 2002a; Karlen et al., 2001). Indexing methods include: soil quality test kits (Liebig et al., 1996); visual assessment of soil (VSA) (Shepherd, 2000; Shepherd et al., 2000; Shepherd and Janssen, 2000); visual assessment of soil structure (VESS) (Ball et al., 2007); and linear and non-linear scoring of soil quality indicators to produce additive and weighted additive indices of soil quality (Andrews et al., 2002a). Among available assessment approaches of agricultural soil quality, we considered a method that focuses more directly on the quantification of land productivity potential. The Muencheberg Soil Quality Rating (M-SQR) (Mueller et al., 2007) has been developed for the assessment of cropland and grassland quality for crop production. This method is based on the ratings of indicators relevant for the productivity function of soil and has been reported to produce reliable, transferable and universally acceptable results (Mueller et al., 2012; Richter et al., 2009). It works with two types of indicators, i.e. "basic indicators" and "hazard indicators". The former relates mainly to the soil substrate (texture) and structural properties of soil that are both relevant to soil productivity function (plant growth). The latter relates to factors that severely restrict plant growth. Two visual methods (VSA and VESS) are used to evaluate crucial soil structural indicators (i.e. porosity, root frequency, and aggregate size and shape). Both can be used in the rating of the Muencheberg overall soil quality score. By including these visual assessment tools (i.e. VSA or VESS) M-SQR method benefits from their strength in soil quality assessment and then supplements this with other aspects of land productivity such as climate conditions and other inherent soil properties.

The purpose of this study was to quantify (rate) the "productivity function" of soil following the application of different crop rotations and tillage systems, using the M-SQR method at two experimental sites in Denmark. Another purpose was to quantify the effects of crop rotations and tillage systems on the relative yield (RY) and other soil quality indices. Lastly, the aim was to explore the relationship between RY and soil quality indices.

2. Materials and methods

2.1. Rating overall soil quality

The M-SQR uses both inherent and management-induced soil quality indicators and climate data, including thermal and moisture regimes of soil (Fig. 1). Using the scoring tables, two types of indicators ("basic soil indicators" and "soil hazard indicators") are scored, weighted and summarised to produce a final score in the range of 0–100 (Mueller et al., 2007). Basic soil indicators include soil substrate (texture), A-horizon depth, topsoil structure, subsoil compaction, rooting depth, profile available water, wetness and ponding, and slope and relief, which are assessed *in situ* (Fig. 1). Each indicator is scored on a scale ranging from 2 (best condition) to 0 (worst condition) with increments of 0.5. Soil hazard indicators are critical soil parameters (mostly determined by climate factors) that may limit soil functions and thus total soil quality. They are considered as multipliers for the basic soil score. The score for the most severe hazard indicator (0.01–2.94) is used as a multiplier for the basic soil indicator score to produce the overall soil quality rating index (M-SQR score), ranging from 0 to 100 (Fig. 1). Classes of M-SQR rating are: <20 = very poor, 20–40 = poor, 40–60 = moderate, 60–80 = good and 80–100 = very good (more details on the rating system and scoring tables can be found in Mueller et al. (2007)).

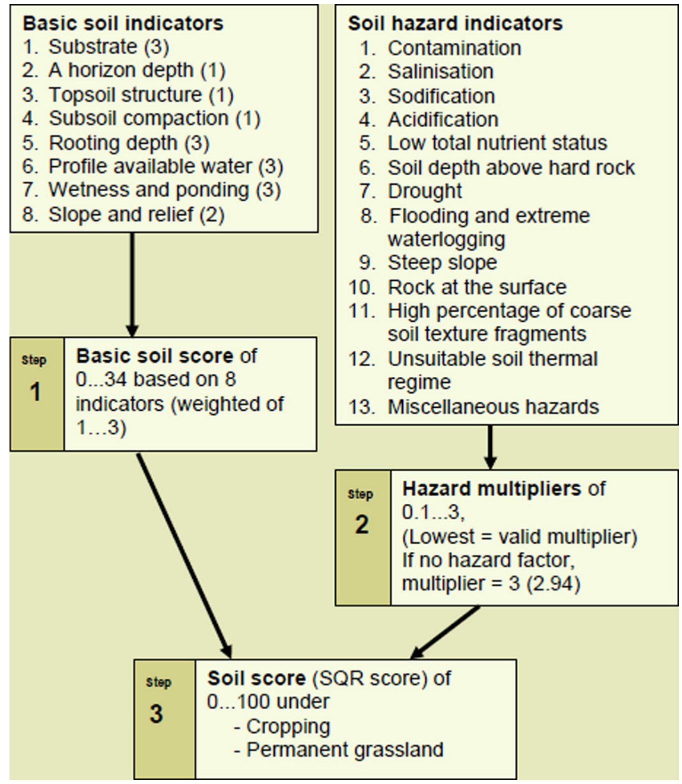

Fig. 1. Scheme of the M-SQR.
Adapted from Mueller et al. (2007), Fig. 2.-1.

2.2. Study sites and their basic soil indicators

The study sites were located at research centres Foulum (56°30′N, 9°35′E) and Flakkebjerg (55°19′N, 11°23′E), on sandy loam soils in Denmark. Both soils are based on ground morainic deposits from the last glaciation. The soil at Foulum is classified as a Mollic Luvisol and the soil at Flakkebjerg as a Glossic Phaeozem according to the WRB (FAO) system (Krogh and Greve, 1999). The clay (<2 μm), silt (2–20 μm), fine sand (20–200 μm) and coarse sand (200–2000 μm) contents of the soil (0–25 cm) were 92, 126, 444 and 307 g kg^{-1} and 147, 137, 426 and 270 g kg^{-1}, for Foulum and Flakkebjerg, respectively. At both sites, an experiment involving different rotation and tillage treatments has been running since 2002. The experimental design was a randomised complete split plot with four

Table 1
Crop rotations and straw management during the study period.

Year	R2	R3	R4
2009	Winter (W.) wheat	Spring (S.) oats	S. oats
2010	W. wheat/S. barley[a]	W. wheat/CC[c]	W. wheat/CC[c]
2011	W. barley[b]	S. barley/CC[c]	S. barley/CC[c]
2012	W. rape/W. wheat[d]	S. oats	S. oats
Straw	Left	Removed	Left

[a] Spring barley was sown at Foulum where winter wheat was damaged by frost.
[b] Spring barley was sown in the direct drilling plots at Flakkebjerg where winter barley was damaged by frost.
[c] Fodder radish (*R. sativus*) was under sown as a cover crop 14 days before expected harvest.
[d] Winter wheat at Foulum (sown instead of winter rape to avoid too late sowing of winter rape in a wet autumn).