Soil & Tillage Research 134 (2013) 1–10

Contents lists available at SciVerse ScienceDirect

Soil & Tillage Research

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

The visual evaluation of soil structure under arable management

Mohammad Sadegh Askari [a,*], Junfang Cui [a,b], Nicholas M. Holden [a]

[a] UCD School of Biosystems Engineering, University College Dublin, Dublin 4, Ireland
[b] Institute of Mountain Hazards and Environment, CAS, Chengdu, Sichuang, China

ARTICLE INFO

Article history:
Received 11 February 2013
Received in revised form 19 June 2013
Accepted 22 June 2013

Keywords:
Visual assessment
VESS
Soil quality
Soil structure
Tillage systems

ABSTRACT

Conventional methods for assessing soil quality under different management practices require considerable time and knowledge. A visual method based on field assessment can provide a reliable, rapid evaluation of soil quality. The aim of this study was to use the visual evaluation of soil structure (VESS) method in arable soil in Ireland and to assess the ability of the method for evaluating soil structural quality under different arable management systems. The study was conducted over twenty sites used with conventional and minimum tillage, with crop rotation or mono-cropped. At each site a VESS score and soil properties associated with soil structural quality were measured in order to assess the visual soil quality score (Sq). Sq for conventional management (Sq = 2.29) was significantly greater than minimum tillage (Sq = 1.95) indicating slightly poorer structure. Measured soil parameters confirmed a negative effect of conventional tillage on soil quality and supported the VESS results. Under minimum tillage Sq indicated significantly different soil structure under mono-cropping (Sq = 1.66) compared to rotation (Sq = 2.06), but this trend was not supported by the other soil properties and the difference probably had no physical meaning as both Sq scores indicated good soil structure. The effects of crop management on soil structure could not be differentiated by VESS under conventional tillage, while the measured soil properties suggested soil structural quality was better under crop rotation. While visual Sq scores were not strongly correlated with individual soil properties indicative of soil quality, Sq scores were generally supported by the measured soil properties with regard to differentiation of tillage system. This independent evaluation of the VESS method on arable farms in Ireland indicated that it was capable of differentiating the effects of tillage management practices on soil structural quality, and is suitable for use as a reliable, rapid method for assessing soil quality on arable farms.

1. Introduction

Soil and crop management practices can enhance or reduce soil quality, which in turn can be associated with an increase or decrease in soil productivity (Pankhurst et al., 2003; Ogle et al., 2012). Conventional methods for measuring soil properties and evaluating soil quality require varied methodological knowledge, resource infrastructure (equipment and laboratories) and considerable time and money (Guimarães et al., 2011). Therefore a reliable, rapid method to quantify soil structural quality that is sensitive to the effects of management on soil quality would be useful for both scientists and land managers.

Visual methods for objectively and reproducibly evaluating soil quality based on field assessment and measurements have been developed (Shepherd, 2000, 2009; Ball and Douglas, 2003; Ball et al., 2007), tested (Mueller et al., 2009a,b) and modified (Guimarães et al., 2011). These methods range from easily understood and quick tests to more complex multifaceted assessments, but all are designed to help land managers make better decisions as part of their soil management system, and scientists to acquire low-cost, objective, reproducible data on soil structure over large areas with high sampling frequency. The simpler methods such as Shepherd (2000) and Guimarães et al. (2011) do not require particular knowledge and specific equipment yet provide a rapid and meaningful result (Giarola et al., 2010).

Peerlkamp (1959) introduced a soil structure evaluation method that was further developed by Ball et al. (2007) as visual soil structure assessment (VSSA). This method uses a chart of structural qualities compared against a block of soil, which is extracted by spade and manipulated, in order to distinguish key factors for classifying soil into one of five categories and to give it a score from 1 (good soil) to 5 (poor soil). Visual keys such as size, shape and appearance of aggregates, porosity, clustering,

* Corresponding author at: Room 325, UCD School of Biosystems Engineering, University College Dublin, Belfield, Dublin 4, Ireland.
Fax: +353 1 7167415; mobile: +353 870979531.
E-mail address: mohammad.askari@ucdconnect.ie (M.S. Askari).

0167-1987/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.still.2013.06.004

thickness and deflection of roots and difficulty in extracting the soil block are considered by the VSSA method. The final grade is calculated by averaging the scores multiplied by the thickness of each layer in the soil (Ball et al., 2007). VSSA correlates well with measured soil physical properties and it may provide a quick and semi-quantitative evaluation of soil quality and productivity. Furthermore, differences in physical soil quality and crop yields have been associated with VSSA scores (Mueller et al., 2009a,b).

The VSSA method was further developed into a tool known as Visual Evaluation of Soil Structure (VESS) (Guimarães et al., 2011), which has the potential for practical evaluation of soil physical quality. It was demonstrated with Oxisols subject to different tillage systems and it provides a technique to select a proper mechanical and biological management system in order to achieve sustainable soil productivity (Giarola et al., 2010). The Muencheberg Soil Quality Rating (MSQR), which is an indicator-based visual method for assessing soil quality, was developed by Mueller et al. (2007). In MSQR soil quality scores (rated between 0 and 100) are defined based on climate, topography, soil structure and texture factors by assessing 20 indicators. The validity and reliability of MSQR were verified on grassland and cropland in different countries, and a good correlation between soil quality rating and crop yields was reported (Mueller et al., 2012). Despite the ability of MSQR for evaluating soil quality, the method is time consuming and requires specific training to perform it properly in the field. Similarly the Profile Cultural method (Gautronneau and Manichon, 1987) is quite complex to deploy, but has been shown to be sensitive to temporal change in soil structure (Roger-Estrade et al., 2004).

The subjectivity of visual assessment methods has been a concern raised by scientists more familiar with quantitative measurement. Guimarães et al. (2011) revised the scoring guide of VSSA in order to make it more objective (as VESS) by focusing on the gradual diminution of aggregates and assessing their shape. Soil structure and physical properties were compered under rye and corn silage double-cropping and continuous corn silage using VSSA method by Liesch et al. (2011). This study indicated visual scores improved by 57% under the double-cropping systems and the better Sq values were associated with lower bulk density, smaller aggregate size, higher porosity and increased saturated hydraulic conductivity values (Liesch et al., 2011). Muller et al. (2012) applied VESS and measured soil physical properties including bulk density, total porosity, penetration resistance, gravimetric moisture and the aggregate-tensile strength to assess the impacts of gypsum application on soil quality under no-tillage. They utilized the ability of VESS to evaluate soil structural quality and concluded that 50 months of gypsum application affected soil quality.

Soil structure is known to interact with physical, chemical and biological properties (Da Silva et al., 1997; Kay et al., 2006; Mueller et al., 2009a,b), and these in turn are directly influenced by arable management (Mosaddeghi et al., 2009). In addition, many soil functions related to biological diversity, activity, and productivity, which provide soil physical stability and support plant growth, nutrient and carbon cycling, are also related to soil structure and are indicators of soil quality (Kavdir and Smucker, 2005). Soil structure is the main focus of the VESS method and therefore VESS scores should reflect the impact of arable management practices on soil quality and provide an indication of the sustainability of arable management.

Although the VESS method has been tested in different soils, it has not been evaluated under a range of different management system, regardless of soil type, or as a practical tool for assessing the effect of management practices on soil quality. In particular there are few examples of testing or application that are independent of the method developers. While bulk density, porosity, water infiltration rate, and penetration resistance are commonly used for evaluating soil structure (Giarola et al., 2010), there is a need for rapid methods such as VESS that integrate these soil properties in a single score. In addition these traditional measurements can be utilized for assessing the results of VESS deployment under different management practices. In this study Visual Evaluation of Soil Structure was tested under different field management on arable farms in Ireland in order to assess the suitability of VESS for differentiating the effects of soil management practices on soil structural quality. The objectives were to relate type of management (conventional vs. minimum tillage; mono-cropping vs. rotation) to VESS score and to validate the VESS scores by reference to established physical indicators of soil quality.

2. Materials and methods

2.1. Site characterization

The study was conducted over 20 arable sites under combinations of different land management practices in the eastern half of Ireland between August and November 2011. The sites are located between latitude 52°12′41″ N and 53°53′3″ N; longitude 6°22′42″ W and 7°34′56″ W (Fig. 1). According to climate information for Ireland (http://www.met.ie), mean daily temperature in winter varies from 4.0 °C to 7.6 °C, and in summer from 12.3 °C to 15.7 °C and annual rainfall in the east of Ireland is between 750 mm and 1000 mm.

The sites were characterized based on type of tillage and type of crop rotation, thus four management practices were defined: (i) minimum tillage with mono-cropping; (ii) minimum tillage system with crop rotation; (iii) conventional tillage system with mono-cropping; and (iv) conventional tillage system with crop rotation. For the crop rotation systems barley and wheat were the dominant crops, with one or more of oilseed rape, maze, oat, potato and bean in the rotation. The mono-cropping produced either wheat or barley. This means the sample sites were representative of arable crops in Ireland, around 79% of which are cereals, dominated by winter wheat (18%) and spring barley (42%) (DAFF, 2004).

Prior to field sampling, soil and crop management practices were recorded through semi-structured interviews with the farmer responsible for each field. The questionnaire was developed to collect necessary information regarding the management regime at each site including; type and duration of current and previous management, soil fertility management, type and rotation of crops and annual yield.

2.2. Experimental design

At each site a 30 m^2 sampling square was laid out with random orientation in a representative part of the field with uniform soil and land cover (based on a visual assessment on arrival in the field). Gateways, atypical dry or wet areas, headlands and highly trafficked areas were avoided. Five sub-plots 2 m^2, approximately equal distance apart were then selected across the central diagonal of the main plot for replicate sampling based on walking a 'W' between opposite corners of the sampling square.

At each sub-plot a ring 25 cm high and 10 cm diameter was inserted 10 cm into the soil and about 2 or 1 cm depth of water was applied to determine soil sorptivity according to the method of Philip (1957). The initial amount of water for the soil sorptivity calculation was defined according to the top soil permeability (Sepaskhah et al., 2005). A loose soil sample was also collected from between the surface and 10 cm for laboratory analysis and