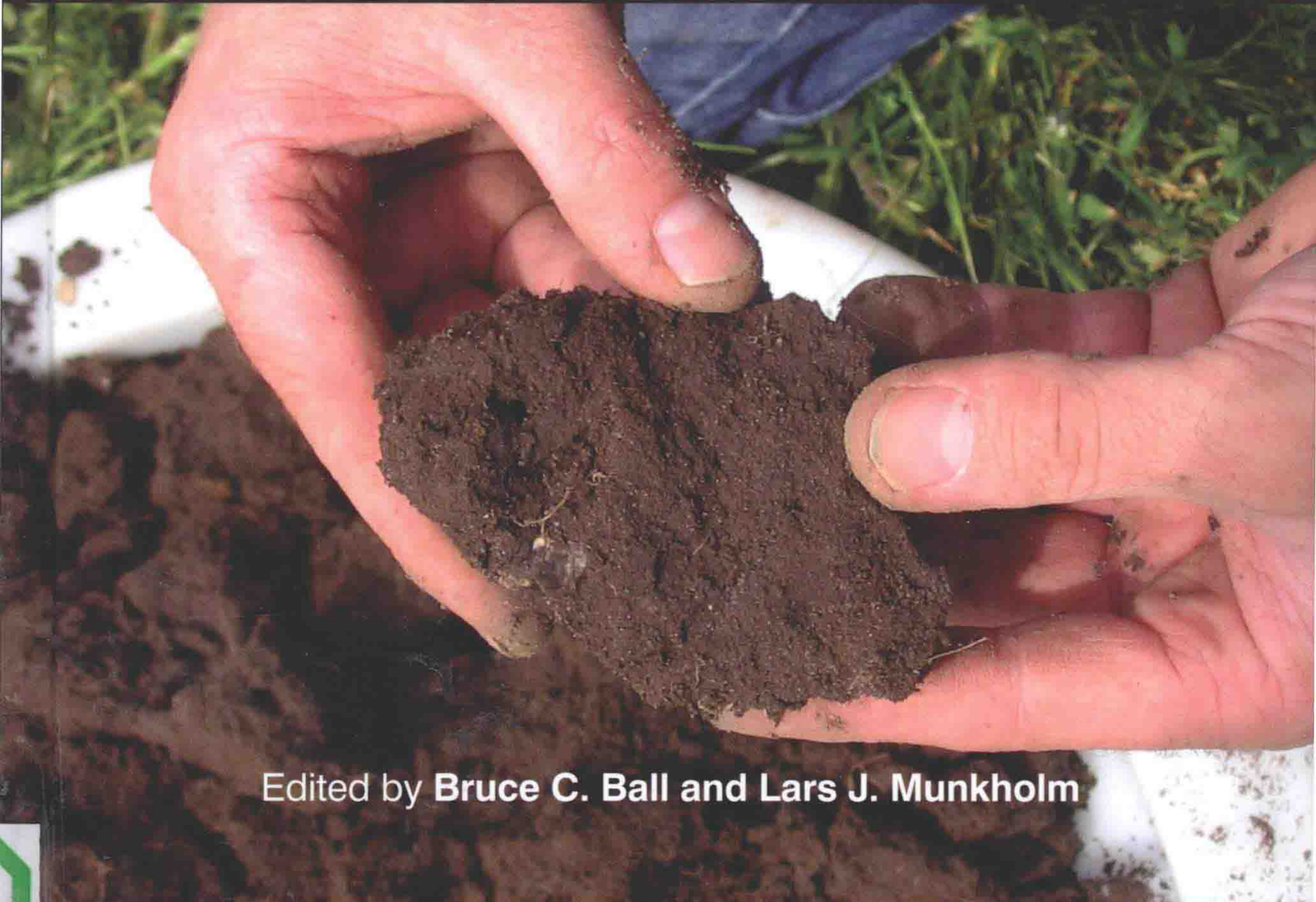
Visual Soil Evaluation

Realizing Potential Crop Production with Minimum Environmental Impact



Edited by **Bruce C. Ball and Lars J. Munkholm**

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Preface

This book describes the main methods for Visual Soil Evaluation (VSE) of soil structure and soil-related properties. It includes clear visual images of the variation of soil quality and how these relate to soil productivity and environmental sustainability. Such images raise awareness and provide a measure of the soil degradation that is a looming threat to the viability of world agriculture. Emphasis is given to recognizing, protecting and restoring soil quality as these are of vital importance for tackling problems of food insecurity, global change and environmental degradation. We show how these aims can be achieved with Visual Soil Evaluation by describing tools that can readily be used by land users and environmental authorities to assess crop performance, soil improvement and soil productivity. Visual Soil Evaluation is also placed in the context of future sustainable intensification of agriculture including factors of soil loss, resilience, climate change, scarcity of water and other resources, nutrient retention and increased risk of degradation. This book is relevant not only to students, lecturers, scientists and advisors working directly with soils but also to policy makers, food security experts, environmentalists and engineers who have an interest in soils and sustainable agricultural production. Last, but not least, we hope that these simple VSE techniques will be used extensively in years to come as a tool to link soil specialists and non-specialists together with the mutual aim of developing sustainable soil management to advance global food security and improve the environment.

This book developed mainly from the activities of members of the 'Visual Soil Examination and Evaluation' working group within the International Soil Tillage Research Organisation. The editors thank all the authors for their valued contributions, summarizing their extensive knowledge and experience. The editors are also grateful for the support from the publishers.

Bruce C. Ball
Lars J. Munkholm

Contents

1 Describing Soil Structures, Rooting and Biological Activity and Recognizing Tillage Effects, Damage and Recovery in Clayey and Sandy Soils

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Soil compaction and erosion have emerged as major threats to global agriculture as they negatively affect plant production and have detrimental impacts on the environment. Soil compaction is responsible for decreased crop yield and quality, emissions of greenhouse gases and increased water runoff (Hamza and Anderson, 2005; Ball *et al.*, 2008). Unless severe, it is often unrecognized because plant growth can appear normal, especially when mineral fertilizers are used liberally. The major cropping factors affecting soil compaction are the weight of machinery, poor timing of field operations with respect to soil water content and intensification of crop production. Soil erosion is responsible for losses of soil particles, nutrients and agrochemicals resulting in decreased soil fertility as well as eutrophication of rivers and lakes (Rasouli *et al.*, 2014). Site characteristics (rainfall quantity and intensity, slope and soil texture) have strong effects on soil erosion; in addition, important cropping factors related to soil erosion are crop rotation, percentage soil cover and management practices affecting soil structure and compaction (Pimentel *et al.*, 1995; Morgan, 2005). Erosion deposits are mostly silt and fine sand with little structure and porosity and thus resemble soil damaged by compaction. Because compaction plays a central role in soil degradation and yield losses, it has to be properly diagnosed in the field. This can be done by observing soil structure, root development, aeration and evidence of biological activity.

This chapter will therefore focus on describing and illustrating important soil structural features associated with compaction and anaerobic conditions. It will cover the evaluation of soil structure and compaction status for both clayey and sandy soils. Since tillage is often responsible for the creation of a number of anthropic layers, each having a different structure, the identification of the different soil layers will be explained. The use of other indicators of soil compaction such as root development (density, deformation, concentration in cracks or between layers), aeration (soil colour) and biological activity (soil macroporosity of biological origin, rapidity of residue turnover, presence of earthworms) will also be covered.

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A quick, preliminary evaluation of soil structure can be done using a spadeful of soil, allowing rapid verification of soil structure over the entire field. Since agricultural practices can often affect soil conditions to a depth of 30–50 cm, and sometimes more, soil condition may have to be investigated to such depths, depending on the situation.

Different tools can be used to assess soil structural quality, either using spade methods (e.g. the visual evaluation of soil structural quality, VESS, Ball *et al.*, 2007; Guimarães *et al.*, 2011), visual soil assessment (VSA, Shepherd *et al.*, 2008; Shepherd, 2009), or profile methods (e.g. Cultural Profile, Manichon, 1987; or the SoilPAK method, McKenzie, 2001). These tools are described by Batey *et al.*, Chapter 2, this volume.

Some helpful information for soil compaction diagnosis should also be collected by checking soil maps and interviewing farmers. The following information should be gathered:

- The origin and characteristic of the soil;
- The field situation; for example, surface and sub-surface drainage situation, crop rotation, yield variation in the field, size of the equipment for manure spreading and timing for spreading, harvesting strategy, tillage and number of passes, depth of tillage, etc.

For the purposes of this chapter a soil is considered to be in good condition if it has good structure, is well aerated and contains a sufficient amount of organic matter in the A horizon to be capable of supporting microbial activity and optimum plant growth.

1.1 Evaluation of Soil Structure

Soil structure is best evaluated considering soil texture because the criteria for assessing structure depend on the clay content. The pressure exerted on the soil by machinery forces aggregates to stick to each other and to form clods. Texture is important because the clods resulting from compacted clayey soil are often hard and difficult to break down, while clods resulting from compacted sandy soils are fairly easy to break. Although the relationship between soil characteristics and clay content lies on a continuous spectrum, the evaluation of soil structure will only be described here for two main, discrete groups labelled as follows: clayey soils (more than 25–30% clay) and sandy soils (less than 25–30% clay). Soil having 20–30% clay content will sometimes behave more like a clayey soil and sometime more like a sandy soil, depending on clay type and the organic matter content.

1.1.1 Evaluation of the structure of clayey soils

The structure of clayey soils can mostly be evaluated by observing the shape of aggregates and clods. When describing structure, soil horizonation needs to be taken into account because organic matter content, root density, aeration and biological activity tend to be much higher in the A horizon and these foster aggregation. This section aims at describing typical good and typical poor structure for clayey soils for both topsoil (A horizon) and subsoil layers (B and C horizon). The structure of naturally recovered clay soil is also described.

1.1.1.1 Soil structure of clayey soils in good condition

TOPSOIL (A HORIZON). Aggregates of a well-structured clayey topsoil are small, in the 1–10 mm range, and well separated (Fig. 1.1a). They can be observed in some grasslands, some non-cultivated soils and in some areas that are not trafficked (permanent beds, controlled traffic systems). They are also common in intensively tilled top layers of recently cultivated soils.

If the compaction pressure is light enough, the clods that are formed have a rough surface because the aggregates that constitute them keep their individual shapes (Fig. 1.1b). They are porous because of the space between the aggregates (not always visible with the naked eye) and the biological activity which creates pores.

In a non-compacted soil it should be very easy to separate the aggregates in the clod by simply squeezing the clod in the fist. However, to do this the clod must be fairly moist. Clay becomes very hard when it dries, which can give a false impression of being highly compacted.

When examining a spadeful of healthy soil, it is often possible to see an excellent structure with aggregates well separated from each other

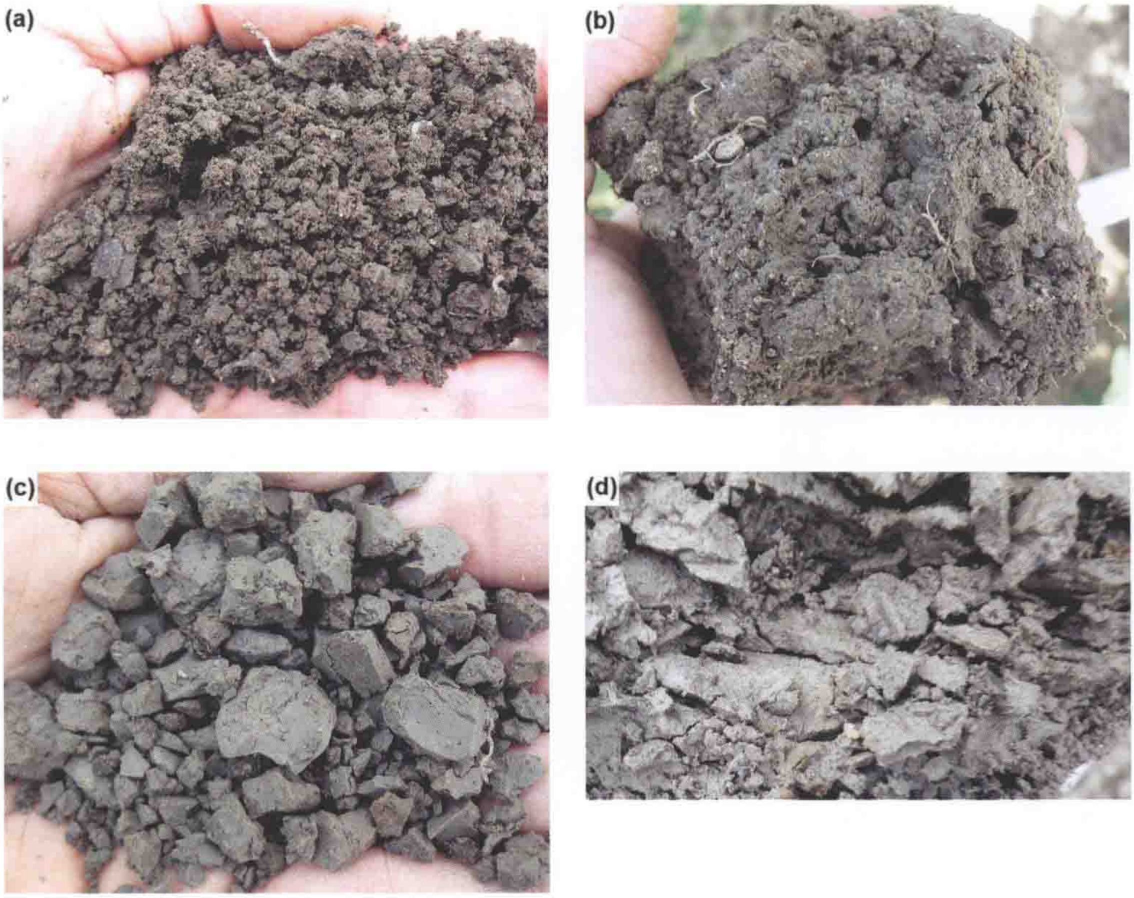

Fig. 1.1. Aggregates and clods in well-structured clayey soils. (a) Topsoil: small round aggregates, 1–5 mm in size, coming from a healthy A horizon. (b) Topsoil: very rough and porous clod coming from a very biologically active soil. The aggregates should detach from each other when the clod is squeezed. (c) Subsoil: small non-porous, angular, 2–10 mm aggregates. (d) Subsoil: lamellar structure, usually found in soil that contain less clay and more silt.

in the seedbed layer because of the effect of harrowing. Below the seedbed, the clods are rough and easy to break (Fig. 1.2).

SUBSOIL (B AND C HORIZONS). In a well-structured subsoil the aggregates are small (2–10 mm) and can either be rounded (Fig 1.1a) or more angular in shape (Fig. 1.1c). They can be fairly massive and non-porous. Soils that are rich in silt sometimes have a lamellar structure (Fig. 1.1d). The thickness of the lamellae can be 2–10 mm.

1.1.1.2 Soil structure of compacted clayey soils

As the pressure exerted on the soil (topsoil or subsoil) by machinery increases, the aggregates are more and more tightly pressed together and stick to each other more and more strongly. They form clods that are increasingly more difficult to break apart, more massive, less porous and smoother.

When examining a shovel full of compacted soil, the soil must be gently broken into pieces that can fit into a hand (Fig. 1.3a) (Ball *et al.*, 2007). When it is possible to break up the clods with pressure, the result will be a mixture of small and large aggregates (Fig. 1.3b). The more compact the soil, the smaller will be the proportion of small aggregates.

When compaction is severe the aggregates fuse to each other and lose their individual shape in the clod (massive structure) (Fig. 1.4a), which cannot be broken down in the hand.

Fig. 1.2. Healthy clay soil with mostly aggregates in the top part (seedbed) and rough and porous clods in the bottom part (below seedbed).

1.1.1.3 Effect of texture on the identification of compaction of clayey soils

When the soil is moist, but not waterlogged, the strength of clods of compacted soils increases with clay content (Barzegar *et al.*, 1994; Barzegar *et al.*, 1995); as a result soils with a low clay content can be broken down much more easily even when the soil is quite compact. As the clay content of a soil decreases, the situation will resemble more and more that of a sandy soil as described in the next section. Very wet, compacted clayey soils may have a plastic consistency, which results in clods being easily deformed by pressure.

1.1.1.4 Natural recovery of clayey soils after compaction

In clayey soils, the cycles of shrinking/swelling and freezing/thawing will fracture the soil by cracking. The clods (Fig. 1.4a) will crack into two pieces, then four and so on. Aggregates formed in this way often have flat sides and angular edges. However, full recovery of structure in the A horizon such as that shown in Fig. 1.4b will only occur if roots and other biological activity develop in the soil.

1.1.2 Evaluation of the structure of sandy soils

The structure of sandy soils tends to be weaker than that of clayey soils because of their lower clay content and is more dependent on organic matter level and biological activity. In the topsoil it is also affected by tillage intensity. Visual assessment of sandy soil structure can be challenging and often needs to be complemented with observations of root development (see section below). This section aims at describing typical good and typical poor structure for sandy soils for both the topsoil and subsoil layers.

1.1.2.1 Soil structure of sandy soils in good condition

TOPSOIL (A HORIZON). As for the clayey soils, aggregates of well-structured sandy topsoils are small and rounded, in the 1–10 mm range (Fig. 1.5a). Such structure can be seen in soils that have a lot of organic matter, roots and biological activity. These are mostly grassland, non-cultivated soils and some cultivated soils with crops having a very dense rooting system and excellent biological activity. Small and rounded aggregates can also commonly be seen in recently tilled topsoil layers – particularly in seedbeds. They may be formed by the breaking up of larger aggregates during tillage and do not necessarily indicate a good stable structure. If the soil has been too intensively tilled the structure may easily collapse.

The lack of clay, unless organic matter content is high, causes aggregates of sandy soil to have a low resistance to compaction and they are easily crushed or compressed. After aggregate compression, the soil can appear massive whether it is very compact or not. The resulting clods have a smooth surface and are usually easy to break (Fig. 1.5b). When a clod is squeezed it usually crumbles easily into pieces that do not correspond to the