A scientific report of Molter Exchange visit: Response of soil to different farming practices

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Purpose of the visit

Arable land covers approximately one fourth of the global land area, but only half of it can be used efficiently for cultivation to feed the world population. Modern agriculture based on industrial principles has become highly productive but faces numerous environmental challenges. Organic agriculture has expanded as an alternative towards a more sustainable food production. This agricultural practice aims to maintain the key functions and ecosystems services of soils and to keep nutrients in a cycle through crop rotation. It is well known that the composition of soil organic matter (SOM) is altered under different management practices (e.g. tillage, manuring) and its turnover plays a pivotal role in the biogeochemical cycling of nutrients. SOM dynamics are mainly determined by its properties and the presence and physiology of soil organisms. A key to understand and define a sustainable agricultural soil system is to quantify the impact of different land management on soil biogeochemistry, with emphasis on nutrient turnover.

This study investigates the changes in SOM quantity and its composition as well as soil nutrient status resulting from different farming practices (organic vs. conventional) in Austria and Iceland. Further, soil macro- (> 250µm) and microaggregates (< 250µm), physicochemical soil properties and soil microbiology characterization are linked to the present soil structure. Specific aims of the study are:

- How do different farming practices (organic vs. conventional) influence soil?
- How does biodiversity differ in organic versus conventionally managed soils?
- How is microbiology linked to soil structure?

In order to understand the composition of the organic matter better, an exchange visit to the department of Soil Science at TUM Munich was carried out for 4 weeks in November 2012. Professor Ingrid Kögel-Knabner has a well-established laboratory dedicated to the study of SOM characteristics, and therefore it was beneficial to get in-depth knowledge of the methods available and professional comments on my on-going work.

Description of the work carried out during the visit

Soils investigated were selected from a total of four farms along cultivation age gradients under continental climate in Austria (Chernozems) and under sub-arctic climate in Iceland (Andosols). Topsoil (0-10 cm/0-15 cm) and subsoil (10-20 cm/30-40 cm) samples were collected in five replicates and gently crushed to pass a 5 mm sieve in order to gain < 5 mm aggregates. Bulk soil characteristics included e.g.: soil pH, BD, CEC,

C, N, Fe oxides, bacterial growth rates and biomass, fungal biomass, potential C and N mineralization, protozoa, nematodes, enchytreids and micro-arthropods.

A three-step combined physical and density fractionation procedure was carried out in triplicate for both farming approaches modified from Mueller *et* al. (2009) and Steffens *et al.* (2009). 20 g of air-dried soil (< 5 mm) was capillary-saturated with Na-polytungstate solution (1.8 g cm^{-3}) and allowed to settle overnight. The free light fraction (referred to as fLF) was extracted by aspiration via a water jet pump. This fraction was sieved at 20µm and the remaining solution subsequently filtered to 0.45um (referred to as fLF$_{small}$).To obtain LF occluded in aggregates (referred to as oLF), the subsequent heavy fraction was (> 1.8 g cm^{-3}) was treated by ultrasound. We used 7.5 J ml^{-1} in order to disrupt all macroaggregates and to protect the microaggregates as well as to minimize the production of artefacts following heavy ultrasonication. With a subsequent density fractionation step (Na-polytungstate solution, 1.8 g cm^{-3}), the oLF floating on the suspension was obtained after centrifugation (10 minutes at 4350 rpm). This fraction was sieved at 20µm and the remaining solution subsequently filtered to 0.45µm (referred to as oLF$_{small}$). All LF fractions were washed with deionized water until the electric conductivity dropped below 5 uS cm^{-1}. The residue of the density fractionation procedure – mineral particles and organomineral associations – was sieved at 250µm and 20µm to obtain macroaggregates and microaggregates (250-5000µm, 20-250µm and < 20µm). All aggregate fractions were washed with distilled water, oven dried at 60°C, weighed and ground for analyses. The light fractions (fLF, fLF$_{small}$, oLF, oLF$_{small}$) and aggregates (250-5000µm, 20-250µm, < 20µm) gained from the procedure will be characterized for C and N contents.

In total 48 samples (Table 1) of light fractions (fLF, oLF) gained from the combined physical and density fractionation procedure, and bulk soils were selected to be analysed by solid-state ^{13}C NMR spectroscopy (BRUKER DSX 200 NMR spectrometer, Bruker, Karsruhe, Germany), in order to determine the relative contributions of the various C groups. The analyses were carried out according to Steffens et al. (2009). The cross-polarization magic angle spinning (CPMAS) technique with a ^{13}C-resonance frequency of 50.32 MHz and a spinning speed of 6.8 kHz was applied. A ramped ^{1}H-pulse starting at 100% to 50% of the initial power was used during a contact time of 0.2 ms in order to circumvent spin modulation during the Hartmann-Hahn contact. Pulse delays between 0.4s and 1s were used for all spectra. Depending on the C contents of the samples, between 2000 and 250 000 scans were accumulated and a line broadening between 0 and 50 Hz was applied. The ^{13}C chemical shifts were calibrated relative to teramethylsilane (0 ppm). The relative contributions of the various C groups were determined by integration of the signal intensity in their respective chemical shift regions according to Knicker et al. (2005). The spectra were divided into four chemical shift regions, assignable to alkyl C (-10-45 ppm), O-alkyl-C (45 to 110 ppm), aryl-C (110-160 ppm), and carbonyl (aldehyde and ketone) and carboxyl C (160-220 ppm).

Table 1 Selection of samples analysed by solid-state ^{13}C NMR spectroscopy. Org76 denotes organic farm management since 1976, org80 since 1980, org94 since 1994 and org95 since 1995. Con denotes conventional farming.

	Org76	*Con76*	*Org95*	*Con95*	*Org80*	*Con80*	*Org94*	*Con94*
Top soil	*0-15cm*	*0-15cm*	*0-15cm*	*0-15cm*	*0-10cm*	*0-10cm*	*0-10cm*	*0-10cm*
fPOM	x	x	x	x	x	x	x	x
oPOM	x	x	x	x	x	x	x	x
Bulk soil	x	x	x	x	x	x	x	x
Sub soil	*30-40cm*	*30-40cm*	*30-40cm*	*30-40cm*	*10-20cm*	*10-20cm*	*10-20cm*	*10-20cm*
fPOM	x	x	x	x	x	x	x	x
oPOM	x	x	x	x	x	x	x	x
Bulk soil	x	x	x	x	x	x	x	x

Description of the main results obtained

The preliminary results for Brown Andosols and Histic Andosols show differences between the two soils types, fractions analysed and farm management (Table 2). Clear differences were observed between fPOM and oPOM, Alkyl-C and Aryl-C being lower in fPOM compared to oPOM whereas O-Alkyl-C and Carboxyl-C were higher in fPOM compared to oPOM. Alkyl-C/O-Alkyl-C indicates how decomposed the fraction is, higher values indicating higher decomposition. In general fPOM was less decomposed as oPOM, as would be expected. fPOM resembles the fresh plant input material, whereas oPOM resembles material that is occluded in the aggregates and therefore having undergone more decomposition. The differences between organically and conventionally managed soils were relatively low, but trends could be observed (Table 2).

Table 2 Integrated chemical shift regions obtained by ^{13}C CPMAS NMR spectroscopy for the extracted free particulate organic matter (fPOM) and occluded particulate organic matter (oPOM) conducted on organically (org80) and conventionally (con80) managed Brown Andosols and organically (org94) and conventionally (con94) managed Histic Andosols. Years (80, 94) denote the start of the organic management.

Sample			Alkyl-C	O-Alkyl-C	Aryl-C	Carboxyl-C	Alkyl-C/O-Alkyl-C
					%		
Org80	0-10 cm	fPOM	16.28	57.69	14.88	11.15	0.31
		oPOM	19.75	52.12	17.89	10.23	0.34
	10-20 cm	fPOM	14.33	58.49	16.75	10.43	0.26
		oPOM	18.43	55.34	16.58	9.65	0.36
Con80	0-10 cm	fPOM	17.07	52.86	17.70	12.37	0.33
		oPOM	18.70	55.69	15.90	9.71	0.34
	10-20 cm	fPOM	13.05	55.29	19.90	11.76	0.24
		oPOM	19.20	53.84	17.84	9.12	0.39
Org94	0-10 cm	fPOM	25.50	46.76	15.35	12.40	0.52
		oPOM	25.25	48.83	14.45	11.46	0.56
	10-20 cm	fPOM	25.86	45.33	15.72	13.09	0.56
		oPOM	27.74	46.17	15.59	10.50	0.64
Con94	0-10 cm	fPOM	30.49	43.53	15.10	10.88	0.68
		oPOM	30.45	44.70	14.64	10.20	0.73
	10-20 cm	fPOM	34.27	41.05	13.92	10.76	0.59

oPOM	27.96	41.74	15.73	14.57	0.68

The preliminary results for Chernozems showed similar differences than in Andosols (Table 3). The results presented here will be interpreted in more detail when the results from bulk soils are also available (see future collaboration below). The SOM characterization will also be linked to other soil properties that have already been measured.

Table 3 Integrated chemical shift regions obtained by ^{13}C CPMAS NMR spectroscopy for the extracted free particulate organic matter (fPOM) and occluded particulate organic matter (oPOM) conducted on Chernozems on organically (org76) and conventionally (con76) managed potato fields and organically (org95) and conventionally (con95) managed wheat fields. Years (76, 95) denote the start of the organic management.

Sample			Alkyl-C	O-Alkyl-C	Aryl-C	Carboxyl-C	Alkyl-C/O-Alkyl-C
					%		
Org76	0-15 cm	fPOM	15.02	49.29	23.91	11.78	0.34
		oPOM	20.06	44.56	23.91	11.47	0.45
Con76	0-15 cm	fPOM	16.65	48.70	23.08	11.58	0.34
		oPOM	19.38	48.50	22.20	9.92	0.40
Org95	0-15 cm	fPOM	15.81	52.98	21.38	9.84	0.30
		oPOM	18.14	45.95	24.92	10.99	0.39
Con95	0-15 cm	fPOM	16.03	43.41	26.47	14.09	0.37
		oPOM	19.04	43.54	27.08	10.34	0.44

Future collaboration with host institution

Of the selected 48 samples, the bulk soil samples required HF treatment prior to the NMR analyses. This has been carried out by the lab personal at TUM in the beginning of December and these samples will further be analysed by NMR by Dr. Markus Steffens by end of the year 2013. In addition, the selected subsoil (30-40 cm) samples from Chernozems will be analysed by Dr. Steffens. Results of all the samples will be discussed with Dr. Steffens, before final interpretations and conclusions to be made.

Projected publications to result from the grant

The research carried out during the exchange visit yielded results which will be incorporated into two publications that will be included in the dissertation of Taru Lehtinen. The preliminary titles for the publications are:

- "Response of soil to different farming practices in Icelandic permanent grasslands"
- "Response of soil to different farming practices in Austrian croplands"

The first publication is planned to be finalized by end of April 2013 and the second by end of September 2013. It is also planned to present the results at two conferences in 2013, at "Soil Carbon Sequestration for climate, food security and ecosystem services" and at "5th Nordic Geographer´s Meeting", both held in Reykjavik, Iceland. The support received from the European Science Foundation (ESF) for the activity entitled "Natural

molecular structures as drivers and tracers of terrestrial C fluxes" will be acknowledged and a reprint will be sent to the ESF Secretariat as soon as the publications are available.

References

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