Initial soil structural development under different types of vegetation

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Abstract

In September 2007, undisturbed soil cores were taken from experimental fields in The Netherlands and in Northern Sweden that had been under different types of vegetation during four years. From these cores, thin sections were prepared to study the initial soil structural development, changes in organic matter distribution and soil biological activity in relation to plant species growing on the plots. In the Swedish samples, differences between plots with *Poa pratensis* and *Phleum pratense* were striking. The *Poa* plot showed more filled biological burrows, more rounded soil aggregates and also the amount of fine disperse organic matter seemed higher, whereas under *Phleum* the individual mineral grains more often showed a thin coating of very fine organic matter. Plots with *Trifolium repens* showed a slightly less pronounced development when compared to the *Poa* plots. The plots of *Trifolium pratense* plots and the mixed plot showed highest amounts of biological activity and soil structural development.

The samples taken from the clay soils from The Netherlands showed similar biological activity under pure *Lolium perenne* and binary mixtures of *L. perenne* with the legumes *T. repens, T. pratense* and *Medicago sativa* from a trial that was not fertilized with N. A high activity of *Lumbricus festi* was shown by common excremental pellets in channels. In contrast, under *Achillea millefolium* in an adjacent N fertilised experiment, this activity was completely absent.

Introduction

Soil structure is essential for soil quality and biological productivity. A well structured soil contains macropores, which are important for the regulation of soil aeration and water infiltration. Soil structure is dependent on various factors such as soil texture, presence of Fe and Al-oxides and $CaCO_3$, the amount and type of organic matter, the presence of roots or mycorrhiza and soil fauna activity. Soil structure also shows temporal dynamics (Blackman, 1992) related to microbial and macrobial activity, and physical processes such as swelling,

shrinkage, and soil water dynamics (Bronick and Lal, 2005). Agricultural practices affect soil structure, and newly established vegetation influences soil structure dynamics. This may involve a complex interaction between below- and aboveground biomass production and soil biological activity. These factors play a major role in soil organic matter incorporation into the mineral soil and organic matter decomposition. In this study we looked at the first stages of soil structural development on experimental fields that were newly established in 2003 with pure and mixed grass and legume species in Northern Sweden and in The Netherlands.

Materials and methods

The Swedish fields were located near Piteå (65°21'N 21°23' E) on a fine sandy-to silty substratum and the Dutch fields near Wageningen (51°57' N 5°38' E) on a clayey substratum. Plots were located at 5 – 7 m.a.s.l. and were established in 2003 as part of a COST experiment. Swards were cut during 2003 – 2007.

The Swedish sampled plots consisted of four monocultures: *Phleum pratense*, *Poa pratensis*, *Trifolium pratense* and *Trifolium repens*, as well as a mixture of these four species, fertilized with 30 + 30 kg N/year and with P, K and S. The Dutch sampled plots were a pure *Lolium perenne* sward, and binary mixtures of *L. perenne* and either *T. pratense*, *T. repens* or *Medicago sativa*, all from a COST WG3 trial field that was not fertilized with N, only with P and K. Also, a pure herb plot with *Achillea millefolium* was sampled from an adjacent cutting trial that had been fertilized since 2003 with 30 + 21+ 21 + 21 kg N/year and with P and K. As no replicate treatments were sampled, outcomes are descriptive.

Undisturbed cores were sampled in small plastic containers (10 x 5 x 5 cm) and immersed in resin that was allowed to dry for 8 weeks. Next, thin sections were prepared from the impregnated soil blocks, which were cut and attached to a glass plate and then polished to a thickness of 30µ. The thin sections were studied with a polarizing petrographic microscope. For each of the different soils and vegetation covers, the thin sections were studied with regard to the presence and types of soil structural elements, type and occurrence of macropores, biological activity including rooting and soil macrofauna activity.

Results and Discussion

The soils of the Swedish site were lighter textured and a clear difference could be observed between the soil mineral particles and fine and course soil organic matter for all the thin sections studied. The soils of the Dutch sites had a much more heavy texture, not allowing a distinction between the organic matter and the fine silt and clay particles.

Table 1. Overview of observed soil characteristics in the thin sections.

Vegetation cover	Organic matter	Macropores	Burrows	Roots	Structural elements
Sweden					
Phleum pratense	+/-	-	+/-	+	+/-
Poa pratensis	+	+	+/-	++	+
Trifolium pratense	+	++	++	+	++
Trifolium repens	+	+/-	+/-	+	+
"4 species mixture"	+	++	+	+	++
The Netherlands					
Lolium perenne (*Lp*)	*	++	++	+/-	+
Lp + *T. pratense*	*	++	++	+/-	+
Lp + *T. repens*	*	++	++	+/-	+
Lp + *M. sativa*	*	++	++	+/-	+
Achillea millefolium	*	++	+	+/-	+

- absent, +/- few occurences, + common ocurrence, ++ abundant occurrence, * incorporated in plasma

More specific observations per soil cover type were:
Phleum pratense: Rounded small soil aggregates were present, but not very well developed and they showed faint borders. Soil macropores were not prominent and were mainly related to rooting channels. *Poa pratensis*: Clear aggregated soil structure, clear borders and dense rooting, more diffusely distributed organic matter. *Trifolium pratense*: The soil structure was best developed near the top of the soil, where surface organic matter was being incorporated into the soil and clear rounded soil aggregates were present, which become less clear downwards. *Trifolium repens*: Vague rounded and often welded soil aggregates, with elongated soil macropores instead of rounded macropores. The "four-species grass-clover mixture": Clear aggregates, but smaller along burrows and more rounded macropores.

For the Dutch experiments all soils under *Lolium perenne* showed a clear aggregation, but with a more sub-angular structure. Organic matter was not clearly recognizable as a separate fraction and clear macrobial burrows and excremental pellets were present. However, in the thin section of the soil under pure *Achillea millefolium* these last phenomena were not observed.

In contrast to our hypothesis, no differences were observed within the Dutch trial field between pure grass and grass-legumes, despite the lower productivity and N concentration of the grass vegetation. Also, the soils below *T. repens* and *T. pratense* grass-clover mixtures were similar, whereas in Sweden they did differ between pure stands of these clover species. For the moment we do not have a clear explanation for this finding.

Conclusions

Striking were the differences between the Swedish plots with *Poa pratensis* and *Phleum pratense*. Plots with *Trifolium repens* showed a slightly less pronounced development when compared to the *Poa pratensis* plots. The plots of *Trifolium pratense* plots and the mixed plot showed highest amounts of biological activity and soil structural development. The samples taken from the clay soils from The Netherlands showed a very clear difference in soil biological activity between unfertilised plots in a trial with *Lolium perenne* and mixtures with legumes on one hand and a N-fertilised *Achillea millefolium* plot on the other hand, but no differences among pure *L. perenne* and mixtures with legumes.

References

Blackman, J.D., 1992. Seasonal variation in the aggregate stability of downland soils. Soil Use and Management, 8: 142-150.

Bronick, C.J. and Lal, R., 2005. Soil structure and management: a review. Geoderma, 124: 3-22.