Plant nutrition and soil compaction

Participants

Nikola Hejnová (University of South Bohemia, Czech Republic)
Michaela Pocová (University of South Bohemia, Czech Republic)
Emma Valadas (University of Aix-Marseille, France)
Deborah Cabes (University of Aix-Marseille, France)
Kaarel Kilki (Eesti Maaülikool, Estonian University of Life Sciences, Estonia)

Introduction

There are different kinds of farming systems all around the world and throughout ages. Crop rotation is one of them and has existed from the Roman times. At that time, they used two fields crop rotation, then the red clover (*Trifolium pratense)* was introduced to improve the soil fertility. In following decades, also potatoes were introduced in a three fields crop-rotation.

The aim of the crop rotation is to plant alternate groups of plants in the same field. The main functions are to add fertility or nutrients (clover), prevent pest and diseases from building-up, maintain soil organic matter and reduce erosion (1).

Our agricultural system has abandoned these agricultural ways, but now there is a tendency to bring back the crop-rotations which is more respectful to Earth's needs.

The Botanical garden of Ulm University has begun to work on three field rotation experiments. One of their goal is to understand how these farming systems influence soil nutrients and structure and the impact on plant nutrition. Especially, they are trying to explain the soil compaction due to the current way of farming (industrial and single-crop).

The practical work of the Summer school 2015 talked about the plant nutrition and soil compaction. For soil structure quality the aggregate stability is important as it is a key-stone factor of soil fertility and environmental problems. Major property, which affects the structure quality, is organic matter content. Different forms of organic fertilization with various decomposition rates have diverse impact on the whole aggregate stability over time. The crop-rotation system has also an impact on the soil organic carbon stock. According to recent studies, with different farming systems (conventional and organic) the effect of crop-rotation is more efficient in the organic systems because it improves naturally the quality and the stability of the soil. Another important factor to be studied is content of nitrogen in the soil as it is one of the most important components of plant nutrition. Different farming systems using green manure and cattle manure have various effects on relocation of nutrients to plants and can solve problems with low nitrogen availability.

The experiments took place in the Botanical garden of Ulm University. Three experimental fields were sampled and the aim was to distinguish impact of different crops (Field 1-spelt, Field 2-oat, upper Field 3-clover and lower Field 3-potato) on the spade test, which determines the soil aggregate structure quality, pH, capacity of infiltration and content of nutrients.

This report talks about the methods employed and describes the results. Analysis and discussion about results allows to make a conclusion about plant nutrition and soil compaction of experimental fields.

Material and Methods

Examined soil had high content of clay and was examined at the end of very dry summer period. Soil aggregate was dry, without any vegetation (except the control field) and hard to work with.

Aggregate structure quality (Spade test)

The test for aggregate structure evaluation was done in Botanical Garden of Ulm University. Three experimental fields and grassland area (control field) were examined on 14 September 2015, 15.00 - 17.00. Samples were dug out with spade and laid out on a plastic sheet (1x1m). For analyses, the visual soil structure assessment (VESS method; Appendix 1: Visual Evaluation of Soil Structure Score Chart) was used as well as earthworms macropores and roots were observed.

pH test

For the pH test, samples of soils from three experimental fields of Botanical Garden were dissolved in solution of 0.01 M $CaCl_2$ in a ratio of soil to solution of 1:2.5, shaken for short time and let solid aggregates to separate from the soil extract. Then the pH was measured using portable pH monitoring system (pH/Ion 340i from WTW, Weilheim, Germany). The experiment was done on 14 September 2015, 17:00-18:00. Average data from each field were further analyzed.

Water stable soil aggregates

The stability of water stable soil aggregates was examined in fields of winter wheat and potato with cover crops and manure addition (40 t/ha) and data were provided for further analysis. For measurement of water stable soil aggregates, the “wet sieving apparatus” was used. This apparatus was composed of different sieves filled with a certain amount of soil aggregates. Sieves were placed in a cans filled with water, which were shaking for a certain time. Then the cans were filled with NaOH dispersing solution and sieving process continued until only sand particles and roots remained on sieves. All destroyed aggregates in both cans were dried so the weight could be determined. With respect to the fact, that unstable aggregates break down more easily and therefore the mass of aggregates is lower, data from this “wet sieving apparatus” were used. The fraction stable was equal to the weight of soil obtained in the dispersing solution cans divided by the sum of the weights obtained in the dispersing solution cans and distilled water cans.
During the practical work, 2 different soil aggregates (Field 1 and Field 3) were put onto two sieves and shaken while merged in water for 3 minutes to see the impact of the water force on the soil aggregates. This method didn't give us any representative result but served for comparison of soil aggregates stability of two different fields.

Infiltration test

Infiltration test was done in Botanical Garden of Ulm University on 14 September 2015, 17.00 - 18.00. According to results from Spade test, experimental fields 1 and 3 was examined to observe the biggest differences. The experiment was repeated three times at each field. Metal square (25x25 cm) was inserted using hammer to the soil, 3l of water for each repetition was used and the time of infiltration was measured. Infiltration rate was measured

C and N

For the analysis soil was sampled in Spring 2014 at the beginning of the growing season. From four locations in each field samples from 0-5 cm soil depth were taken about four shovels of soil into each bag for each location. Field 1 was fertilized with 280 $dt \cdot ha^{-1}$ cattle manure in autumn 2013 and soil activation (10 $dt \cdot ha^{-1}$ 'Oscorna Bodenaktivator') was done in spring 2014. Field 2 was fertilized with green manure (mixing of soil with clover). Field 3 was fertilized with 280 $dt \cdot ha^{-1}$ cattle manure in autumn 2013. Nitrate was determined in extracts (0.01 M $CaCl_2$ solution) from field-moist soil with ion chromatography (702 Basic IC, Metrohm, Filderstadt, Germany). Ammonium was determined in extracts (0.01 M $CaCl_2$ solution) from field-moist soil with ion selective electrode (S7 on pH/Ion 340i, WTW, Weilheim, Deutschland). Contents of soil organic carbon and total nitrogen were determined in elemental analyzer (Euro EA C/N analyser, EuroVector, Milan, Italy) after acid fumigation to eliminate carbonates. The data from three fields each with four samples were provided and the average values were calculated.

Results

Aggregate structure quality (Spade test)

Structure quality varies between different fields and also between depth of the soil. According to VESS chart, the best structure is assigned with 1, the worst with 5. The best aggregate quality is always on the top layer (0 – 5 cm), the quality varies here between 1 – 2 quality points. In the control field quality of the top layer is the best, worse are in fields 1 and 2, where were grown spelt and oat. As the depth increases the compaction also increases and soil structure quality get worse. The worst structure quality is always in the deepest layer, being the worst in the lower Field 3. Results are shown in Figure 1 and detailed in Table 1.

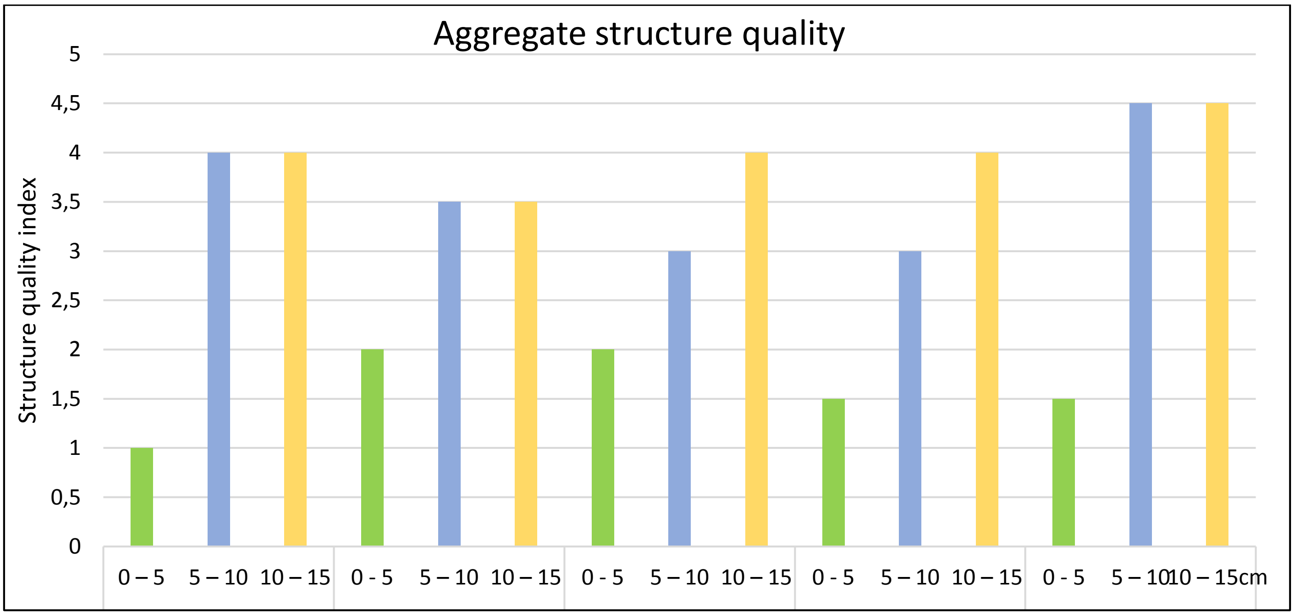


Figure 1.: Aggregate structure quality (green: layer 0-5cm, blue: layer 5-10cm, yellow: layer 10-15cm)

Table 1.: Aggregate structure quality according to Visual Evaluation of Soil Structure Score

	Crop	Layer (cm)	Structure			
			Size (cm)	Porosity	Quality	Comments
Control field	Grassland	0 – 5	< 0,6	Highly porous	1	Aggregates readily crumble with fingers
		5 – 10	> 10	Few macropores and cracks.	4	Effort to break aggregates with one hand
		10 – 15	> 10	Few macropores and cracks	4	Effort to break aggregates with one hand
Field 1	Spelt	0 - 5	0.2 – 7	Most aggregates are porous	2	Aggregates easy to break with one hand
		5 – 10	0,2 – 10 <	Macropores and cracks present.	3,5	Quite compact, break more horizontally. No roots structure (following worms channels
		10 – 15	0,2 – 10 <	Macropores and cracks present.	3,5	Quite compact, break more horizontally. No roots structure (following worms channels
Field 2	Oat	0 - 5	0.2 – 7	Most aggregates are porous	2	Aggregates easy to break with one hand
		5 – 10	0,2 – 10	Macropores and cracks present.	3	Most aggregates break with one hand. It breaks vertically.
		10 – 15	> 10	Few macropores and cracks	4	Effort to break aggregates with one hand
Field 3	Red-clover	0 - 5	< 0,6 – 7	Most aggregates are porous	1,5	Aggregates easy to break with one hand. Quite crumble with fingers
		5 – 10	0,2 – 10	Macropores and cracks present.	3	Most aggregates break with one hand. It break vertically.
		10 – 15	> 10	Few macropores and cracks	4	Requires considerable effort to break agregate with one hand
	Potato	0 - 5	< 0,6 – 7	Most aggregates are porous	1,5	Aggregates easy to break with one hand. Quite crumble with fingers
		5 – 10	> 10	Very low porosity. Few macropores and cracks.	4,5	Difficult to break up. Redox evidence along the roots.. Very compact
		10 – 15	> 10	Very low porosity. Few macropores and cracks.	4,5	Difficult to break up. Redox evidence along the roots.. Very compact

pH measurement

Mean value of pH from different fields is slightly acidic, but the pH values does not differ from each other as shown in the Figure 2.

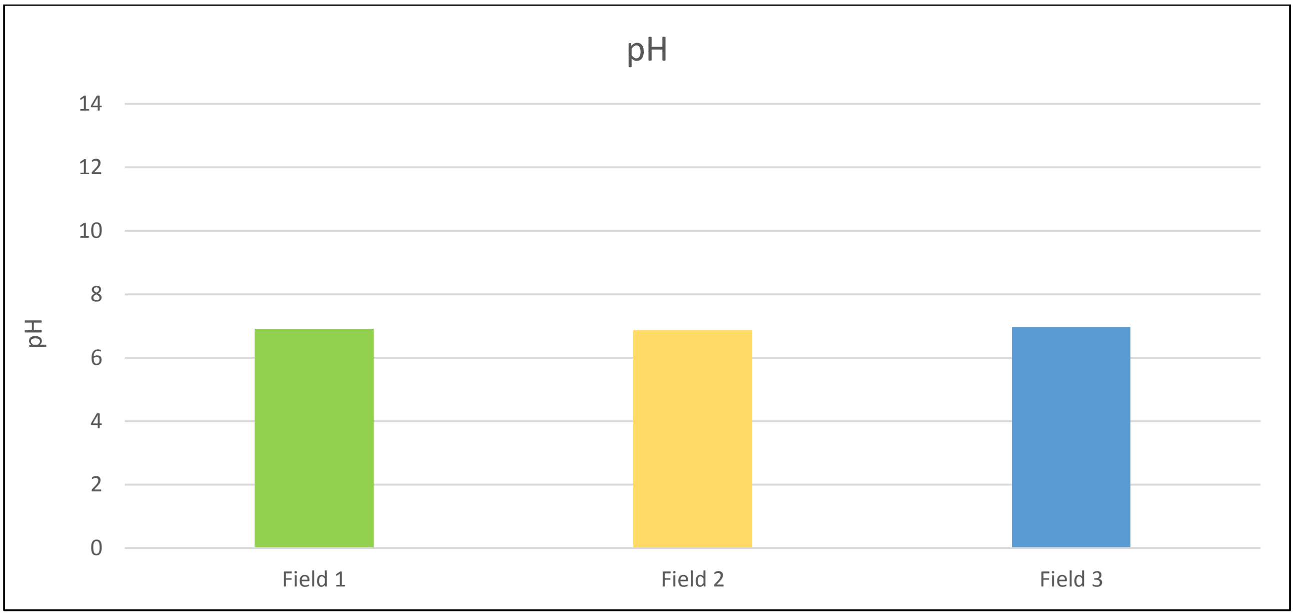


Figure 2.: pH measurement (Field 1: spelt, Field 2: oat, Field 3: red-clover+potato)

Water stable soil aggregates

From the mass of dried aggregates, the percentage were calculated. When cultivating potatoes, the water stable soil aggregates percentage (52.33 %) is statistically significantly lower (P = 0.02) then when cultivating winter wheat (55.58 %). Results are shown in Figure 3.

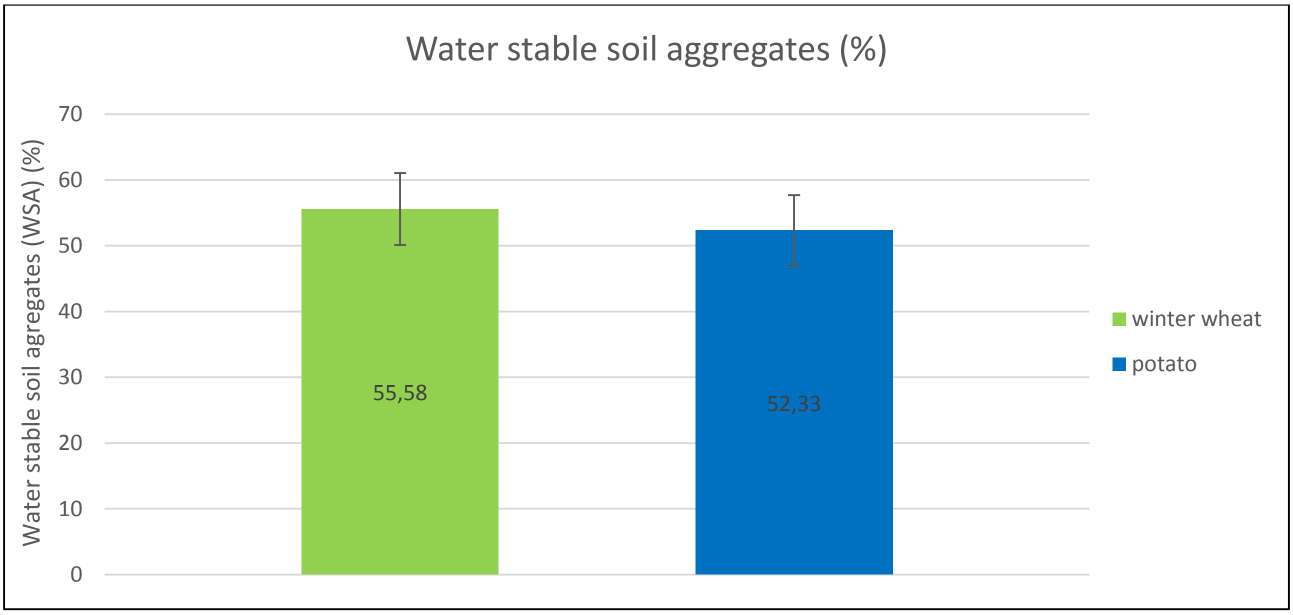


Figure 3.: Water stable soil aggregates in field experiment in Estonia in 2012

Infiltration test

The infiltration rate within the metal square (25x25cm) in Field 1 and Field 3 varies between values 10953.68 cm·day^{-1} and 10005.85 cm·day^{-1} respectively. Results shown in Figure 4 are not statistically significantly different (P = 0.87).

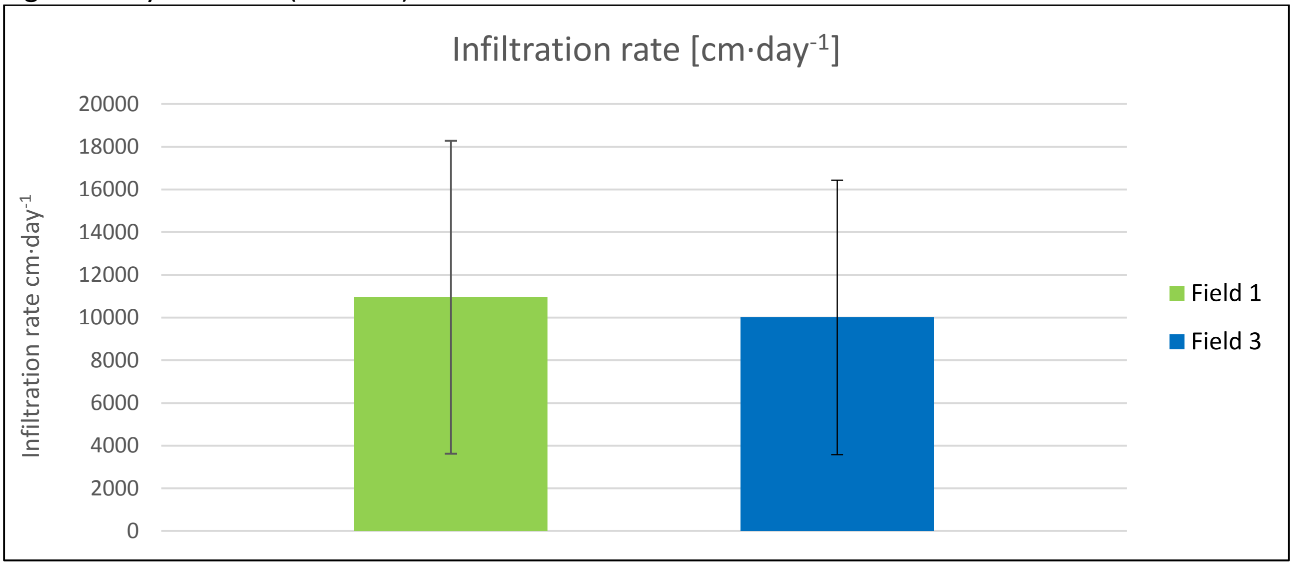


Figure 4.: Infiltration test (Field 1: oat, Field 3: potato)

Nutrition content

The mineral nitrogen content is higher when using soil activation as it was done in Field 1. There are only minor differences between nitrogen content of fields fertilized with green manure (Field 2) and cattle manure (Field 3) as shown in Figure 5 and Figure 6.
Field 1: spelt, Field 2: oat, Field 3: red-clover + potato

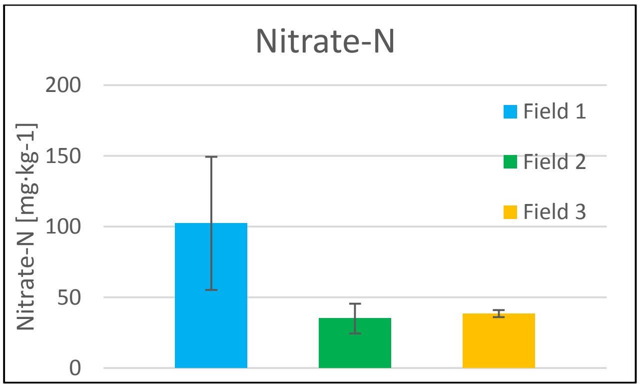


Figure 5.: Nitrate-N content

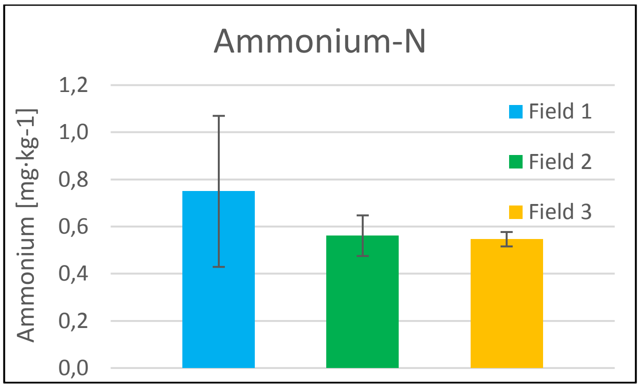


Figure 6.: Ammonium-N content

The percentage of total nitrogen and carbon is higher when using soil activation. Fields without this activation has lower percentage of total nitrogen and carbon as show Figures 7 and 8.

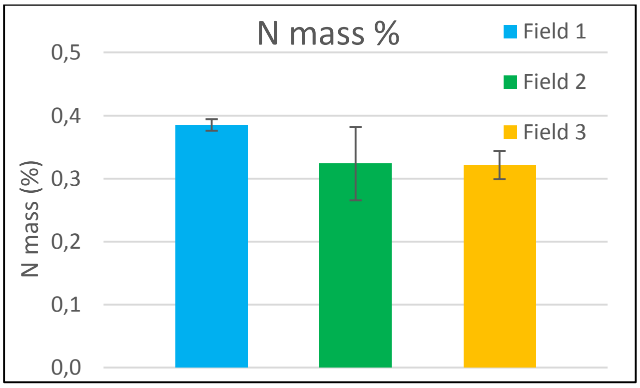


Figure 7.: Percentage of total nitrogen

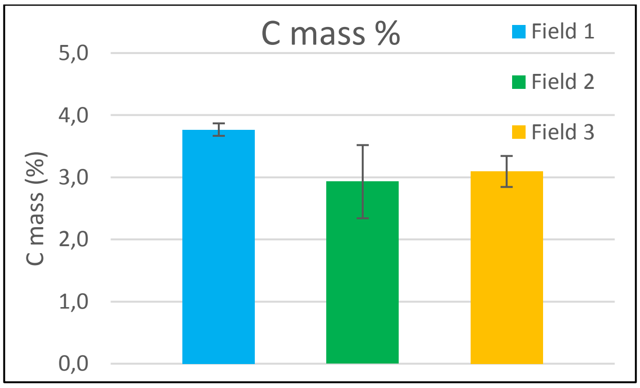


Figure 8.: Percentage of total carbon

Discussion

Soil aggregate structure quality is always better in the most upper than in lower layers as there is the smallest pressure. With respect to different crop on each field, the best impact has predictably no crop on control field (grassland) and the worst potatoes as they need the most intensive tillage.
Results of pH measurements show no statistically significant differences (insufficient number of repetitions and the mean from only two measurements was used). Nevertheless, pH of soils is more or less neutral or slightly acidic as is expected in fields with organic fertilization.
Infiltration rate of the Field 1 and Field 3 does not differ as there were only three repetitions, but we would have expected lower rate on the Field 3 as there is higher compaction of soil and worse quality of soil aggregate structure.
The mineral nitrogen content as well as total nitrogen content is higher when using soil activation as it was done in Field 1. The reason for this effect is probably due to activation of soil microorganisms which process organic carbon and nitrogen and provide nutrients available for plants. There are only minor differences between nitrogen content of fields fertilized with green manure (Field 2) and cattle manure (Field 2) as shown in Figure 5 and Figure 6. Differences do not appear probably because with both treatments the number of active microorganisms do not grow rapidly. Soil activation and following increase of microorganism activity cause also raise of total carbon content as is shown on Field 1 in Figure 8.

Conclusion

Results of experiments prove the impact of different farming systems with respect to the soil aggregate structure quality, pH, infiltration rate and mineral content. We are able to distinguish properties of each field with different crops and approve the positive effect of soil activation. Furthermore, we can see the effect of crop rotation and soil activation on plant nutrition and soil compaction.

Citations

(1) *http://www.soilassociation.org/whatisorganic/organicfarming/croprotations*

References

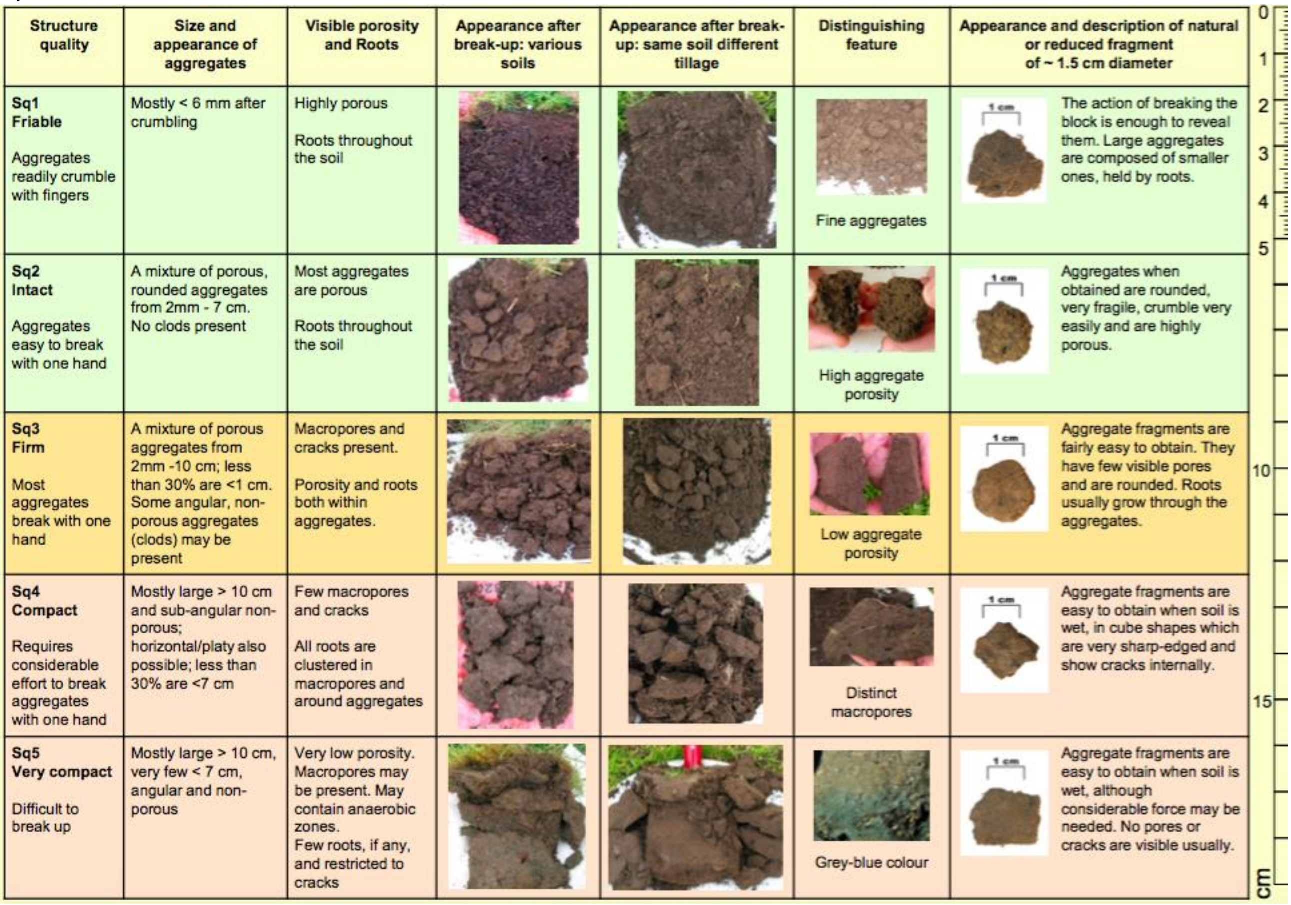
Abiven, S., Menasseri, S. & Chenu, C., 2009. The effects of organic inputs over time on soil aggregate stability - A literature analysis. *Soil Biology and Biochemistry*, 41(1), pp.1–12.

Kauer, K. et al., 2015. Soil carbon dynamics estimation and dependence on farming system in a temperate climate. *Soil and Tillage Research*, 154(October), pp.53–63.

Brozyna, M.A. et al., 2013. Effects of grass-clover management and cover crops on nitrogen cycling and nitrous oxide emissions in a stockless organic crop rotation. *Agriculture, Ecosystems & Environment*, 181, pp.115–126.

Appendices:

1) Visual Evaluation of Soil Structure Score Chart



Structure quality	Size and appearance of aggregates	Visible porosity and Roots	Appearance after break-up: various soils	Appearance after break-up: same soil different tillage	Distinguishing feature	Appearance and description of natural or reduced fragment of ~ 1.5 cm diameter
Sq1 Friable Aggregates readily crumble with fingers	Mostly < 6 mm after crumbling	Highly porous. Roots throughout the soil			Fine aggregates	1 cm. The action of breaking the block is enough to reveal them. Large aggregates are composed of smaller ones, held by roots.
Sq2 Intact Aggregates easy to break with one hand	A mixture of porous, rounded aggregates from 2mm - 7 cm. No clods present	Most aggregates are porous. Roots throughout the soil			High aggregate porosity	1 cm. Aggregates when obtained are rounded, very fragile, crumble very easily and are highly porous.
Sq3 Firm Most aggregates break with one hand	A mixture of porous aggregates from 2mm -10 cm; less than 30% are <1 cm. Some angular, non-porous aggregates (clods) may be present	Macropores and cracks present. Porosity and roots both within aggregates.			Low aggregate porosity	1 cm. Aggregate fragments are fairly easy to obtain. They have few visible pores and are rounded. Roots usually grow through the aggregates.
Sq4 Compact Requires considerable effort to break aggregates with one hand	Mostly large > 10 cm and sub-angular non-porous; horizontal/platy also possible; less than 30% are <7 cm	Few macropores and cracks. All roots are clustered in macropores and around aggregates			Distinct macropores	1 cm. Aggregate fragments are easy to obtain when soil is wet, in cube shapes which are very sharp-edged and show cracks internally.
Sq5 Very compact Difficult to break up	Mostly large > 10 cm, very few < 7 cm, angular and non-porous	Very low porosity. Macropores may be present. May contain anaerobic zones. Few roots, if any, and restricted to cracks			Grey-blue colour	1 cm. Aggregate fragments are easy to obtain when soil is wet, although considerable force may be needed. No pores or cracks are visible usually.

Source: http://www.sruc.ac.uk/downloads/file/1121/visual_evaluation_of_soil_structure_score_chart