Book of abstracts

SSSB Thematic day on soil structure and compaction

Oral contributions

Alejandro, ROMERO-RUIZ

Geophysical method for field-scale soil structure characterization (keynote)

Soil is a critical natural resource. It supports global agriculture and forestry and hosts hydrological processes largely controlling the recharge of the world's groundwater resources. Soil structure is an important trait influencing a wide array of soil hydro-ecological functions. Despite its importance, soil structure remains difficult to define and characterize particularly at scales relevant to field applications. In the past five years, we have evaluated the potential of harnessing geophysical methods to fill the scale-gap in characterization of soil structure. We propose a systematic way to capture soil structure by using a framework that combines geophysical monitoring and soil-process modeling. We tested such integrative framework using monitored geophysical data from a soil compaction experiment, located in the vicinity of Zürich, Switzerland. Seismic data showed the imprint of soil compaction as higher seismic velocities in compacted compared to non-compacted soils. Pedophysical modeling helped to interpret this as increased mechanical contacts between soil aggregates. Similarly, monitored geoelectrical data revealed a strong sensitivity to soil compaction and water dynamics. Geoelectrical signatures are interpreted in terms of reductions of macroporosity and increased connectivity of soil aggregates due to the compaction event. Compacted soils typically presented drier conditions compared to non-compacted soils. Our coupled hydrogeophysical modeling approach provided insights on such effects of compaction on water dynamics and allowed interpreting differences as a result of enhanced evaporation capabilities in compacted soils. Our results motivate discussion on how geophysical characterization of soil structure may benefit from combination of geophysical methods with different sensitivities and spatial support and the need for their integration in agro-ecological modeling. To illustrate this, we present an example of the impacts of animal treading on soil properties and functions and show how they can be sensed by geophysical methods. We envision an increase and diversification of geophysical applications in the near future for informing agronomic activities, diagnosing chronic soil degradation (e.g., compaction) and helping calibrate Land Surface models currently relying on incomplete soil information.

Lin LIN , Jan De PUE, Angela Katherine Martin VIVANCO, Wim CORNELIS

Assessment of soil structural quality across different textures with visual and soil physical analysis methods

Soil structural degradation has become very common and leads to a serious decline in soil health. Improving soil structure is key to build resilience against drought and water excess, and thus contributes to assuring food and water security. However, soil quality is usually evaluated and examined quantitatively by traditional lab-based methods, which are time-, labour- and money-consuming. Visual Evaluation of Soil Structure (VESS) methods comprise rapid and simple tests that offer a numeric semi-quantitative assessment of soil structure. The common criteria are aggregate size and shape, ease of break or rupture resistance, and inter- or intra-aggregate porosity. In this study, the CoreVESS method was applied on 250 cm3 undisturbed soil core samples and derived soil quality scores (Sq) were compared with soil quality indicators (SQi) derived from traditional lab-based methods of soil structure analysis. While CoreVESS was originally developed to evaluate topsoil, it was used here beyond this zone as a simple means of quantifying soil structure. We aimed to assess and quantify potential soil degradation induced by agricultural operations using a suite of methods at a regional scale. Soil core samples have been taken in Belgium from 42 cropped fields, at two positions (headland and in-field zone) and from three layers, i.e. the ploughed topsoil (TOP, 10-20 cm), the compacted subsoil (CSUB, 30-40 cm) and the deeper subsoil (SUB, 60-70 cm), totalling the sample horizons to 252. Test and sampling sites comprised all major soil texture classes according to the Belgian soil textural triangle. In-field positions (IN-FIELD) showed significantly better Sq as compared to headland positions (HEAD), with the CSUB layers always showing significantly lower quality than the other two layers. Lab-derived soil quality indicator (SQi) values presented the same trend, with CSUB layers always indicating worse situations. Significant differences were also found between the mean values of each SQi's of soils with acceptable (Sq =< 3) and degraded (Sq>3) structure. Likewise, grouping soils into the same categories resulted in significant differences in the soil water retention and hydraulic conductivity curves. There were good significant relationships between the SQi values and VESS-based Sq scores, with for example Pearson R correlation coefficients of 0.64 for penetration resistance and 0.58 for bulk density. Also, Sq scores related well with an SQi-based soil quality index (SQI) value was averaged per layer and texture class, and improved the correlation, with e.g., Pearson R of 0.60 when relating Sq to SQI. The study thus confirmed that VESS methods have a potential for monitoring soil structural quality over a variety of textures in a rapid, intuitive, practical and cheap way, as an alternative for or being complementary to more expensive labour-intensive traditional quantitative methods.

Dieter ANSEEUW, Yves DEHONDT, Bregt ROOBROECK, Kaat VANHEGEN

Towards a common VSA standard for Flanders

Crop production in Flanders is, in general, intensive with high inputs and yields. However, as a result of the intensive soil management practices, problems related to low soil organic carbon content, soil erosion and compaction are increasing. Soil structure degradation is a major obstacle to plant growth, particularly under drought conditions while the physical condition can be a key factor in carbon storage and flood prevention. The soil structure quality can be assessed visually by different methods. Visual Soil Assessment (VSA) methods combine various parameters and individual aspects of the soil to attain a comprehensive assessment of the soil structure quality. While, in Flanders, annual chemical soil content analyses have become obliged and common practice for agricultural land, VSA's have not yet become generally established. Moreover, there is no common standard on which parameters should be included in a typical VSA.

Here we present a set of parameters and their score classes with which we aim at a standardized field assessment of the soil structure quality. Our method has been tested in ongoing research projects and by students during practical courses on agricultural soils as well as on urban greenery soils. We found that the relevance of certain parameters may depend on the destination of the soil. This challenges the concept of a common VSA standard that is applicable throughout Flanders by a large number of stakeholders. Yet, our first results show that this preliminary index allows for discriminating street tree soils, park soils and forest soils by differences in their soil structural aspects.t

We call for colleagues in research and higher education to participate in and extend the development of an objective VSA method that finds acceptance and has the potential to become a standard in education programs and research projects.

Adriaan VANDERHASSELT, Tommy D'HOSE, Wim CORNELIS

Remediation of subsoil compaction by subsoiling and deep rooting crops

Soil compaction forms a major threat to the well-functioning of agricultural soils. By reducing the pore volume and continuity both crop growth and ecological services, like water infiltration and storage, can be negatively impacted. It is often the most severe at the interface between topsoil and subsoil, just out of reach of the yearly tillage operations. At this depth a plough pan can be formed, restricting interaction between top- and subsoil for roots and gas and water transport. In this study we looked at a combination of mechanical and biological remediation to alleviate this problem. The experiment was performed on a sandy loam field in Melle with a highly compacted plough pan, which almost completely restricted roots to reach the subsoil and was practically impermeable for gas transport. Subsoiling was performed once in three different maize-based cropping systems: forage maize in monoculture, a ley-arable crop rotation with two years of alfalfa and a maize-winter cereal rotation.

The mechanical remediation (subsoiling) clearly helped to break open the restricting plough pan. Rootablility and air permeability clearly increased, leading to a significant increase in maize yield. On a longer time scale however, we observed that this loosened soil was very prone to recompaction. In the second year after the subsoiling the highly compacted plough pan returned. This same year also showed no difference between the subsoiled and untreated control in maize yield.

To see if deep rooting (cover) crops can help stabilize the loosened soil after subsoiling, this study included a treatment with the cover crop fodder radish. We observed that the cover crop had a high rooting density into the subsoil, especially where the tines of the subsoiler had passed. Although this didn’t seem to lead to an improvement in overall physical soil quality, it did seem to protect the soil from recompaction. The penetration resistance didn’t markedly increase after standard agricultural practice.

Further work in this study will look at the effectiveness of deep rooting (cover) crops, like fodder radish and alfalfa, to help alleviate the problems associated with highly compacted plough pans on their own.

Poster contributions

Brieuc HARDY & Frédéric VANWINDEKENS

The QuantiSlake test : a new simple method to evaluate soil structural stability

Soil structure is one of the main factor controlling the fertility of temperate agricultural soils subject to intensive cultivation. In Belgium, most cropland soils of the loess belt have experienced a long cropping history, responsible for a progressive decrease of soil organic carbon content (SOC) in the topsoil over time. This low SOC content in topsoil coupled to a silt-dominated texture makes these soils particularly sensitive to structural damages such as compaction and erosion, particularly under the increasing risk of extreme climatic events induced by climate change.

In this work, we evaluate the performance of a new, simple test to evaluate structural stability under water. Our method proposes a quantitative approach of the slake test (QuantiSlakeTest, QST), which consists in measuring mass evolution over time of a structured soil sample once immersed in water, in a 8 mm mesh basket. This approach has the advantage to be simple, rapid and to provide a high density of information all over the process of soil wetting and disaggregation under water.

The objective of this work was threefold: we aimed to (1) derive indicators from the curves to evaluate soil structural stability and to relate it to the underlying mechanisms of soil disaggregation; (2) to assess the effect of soil properties (pH, SOC and texture) on soil structural stability indicators estimated from the QST curves; and (3) to assess how QST curves discriminate between soils under contrasting management practices.

To meet these goals, we sampled the soil of 40 plots from three long-term field trials dealing with contrasting farming practices in terms of tillage, soil organic matter restitution and PK fertilization. For each plot, we compared the QST indicators to the mean weight diameters from the three tests of Le Bissonnais (1996).

Shortly after immersion of soil in water, soil mass increases due to the rapid replacement of air by water in the macroporosity. Then soil mass reaches a maximum before decreasing due to disaggregation. The early increase in soil mass is positively correlated to SOC and sand content but negatively correlated to clay content, which supports the view that it is closely related to macroporosity. The early drop following this maximum is correlated to the fast-wetting test of Le Bissonnais (1996), which targets soil resistance to slaking. Soil susceptibility to slaking decreases with SOC content. A maximum correlation with the slow-wetting test of Le Bissonnais (1996) is obtained after about 300 seconds, which indicates that the effect of slaking on soil disaggregation decreases over time whereas that of clay dispersivity increases. Clay is positively correlated with the slope of the curve at each time step, which underlines the role of clay in disaggregation under water by physico-chemical dispersion and differential swelling. QST indicators have a great discriminating power between soils under contrasting tillage, which is in agreement with the common use of visual, qualitative slake tests for the promotion of conservation agriculture.

Clémence Pirlot, Benjamin Guillaume, Aurore Degré

Monitoring the temporal evolution of the soil structure of three innovative production systems in the field

Nowadays, it becomes urgent to develop innovative production systems in order to meet tomorrow's diets while being more environmentally friendly. The impact of emerging alternative agricultural practices on soil structure and hydraulic properties is poorly known or studied. Hydraulic properties such as water retention curve and hydraulic conductivity are the basis for water status modelling in soils. These properties are generally obtained by one-time laboratory measurements on a soil sample. Thus, the retention curve which establishes a relationship between water content and water potential is usually considered as constant in time. However, this single retention curve cannot imitate the water retention characteristics of soils under natural conditions in dynamic situations.

In this study, three innovative production systems are instrumented for hydrological monitoring. The three systems are designed to disrupt current agronomic trials and aim to produce the ingredients of tomorrow’s diets. The innovative systems are pesticide-free and have long-term rotations of 8 years with intercrops. The first system integrates the animal out of soil with only importations and exportations of animal products, the second in an agro-ecological interaction with grazing periods and the third is vegan. These systems are implemented in two different temporalities on the parcels of the University of Gembloux Agro-Bio Tech on a typical loamy soil of northern Wallonia.

The innovative systems were instrumented with 24 Teros 12 water content sensors and 24 Teros 21 water potential sensors from MeterGroup. Both types of sensor are robust, highly accurate and require little maintenance. The Teros 12 probes also measure soil temperature and salinity. Potential probes can measure potential over a wide range of values from -9 to -2000 kPa. All probes are connected to MeterGroup's ZL6 data loggers which allow real-time data collection. The water content and potential probes are placed in parallel in the first three soil layers at 30, 60 and 90 cm depth in 8 plots.

The simultaneous determination of both water content and water potential over time allows the temporal evolution of the hydrodynamic properties to be captured. Soil water retention and hydraulic conductivity curves will be measured over time under natural conditions for the three innovative systems. This monitoring system will then make it possible to quantify the temporal evolution of the structure of a loamy soil under the effect of agricultural practices and climate conditions. The data obtained will be used to diversify the agricultural practices represented in decision support models. The first year's results of the innovative monitoring systems will be presented at the SSSB thematic day on soil structure and compaction.

L. ten Damme, L. J. Munkholm, P. Schjønning, T. Keller, M. Lamandé

Accounting for traction effects for improved assessment of the risk of soil compaction

Arable soil is often exposed to high mechanical stresses during field operations. This bears a high risk of soil structure degradation, with adverse consequences for many soil processes and crop growth. Depending on the stress-state under the wheels, the risk of compression or distortion of the soil structure prevails. Hence, an accurate prediction of the complete state of mechanical stresses within the soil is needed to properly assess the overall risk of soil structure degradation. This, in turn, requires understanding the effects of loading characteristics on the stress distributions at the soil surface. Typically, soil compaction assessments consider only the risk of compression from the applied load but neglect tractive (pulling) forces. We investigated traction effects on both the vertical and (longitudinal) horizontal contact stress distributions in a field experiment, by comparing contact stress measurements under the rear wheel of a tractor that was either pulled (i.e., no traction) or pulling (i.e., with traction). We show how traction influenced tyre behaviour and the tyre-soil contact area, and how it considerably complicated the stress situations under the wheel. Traction enlarged the contact area, reduced vertical contact stress and increased horizontal contact stress. The changes highlight that traction is of critical importance in evaluating the risk of soil compaction, but it also calls for an improved understanding of the stress-strain relationship of soil under different loading conditions. Adaptation of soil compaction assessments to account for traction-effects requires further investigation of the relationship between drawbar pull and tyre behaviour, as well as the relation with and between vertical and horizontal contact stress.

Fien Vandekerchove, Tom Coussement, Pieter Janssens, Tommy D'Hose, Adriaan Vanderhasselt, Wim Cornelis

Remediation of subsoil compaction by deep tillage

About one third of the Belgian farmers reports problems with soil compaction. Especially subsoil compaction, a compacted layer under the topsoil, can cause yield losses. Once established, subsoil compaction is not easy to alleviate and demands for specific remediation techniques. An experimental field in Lubbeek, in Belgium, with a heavily compacted subsoil was used for this research. Half of the field is plowed conventionally and on the other half shallow no-till management is executed by the farmer. In September, in 2019, two strips in the non-tillage part were deep cultivated just below the tillage pan with the 7-shank subsoiler Steeno Profundus Z to break up the compacted layer. The remediation of the tillage pan did not quite worked out across the full width of the compacted layer, as demonstrated by pricking with a poking device. The tillage pan was still present at the places between the shanks of the subsoiler. The effect of the deep tillage on soil density and yield was studied by a comparison of the deep cultivated strips and the non-deep cultivated strips. The deep cultivated strips showed a reduced cone penetrologger resistance up to a depth of 40 centimeters and an increased grain yield of 0.5 ton/ha. Although in this experiment the deep tillage prior to the sowing of winter wheat in 2019 resulted in a remarkable decrease of the penetration resistance and an increase in grain yield it should be carried out with caution. In this case deep tillage was executed in dry conditions, in wet conditions it may result in a disruption of the soil structure.

Gaston MENDOZA VEIRANA, Philippe DE SMEDT

A theoretical improvement of soil pedophysical permittivity models

Geophysical techniques have a key role in the current challenges of detection and monitoring soil structure. The main advantages of conducting geophysical surveys are: rapid and non-invasive large-scale soil mapping, robust interpretation and qualitative characterisation. However, directly linking soil structure to geophysical properties as electrical conductivity or permittivity remains elusive. Some of the physical soil properties that characterise soil structure are porosity, pore connectivity and organic matter content. High dependence of geophysical properties on soil state properties as water content, temperature and salinity, is the most difficult aspect in the interpretation of soil structure. In the particular case of permittivity, around 85% of its magnitude can be explained by the water content of the soil. The functions which links soil to geophysical properties are called pedophysical models, and belong to different groups regarding its formulation type, as volume average and effective medium models. For pedological applications, successful interpretation of geophysical data for soil property quantification, depends on correct use of available pedophysical models, which often are limited in their predictive capacity.

In general, there are three problems that hinder the robust application of available pedophysical models. Firstly, these models often rely on soil properties that cannot be directly quantified in the laboratory or in the field (geometric parameters). These parameters are the cementation exponent (m), Roth's (α) exponent, and depolarizing factor (L). Secondly, they are normally fitted to the bulk permittivity, which tends to reduce the theoretical significance of the physical process involved. Finally, many of the currently available pedophysical models were originally developed for consolidated rocks, while its validity in non-consolidated conditions is still under discussion.
In this work, we will present a theoretical approach to improve relating permittivity, to specific soil properties as a basis to better perform inverse and forward modelling procedures. Both α and m are well known to control the structure of the modelled soil. While in general $\alpha = 1/m$ and particularly, $\alpha = 1$ assumes a soil structure in parallel components, and $\alpha = -1$ in series. Normally, α is assumed to be 0.5, which means homogeneously distributed components, which is not always the real scenario. To solve all the aforementioned challenges, here we present a theoretical approach to calculate α, m, and L. This is achieved by introducing empirical pedotransfer functions linking them with the clay content of the soil. As a result, modified volume average models (Linde and Roth equations) and effective medium models (Feng and Sen equation) exhibit the expected dependence on clay content, as previous well-tested empirical models for permittivity have shown. Furthermore, first field tests on Belgian agricultural soils showed that the proposed modifications exceeded the accuracy of current pedophysical models. Finally, this improved performance and understanding of the role of tuning parameters moves towards more compressive pedophysical models in soil complexity.

Cato Peiten & Jan Staes

Ecological and hydrological functioning of compacted and non-compacted topographical depressions in agroscapes

Soil degradation, more specifically compaction of the soil is a worldwide problem in both agricultural and non-agricultural areas. Soils are an irreplaceable, non-renewable natural resource with a high value because food production depends on more than 90% of these soils. Compaction of the soil results in an increased bulk density and a decline in the total soil porosity. As a result, air and water flow decline, as the microbial activity in the soil. Therefore, soil compaction can influence human society in different ways such as flooding effects, drought effects and productivity consequences.

Under natural conditions, local topographical depressions are hotspots for infiltration. Yet, under intensive soil tillage, these zones become compacted with reduced water permeability. Quite often they become problematic zones with stagnant water. This not only affects crop productivity, but also shifts water flows from infiltration/recharge towards evaporation and run-off. The first aim of this research is to understand the relationship between the compaction of the soil and the infiltration rate. We hypothesize that even on sandy soils, fine particulate matter will further clog micro-pores of the compacted soil layer. We will investigate two fields with compaction problems. Secondly, we need to understand the effects of different restoration and management options. To study this, we use 10 artificial, man-made infiltration zones with different compaction levels and remediation treatments. These research questions will be studied by using different field monitoring techniques. Soil compaction will be measured using a penetrologger. We will investigate the infiltration rates of topsoil and compacted layer by using a double ring infiltration test. Also, bulk density, soil biochemistry (NPC) and grain size distribution will be determined for different soil depths. Soil moisture content will be monitored by using soil moisture sensors and probes. For the 2 field sites, hydrology profiles will be mapped by using Electrical Resistivity Tomography (ERT).