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Visual soil evaluation: reproducibility and correlation with standard measurements

Maricke M.W.J. van Leeuwen[a,*], Gerard B.M. Heuvelink[a], Jakob Wallinga[a], Imke J.M. de Boer[b], Jos C. van Dam[c], Everhard A. van Essen[d], Simon W. Moolenaar[e], Frank P.M. Verhoeven[f], Jetse J. Stoorvogel[a], Cathelijne R. Stoof[a]

[a] *Soil Geography and Landscape Group, Wageningen University, P.O. Box 47, 6700 AA Wageningen, The Netherlands*
[b] *Animal Production Systems Group, Wageningen University, P.O. Box 338, 6700 AH Wageningen, The Netherlands*
[c] *Soil Physics and Land Management Group, Wageningen University, P.O. Box 47, 6700 AA Wageningen, The Netherlands*
[d] *Aequator Groen & Ruimte bv, P.O. Box 1171, 3840 BD, Harderwijk, The Netherlands*
[e] *Commonland, Kraanspoor 24, 1033 SE Amsterdam, The Netherlands*
[f] *BV Boerenverstand, P.O. Box 114, 3500 AC Utrecht, The Netherlands*

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ABSTRACT

Visual soil evaluation (VSE) is a simple and fast method to assess soil quality in situ, and is becoming increasingly popular. Besides soil structure assessment, also other soil properties can be assessed such as grass cover, roots and earthworms. Yet, the full set of visual observations has not been properly evaluated for reproducibility and correlation with standard field or laboratory measurements, for several soil types. The objectives of this study were therefore to evaluate the reproducibility and the correlation of visual observations with closely related field or laboratory measurements. We used quantitative visual observations where possible, to enhance objectivity of VSE. The reproducibility and correlation of visual observations with standard measurements was evaluated for three soil types (sand, peat and clay) in the North Friesian Woodlands, The Netherlands. Reproducibility of quantitative visual observations was tested by comparing observations made by farmers and soil scientists, on the same soils. A linear mixed-effect model indicated that for all quantitative visual observations except for the depth of soil compaction, subjectivity due to the observers' background (farmer or soil scientist) had no significant effect on the observations. For assessment of relative soil quality differences between sites, the results suggested that a single observer can make the visual observations, when assessing the fraction largest soil structural elements, earthworms, gley mottles and the depth of soil compaction. Spearman's rank correlation coefficients indicated that visual observations of grass cover, root count, maximum rooting depth and the fraction largest soil structural elements correlated significantly with closely related field or laboratory measurements regardless of soil type. Maximum rooting depth, root count, soil colour, the fraction largest soil structural elements, and the degree of soil compaction only significantly correlated with field or laboratory measurements for specific soil types. Analyses showed that the correlation of visual observations with standard measurements were soil type dependent, suggesting that the evaluation of soil quality should also be soil type dependent.

1. Introduction

Visual soil evaluation (VSE) methods are becoming increasingly popular among farmers, organisations and companies that focus on soil management and environmental sustainability (Ball et al., 2017). A VSE determines soil quality through several soil quality characteristics that are observable by eye (e.g. Ball et al., 2007; McKenzie, 2013; Shepherd, 2009). After visual observations of soil quality characteristics, weight factors are assigned to indicate the relative importance of each soil quality characteristic, and soil quality is evaluated using a grading system. Visual soil evaluations can be used to monitor soil quality, to identify constraints for soil functioning, and to identify soils that are in an early stage of degradation (McGarry, 2004). Visual soil evaluation is cost-effective and rapid, e.g., the visual soil assessment (VSA) of Shepherd (2009) takes approximately 45 min. Visual soil evaluation is furthermore a valuable addition to soil chemical and physical analyses

* Corresponding author.
E-mail addresses: maricke.vanleeuwen@wur.nl, maricke.vanleeuwen@gmail.com (M.M.W.J. van Leeuwen).

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for the interpretation of land degradation issues (McKenzie, 2013). Because of the increased use of VSE, it is essential that the method is reproducible and the made observations are correct. We therefore focus on the first step in VSE: the visual assessment of soil quality characteristics.

The visual soil assessment (VSA) of Shepherd (2009) uses one of the broadest sets of visual soil quality characteristics among all VSEs. However the relationship between each of the visual soil quality characteristics and soil physical measurements is only assessed for clay soils (Sonneveld et al., 2014) and not for other soil types. As relationships between visual soil quality characteristics and laboratory-measured soil parameters likely vary between soil types, use of VSE methods developed for a single soil type may lead to poor accuracy when it is applied on other soil types. Other VSEs that significantly correlate with soil physical measurements for various soil types are the visual evaluation of soil structure (such as such as SoilPAK (McKenzie, 2001), the Peerlkamp test (Ball et al., 2007; Mueller et al., 2009), Visual Evaluation of Soil Structure (Guimarães et al., 2013; Newell-Price et al., 2013; Pulido Moncada et al., 2014), CoreVESS (Johannes et al., 2017), and VSA soil structure (Mueller et al., 2009)), as well as the visual assessment of soil compaction using the French *profil cultural* method (Peigné et al., 2013). To the best of our knowledge no other VSEs have been related to soil physical measurements for several soil types.

An additional challenge of VSE is that its usefulness is often questioned by critics because of the potential subjectivity in the visual observations, although VSE protocols are easy to use and self-explaining (Guimarães et al., 2017). While the reproducibility of visual assessment of vegetation cover and the visual evaluation of soil structure have been studied (Klimeš, 2003; Ball et al., 2007), the reproducibility of the full range of visual soil quality characteristics has not yet been evaluated for potential users (agricultural land managers and environmental scientists) and contrasting soil types. Klimeš (2003) found that visual grass cover observations were not reproducible among five observers, on seven sites. Ball et al. (2007) in contrast found the visual evaluation of soil structure to be reproducible, assessed by two experts and two non-expert users at two sites. It is relevant to know whether farmers can assess soil quality on their own, or whether a specialist should be hired to assess soil quality.

Aside from the benefit of assessing the correlation between visual observations and standard field or laboratory measurements for contrasting soil types and having insight into its reproducibility, the quality of VSE may improve if a more quantitative approach is taken. VSE is usually based on qualitative or semi-quantitative information, where visual observations are reported as scores rather than numeric quantitative observations (Ball et al., 2007; Peerlkamp, 1959; Shepherd, 2009). However, a quantitative assessment may give a better representation of soil quality and allows VSE methods to be universally applicable (Emmet-Booth et al., 2016).

The objectives of this study were to evaluate the reproducibility of visual observations and to evaluate the correlation between visual observations and standard field or laboratory measurements. The reproducibility of visual observations was tested by comparing visual observations made by farmers and soil scientists at the same sites. We used quantitative visual observations where possible, rather than semi-quantitative or qualitative visual observations as an attempt to make VSE more objective. In this study we use the broad set of visual soil quality characteristics proposed by Shepherd (2009, VSA) as it covers the most used visual indicators of soil quality.

2. Materials and methods

2.1. Study area

The study area is the North Friesian Woodlands in the North of The Netherlands (Fig. 1A). The North Friesian Woodlands were selected because of the various soils present (Fig. 1B). Dominating soil types are cultivated hydromorphic podzols ('veldpodzols' or 'laarpodzols') developed in Pleistocene aeolian cover sand, histosols ('vlierveengronden'), and fluvisols ('poldervaaggronden') developed in Holocene marine clay (Table C.1 in Supplementary material). The cultivated hydromorphic podzols have a dark coloured plough layer (Sonneveld et al., 2002), of around 30 cm deep and with a Munsell colour value < 3. Glacial till can be found within 120 cm depth from the surface. Groundwater often perches on the glacial till, and can be found between 25 and > 120 cm depth (Sonneveld et al., 2006). Histosols have groundwater tables between 0 and 100 cm depth and fluvisols have groundwater tables between 0 and 120 cm depth. The dominant land use in the North Friesian Woodlands is grassland for dairy farming, with approximately 80% of dairy farmers being member of cooperative 'Noardlike Fryske Wâlden' and using sustainable agricultural practices (Noardlike Fryske Wâlden, 2016). Climate in the region is temperate. Temperatures range from 0.3–5.3 °C in winter to 13.2–21.6 °C in summer. Mean annual precipitation was 861 mm in the period 2004–2014.The field study year of 2014 was a warmer, dryer and sunnier year than normal, with temperatures ranging between 2.5–7.3 °C in winter, and 12.4–21.3 °C in summer, and with 671 mm precipitation (Royal Netherlands Meteorological Institute, 2017).

For the reproducibility study, five fields under grassland were selected that were located on sand (n = 2), peat (n = 1), and clay soils (n = 2). The fields were located on three dairy farms that were used in the correlation study (see next paragraph). The fields were homogeneous in terms of topography, grass cover and soil profiles and located close to each other (within a radius of 4 km) so that the observers could analyse all five fields within the same day.

To correlate visual observations with standard measurements, we selected 26 farms in the North Friesian Woodlands. The farms were more or less equally distributed within a radius of 13 km. At each farm we randomly selected one site (a field) under grassland to carry out visual soil observations and standard field or laboratory measurements. These 26 sites were located on sand (n = 11), peat (n = 7), and clay soils (n = 8). Four of the sites had been renewed within the last three years, but most sites were between 10 and 50 years old (Table C.1 in Supplementary material). From the 26 farms, 22 farms had dairy cattle and four farms had meat cattle.

2.2. Procedure of visual observations

From the range of soil parameters in the VSA of Shepherd (2009), we selected grass cover, porosity, root length and root density, soil colour, soil structure, earthworms, gley mottles and soil compaction (Table 1). Except for grass cover, root length and root density, we only considered those indicators that directly assess soil quality characteristics, rather than plant quality characteristics that only indirectly assess soil quality. Soil smell was not considered as this was beyond the scope of the study. In contrast to VSA we assessed most visual observations quantitatively rather than using soil quality scores.

First, grass cover was assessed within 1 m^2 from the place where the soil block would be extracted. Grass cover was observed as the percentage of grass base covering the soil surface. Grass was pulled apart by hand to make bare soil visible, facilitating the estimation of grass cover. We did not cut the grass before assessment, because we wanted farmers to be able to assess grass cover any time without cutting it first. Subsequently, a soil block of 20 × 20 × 20 cm was extracted from the topsoil with a spade. Three parameters were quantified on the bottom of the block: 1) earthworm burrows larger than 2 mm were counted over the entire 20 × 20 cm surface area (biopore count); 2) all roots (living and dead) were counted over a surface area of 10 × 10 cm (root count); and 3) the soil organic matter content was quantified using the colour value of field moist soil (Wills et al., 2007), with the Munsell Soil Color Charts (Munsell Color, 1975). The bottom half of the soil block (the 10–20 cm depth layer) was subsequently used for soil structure assessment as soil structure was often more distinct in this lower part of