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An ecosystem approach to assess soil quality in organically and conventionally managed farms in Iceland and Austria

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Abstract

Intensive agricultural production can be an important driver for the loss of long-term soil quality. For this reason, the European Critical Zone Observatory (CZO) network adopted four pairs of agricultural CZO sites that differ in their management: conventional or organic. The CZO sites include two pairs of grassland farms in Iceland and two pairs of arable farms in Austria. Conventional fields differed from the organic fields in the use of artificial fertilizers and pesticides.

Soils of these eight farms were analysed in terms of their physical, chemical, and biological properties, including soil aggregate size distribution, soil organic matter contents, abundance of soil microbes and soil fauna, and taxonomic diversity of soil microarthropods.

In Icelandic grasslands, organically farmed soils had larger mean weight diameters than the conventional farms, while there were no differences in the Austrian farms. Organic farming did neither systematically influence organic matter contents or composition, nor soil carbon and nitrogen contents. Also soil food web structures, in terms of presence of trophic groups of soil organisms, were highly similar among all farms, indicating a low sensitivity of trophic structure to land use or climate. However, soil organism biomass, especially of bacteria and nematodes, was consistently higher in organic farms than in conventional farms. Within the microarthropods, also taxonomic diversity was systematically higher in the organic farms compared to the conventional farms. This difference was found across countries, farm-, crop- and soil-types. The results do not show systematic differences in physical and chemical properties between organic and conventional farms, but confirm that organic farming can enhance soil organism biomass, and that microarthropod diversity is a sensitive and consistent indicator for land management.

1 Introduction

Soil is considered as one of the most important natural resources for life on Earth. Soil processes govern a wide array of ecosystem services, such as the provision of food, feed and fibre, carbon sequestration, hydrological regulation, and contaminant attenuation (Costanza et al., 1997).

Mostly due to human activities, soil quality, here defined in terms of the soil's ability to deliver ecosystem services, is being drastically reduced in many locations worldwide (Vitousek, 1997). Global loss of soil ecosystem services is due to many different environmental threats, such as climate change, intensive agricultural production, and environmental pollution.

In order to come up with effective strategies to protect and enhance soil quality, the Critical Zone Observatory (CZO) network was established across the USA and Europe (Anderson et al., 2008). The CZO network is an internationally coordinated interdisciplinary research effort to better understand the chemical, physical and biological processes that shape the Earth's surface and supports the terrestrial life on the planet.

As part of the CZO research effort, the European Commission has provided funding for a large multi-disciplinary research project: Soil Transformations in European Catchments (SoilTrEC). This project aims to understand and quantify the physical, chemical, and biological processes that are critical to soil ecosystem functions and services in the European CZO's (Bernasconi et al., 2011; Menon et al., 2014).

The European CZO consists of sites along soil formation gradients (Austria, Switzerland, Iceland), along a soil degradation gradient (Greece), along a pollution gradient (Czech Republic), and of agricultural sites differing in soil managements (Austria, Iceland) (Menon et al., 2014; Banwart et al., 2011).

This paper presents the soil quality assessment as carried out for the agricultural CZO sites in Europe. The agricultural sites have been chosen as part of the CZO network, because intensive agricultural production is an important driver of loss in soil quality, e.g. due to decreased organic matter contents. Intensive agriculture may also cause environmental problems, e.g. nitrate leaching to nearby natural ecosystems, and pesticide contamination of surface and groundwater (Skinner et al., 1997). The agricultural CZO sites consist of in total 8 farms: four grassland farms in Iceland, of which two are conventional and two organic, and four arable farms in Austria, of which two are conventional and two organic. The organic farms differed from the conventional farms in that only organic fertilizers were applied and no pesticides were used. At the conventional grassland farms in Iceland some organic fertilization was used in addition to the artificial inorganic fertilizers. At the conventional arable farms in Austria only artificial inorganic fertilizers were applied together with pesticides. The central idea behind the organic farming practice is that the community of soil organisms will become more important in terms of delivering important soil ecosystem functions, especially in terms of soil structure formation, soil carbon dynamics and nutrient mineralisation, and the suppression of soil borne diseases (Birkhofer et al., 2008). The present study investigated biological, physical, and chemical soil quality parameters, focused on soil structure formation, soil organic matter dynamics and nutrient cycling, and the soil as a habitat for species rich communities.

Soil structure is an important attribute of soil quality. Soil aggregates, and the pores between the aggregates provide space, water and oxygen, and thereby create habitats for a large diversity in soil organisms (Anderson, 1978; Sulkava and Huhta, 1998). Soil organisms play an important twofold role in determining soil structure formation. Firstly, micro-organisms produce exudates (polysaccharides) that enhance aggregation of soil particles and fungal hyphae also physically bind soil particles (de Gryze et al., 2005; Wright et al., 2007; Tisdall and Oades, 1982). Secondly, the soil fauna plays a role in creating a stable soil pore structure through moving in the soil and the formation of faecal pellets (Oades, 1993; Lee and Foster, 1991; Jastrow and Miller, 1991; Lavelle et al., 2006). Furthermore, soil structure is strongly linked to soil organic matter (SOM) dynamics as incorporation of SOM into the soil aggregates “protects” it from microbial decomposition, thereby stabilizing SOM content and sequestering carbon in the soil, with potentially positive effects on plant productivity (Golchin et al., 1994).

Soil organic matter is an essential component of soil quality, governing processes like carbon sequestration, nutrient cycling, water retention and soil aggregate turnover. Soil organic matter dynamics are driven by land use through root-turnover, deposition of plant residues, and decomposition by the soil microbial populations. Soil organisms are known to play important roles in SOM dynamics (Wardle et al., 2004; de Ruiter et al., 1994; Lavelle et al., 2006) by decomposing SOM. This process mineralises carbon (C) and nutrients like nitrogen (N), making these available for plant uptake. To understand the role of soil organisms in decomposition processes, SOM has been defined in terms of fractions based on decomposability (Golchin et al., 1994). The idea behind this fractioning is that the labile fractions, such as dissolved and particulate organic matter, are better available for biological decomposition, contribute more to soil structure formation, and are more sensitive to soil management than more stable fractions such as lignin (Beare et al., 1994; Tisdall and Oades, 1982).

The soil as habitat for species rich communities has increasingly received attention for the intrinsic and functional value of soil biodiversity. High levels of biodiversity are thought to enhance stability of soil functions and services against perturbations and disturbances, and the suppression of soil-born pests and diseases (Griffiths et al., 2000; Altieri, 1999; Barrios, 2007). Soil biodiversity is also recognised as a sensitive biological indicator for effects of environmental change and disturbance (Wardle et al., 1995; Ritz et al., 2009; Pattison et al., 2008; Ponge et al., 2006). One of the key indicator groups are the soil microarthropods, because these are abundant, functionally diverse, and respond to a variety of ecological and environmental factors (Gardi and Parisi, 2002; Parisi et al., 2005). In addition, the area covered during the life-cycle is representative of the examined site and their life histories permit insights into soil ecological conditions (Gardi et al., 2009).

The results presented in this paper are from a field survey at all agricultural CZO sites, in which soil was analysed in terms of its physical, chemical, and biological properties. Soil physical and chemical measurements included soil aggregate size fractions (< 20, 20–250, 250–5000 µm), soil organic matter contents and distribution (based on different organic matter fractions), nutrient contents, including nitrogen (N), phosphorus (P), and potassium (K), and soil pH. Soil biological measurements included the presence and abundance of soil microbes (bacteria, fungi) and soil fauna (protozoa, nematodes and microarthropods), representing the main taxonomic groups and trophic levels in the soil food web. In addition we measured the taxonomic richness and diversity within the group of microarthropods, and vegetation diversity.

2 Methods

2.1 Site description

The soils analysed were sampled from the eight agricultural CZO research sites of which four under sub-arctic (Iceland) and four under continental (Austria) climatic conditions. The four farms in Iceland were grassland farms, the four in Austria were arable farms practicing crop rotations (Table 1). In each country two farms applied “organic” practices and two farms applied “conventional” practices. The organic farms differed from the conventional farms in that only organic fertilizers were applied and no pesticides. At the conventional grassland farms in Iceland some organic fertilization was used in addition to the artificial inorganic fertilizers. The organic fields in Iceland were ploughed the first three consecutive years when grasslands were renewed to apply green manure, whereas conventional fields were ploughed only once. At the conventional arable farms in Austria only artificial inorganic fertilizers were applied together with pesticides. In Iceland, one pair of organic and conventional farms (in the South West) were on Histic Andosols; the other pair (Southern Iceland) on Haplic (Brown) Andosols. In Austria, one pair of organic and conventional farms grew potatoes as current crop; the other pair grew winter wheat. All Austrian farms were situated in the Marchfeld, southeast of Vienna, on Haplic Chernozems. Farm properties are listed in Table 1.

2.2 Sampling scheme

Samples were taken in May–June 2011 (0–10 cm in Iceland, 0–15 cm in Austria). At each farm three plots were selected at which all measurements were carried out; the plots were separated by approximately 30–40 m. At each plot, mixed soil samples (ca. 1 kg) were taken by use of a 8 cm diameter corer for microbial (bacteria, fungi), microfaunal (protozoa, nematodes), soil chemical and physical measurements, and a 5 cm diameter corer for the mesofauna (enchytraeids and microarthropods). In the grasslands on Iceland vegetation diversity was estimated by application of four 2 m line transects at all farms, except for the conventional farm in Southern Iceland, for which the vegetation data were supplied by the farmer. A line-intercept method was applied and four 2 m-length tapes were laid out from the sampling point, each tape separated by 90°. Species were recorded each time a plant species intercepted the tape, or when a group of equally mixed plant species occurred (e.g. Kent and Coker, 1992). Vegetation richness was calculated as the total number of plant species present on the transects.

2.3 Soil physicochemical measurements

Particle size distribution (clay content) was determined with a combined sieve and pipette method after removal of organic matter with hydrogen peroxide and dispersion by reciprocal shaking with sodium metaphosphate solution for 12 h (Burt, 1992). Soil pH was measured electrochemically (Microprocessor pH Meter pH196 WTW, Weilheim, Germany) in H_2O at a soil : solution ratio of 1 : 2.5 (Burt, 1992). Calcium (Ca) content was measured by flame atomic absorption spectrophotometry (Perkin-Elmer 2100). Plant available phosphorous (P) and potassium (K) were determined by calcium-acetate-lactate(CAL) extraction (ÖNORM L1087).

A three-step procedure was carried out to fractionate soil aggregates and organic matter. Free particulate organic matter (fPOM, 20–5000 µm) was separated using Na-polytungstate solution (density of 1.8 $\mathrm{g\,cm^{-3}}$). To obtain particulate organic matter occluded in aggregates (oPOM, 20–5000 µm), the heavy fraction of soil aggregates

($>1.8\,\mathrm{g\,cm^{-3}}$) was treated by ultrasound ($8\,\mathrm{J\,mL^{-1}}$) which disrupted the macroaggregates and protected the microaggregates (Lehtinen et al., 2014). With a subsequent density fractionation step (Na-polytungstate solution, $1.8\,\mathrm{g\,cm^{-3}}$), the oPOM floating on the suspension was obtained after centrifugation (10 min at 4350 rpm). POM fractions were washed with deionized water until the electric conductivity dropped below $5\,\mathrm{\mu S\,cm^{-1}}$ (Steffens et al., 2009). The residue of the density fractionation procedure – mineral particles and organo-mineral associations – was sieved at 250 and 20 µm to obtain macroaggregates (250–5000 µm) and microaggregates (20–250 µm and < 20 µm). All aggregate fractions were washed with deionized water until the electronic conductivity dropped below $5\,\mathrm{\mu S\,cm^{-1}}$; subsequently they were oven dried at 100 °C and weighed. The weights of aggregates were corrected for the sand content of the same size (for aggregates 20–250 µm, and > 250 µm), in order to exclude a sand particle from being weighed as an aggregate (Six et al., 2000; Lehtinen et al., 2014). Mean weight diameter (MWD) of the sand-corrected aggregates was calculated according to Kemper and Rosenau (1986) as the sum of the geometric means of aggregate sizes multiplied by the respective fraction.

Total carbon (TC) and nitrogen (TN) in bulk soil, aggregates and POM fractions were quantified by dry combustion using an elemental analyzer (Carlo Erba Nitrogen Analyser 1500). For the analysis, 5 g of sieved (< 2 mm) soil without visible roots and litter was ground to size < 63 µm for homogenization and 1–1.5 mg soil was used for the analysis. Total organic carbon (TOC) was calculated as the difference of total and inorganic C, measured as carbonate C by treating 0.5–2 g of fine-ground soil material with 10 % HCl acid and quantifying the evolved CO_2. Hot water extractable carbon (HWC) was measured as the C present in solution after 16 h at 80 °C, while water soluble carbon (WSC) was measured after 30 min at 20 °C (Ghani et al., 2003). Recalcitrant carbon was determined as the difference between TOC and HWC, while labile carbon was defined as the sum of WSC and HWC. Potentially mineralisable nitrogen (PMN) was measured as the increase in NH_4 during one week of anoxic incubation in slurry at 40 °C (Canali and Benedetti, 2006). Potential carbon and nitrogen mineralisation were measured by incubation of 200 g of homogenised and sieved soil for 6 weeks at 20 °C (Bloem et al., 1994). Results of the first week (disturbance) were not used. N mineralisation was calculated from the increase in mineral N (nitrate and ammonium) between week 1 and week 6. O_2 and CO_2 were measured weekly using a gas chromatograph (Carlo Erba GC 6000) equipped with a hotwire detector (HWD 430) and helium as carrier gas. For the statistical analyses, we took the average of weekly rates over the 5 week period after the first week.

2.4 Soil food web measurements

The soils were analysed for the presence and abundances of the major taxonomic groups of soil organisms: bacteria, fungi, protozoa, nematodes, enchytraeids, and microarthropods. Within these taxonomic groups we defined "trophic groups" based on diet and life-history traits, following the method of Moore et al. (1988). Abundances were transformed into estimates of biomass based on body-size information, and expressed in units of kg carbon per hectare for the 0–10 cm top soil layer.

Bacterial biomass, fungal biomass, leucine incorporation, and protozoa were measured after a pre-incubation period of 2 weeks at 20 °C. Bacterial numbers and cell volumes and fungal hyphal lengths were measured in microscopic slides (Bloem and Vos, 2004). Bacterial cell numbers and volume were determined using confocal laser scanning microscopy combined with an image analysis system. The data were transformed into bacterial biomass, taking a specific carbon content of $3.20 \times 10^{-13}\,\mathrm{g\,C\,\mu m^{-3}}$ (Bloem et al., 1995). For the transformation of fungal hyphal lengths to fungal biomass we described fungal volume as a cylinder with spherical ends ($V = (\pi/4)W^2(L-(W/3))$ where V = volume (μm^3), L = length (µm) and W = diameter (µm)), with a mean hyphal diameter of 2.5 µm and a specific carbon content of $1.30 \times 10^{-13}\,\mathrm{g\,C\,\mu m^{-3}}$. Bacterial growth activity was estimated by measuring incorporation rates of [^{14}C] leucine (Bloem and Bolhuis, 2006).

Two trophic groups of protozoa (flagellates and amoebae) were measured using the most probable number method (Bloem et al., 1994). Numbers were converted to biomass assuming a spherical shape with diameters of 4.6 and 9.1 µm for flagellates and amoebae respectively, and a volume to C conversion factor of $1 \times 10^{-13}\,\mathrm{C\,\mu m^{-3}}$ (Bloem et al., 1994).

Soil nematodes were counted in 9 mL soil solution extracted by Oostenbrink elutriators from 100 g soil. Numbers per trophic group (bacterivore, fungivore, herbivore, omnivore, predaceous) were derived from species composition in the samples (Bongers, 1988). Nematode biomasses were calculated using fresh weight data from Didden et al. (1994), and taking a moisture content of 75 % and a carbon content of 40 % (Didden et al., 1994).

Enchytraeid numbers were obtained through a (wet) extraction using Baermann funnels with increasing light and heat each 30 min after the start of the extraction during a total extraction time of 3 h. Enchytraeid numbers were converted into biomass C by measuring the average fresh weight and taking a moisture content of 85 % and a carbon content of 50 % of the dry weight (Didden et al., 1994).

Microarthropods were extracted during a 1 week period with Tullgren funnels, and processed using the gel-based sub-sample methodology (Jagers op Akkerhuis et al., 2008). Total numbers were recorded, while species composition was assessed in subsamples of 100 individuals following Jagers op Akkerhuis et al. (2008), and references therein. Microarthropod biomass C was calculated based on individual weights, moisture contents and C contents from Didden et al. (1994).

Microarthropod diversity was quantified in three ways: absolute number of taxa present, by the Shannon's Diversity Index (H), and by the Pielou evenness index. For the Shannon's Diversity Index (H) we used the following formula:

$$H = -\sum_{\mathrm{i}=1}^{S} (p_\mathrm{i} \cdot \ln p_\mathrm{i})$$

in which p_i is the proportion of the total biomass (S), i.e. the relative biomass, of species i. For the Pielou evenness index (J) we used the formula

$$J = \frac{H}{\ln(N)}$$

in which H represents Shannon's Diversity Index, and N the total number of taxa present.

2.5 Statistics

The data were from eight farms that differed in various ways: climate, soil type, soil management and crop. There were no real replicates, as the triplicate measurements for all variables were from plots within the same farm. Hence, we performed a nested two-way ANOVA with two factors: country (Iceland – Austria) and farm management (organic – conventional), and farm as a random nested factor. By taking country as a factor, we separated the grassland (Iceland) from the cropland (Austria) farms. By including farm as a random nested factor, we were able to test differences in soil type (Iceland) and crop type (Austria). All data were log-transformed to obtain homogeneity of variances. Statistical analyses were carried out using SPSS (20.0.0) and R (2.15.2).

3 Results

3.1 Soil physicochemical measurements

Many physicochemical soil characteristics varied strongly over farms, as a consequence of different soil types, soil management, and climatic conditions (countries) (Table 2). The most pronounced differences were found between the soils from the two different countries. Clay content was lowest in the Haplic Andosols in Iceland ($p = 0.001$). Soils in Austria were alkaline (pH 8) as a result of the much higher Calcium content of the Chernozems, whereas the Andosols in Iceland had a lower pH (pH 5–6). Plant available nutrients (P, K) were much higher in the farms in Austria than in Iceland, due to the strong nutrient retention in Andosols ($p = 0.001$ and $p = 0.026$, Table 2).

For the mean weight diameter (MWD) of soil aggregates we found a difference between farm management: in the organic farms in Iceland the MWD was more than twice as high as in the conventional farms ($p = 0.173$). The opposite was found in Austria, although here the differences were relatively small (Table 2). Mean weight diameter was positively correlated to fungal (Pearson test, $r = 0.739$, $p = 0.006$) and bacterial biomass (Pearson test, $r = 0.664$, $p = 0.019$), whereas no significant correlations were found with organic matter parameters. The content of free particulate organic matter (fPOM) and occluded particulate organic matter (oPOM) varied strongly between the different countries and between soil types within countries. The fPOM content in the Icelandic Histic Andosols (358–444 g kg^{-1}) was higher than in the Icelandic Haplic Andosols (23–33 g kg^{-1}) and all Austrian soils (2–3 g kg^{-1}, $p < 0.001$). The oPOM content showed a similar pattern. The high contents of particulate organic matter in Iceland, especially at the Histic Andosols reflect the very high content of organic carbon (contents of TOC, HWC and WSC) and nitrogen (both total N and PMN) in these soils: total organic C (TOC, $p = 0.010$), hot water extractable C (HWC, $p = 0.072$), total N ($p = 0.020$) and potentially mineralisable N (PMN, $p = 0.022$) were all higher in Iceland compared to Austria. The farms on Histic Andosols in Iceland had a lower C mineralisation rate (2157–2654 $\text{kg ha}^{-1}\ \text{years}^{-1}$), but a much higher potential N mineralisation rate (746–1010 $\text{kg ha}^{-1}\ \text{years}^{-1}$) than the farms on Haplic Andosols in Iceland; these differences were even more pronounced compared to the farms in Austria ($p = 0.032$).

The way organic carbon (OC) and nitrogen (N) were distributed over aggregate sizes and organic matter fractions, was also different between farms. At the organic farm on Haplic Andosol in Iceland macroaggregates > 250 µm contributed the greatest quantities of OC and N to bulk soil (65 % OC, 65 % for N). On both farms on Histic Andosols in Iceland the fPOM fraction contributed the largest quantities of OC and N to bulk soil (61 and 69 % for OC, 56 and 62 % for N, respectively). At the winter wheat farms in

Austria microaggregates 20–250 µm contributed the greatest quantities of OC and N to bulk soil (46 and 50 % for OC; 45 and 45 % for N, respectively), while at the potato farms in Austria the microaggregates < 20 µm contributed the greatest quantities of OC and N to bulk soil (51 and 46 % for OC; 51 and 47 % for N, respectively).

3.2 Soil food web measurements

Based on presence-absence data of the soil organisms, we constructed soil food web diagrams for all farms (Fig. 1). These diagrams were very similar; despite differences in climatic conditions, crop type, soil type, and soil management, most of the trophic groups were present at all farms. Some of the trophic groups were only present at some farms, including predaceous nematodes, bacterivore mites, herbofungivore mites and Diplura (Fig. 1, Table 3).

Trophic groups showed differences in abundances (Table 2) and species composition (see microarthropod diversity). Bacterial biomass was consistently higher in organic farms in both countries, although the differences were not statistically significant. Bacterial activity, measured as the incorporation rate of [^{14}C] leucine, did not differ significantly between farms. Fungal biomass did not show a consistent pattern over all farms, although fungal biomass tended to be lower in the farms on Histic Andosols. Protozoa (amoebae, flagellates) showed no clear pattern in biomass (Table 3).

Nematode biomass was consistently higher in organic farms than in conventional farms, regarding all trophic groups, although differences were only significant for herbivorous nematodes ($p = 0.035$) and total nematode biomass ($p = 0.015$, Fig. 2a).

Microarthropod abundance varied strongly from just over 12 000 m^{-2} to over 200 000 m^{-2}. We did not find systematic differences between country or management type. Total microarthropod biomass was much higher in the conventional farms in Iceland compared to all other farms (Fig. 2c). Total Acari biomass was significantly higher in conventional farms compared to organic farms ($p = 0.023$, Table 3). The higher biomass of omnivorous mites ($p = 0.012$) and, to a lesser extent, also the consistently higher Acari biomass ($p = 0.023$) in conventional farms was fully accounted for by the high biomass of the astigmatid mite *Tyrophagus similis. T. similis* counted for 98.1 and 99.7 % of the total omnivorous mite biomass, and 59.8 and 69.7 % of the total microarthropod biomass at the conventional grasslands in Iceland, while this species was (nearly) absent at all other farms (Table A1). In Iceland, Collembolan biomass was higher in conventional farms compared to organic farms (Table 3).

3.3 Microarthropod species identity and diversity

In total, 82 taxa of microarthropods were found in our study sites, with an overall larger diversity in Austria than Iceland. All farms showed striking differences in the microarthropod species composition: only three taxa out of the 82 taxa were present at all farms (the mesostigmatid *Arctoseius cetratus* and the prostigmatids *Eupodes sp.* and *Pygmephorus sp.*). In Iceland 27 taxa were found that did not occur in Austria, and 37 taxa were found only in Austria, while only 18 taxa were found in both countries. The number of taxa only occurring in organic farms amounted to a total of 33, either in Iceland (14 taxa) or in Austria (18 taxa), while 1 taxon (*Tyrophagus sp.*) was found in organic farms both in Iceland and in Austria. Moreover, 12 taxa were found only in conventional farms, of which 5 in Iceland and 7 in Austria. The organic wheat farm in Austria had a remarkably high microarthropod taxonomic richness with 34 taxa present, of which 12 unique for that farm. Especially the conventional grasslands in Iceland had low taxonomic richness of only 18 taxa (HiAcon) and 17 taxa (HaAcon).

Organic farms had a significantly higher microarthropod diversity measured according to all diversity measures; for the Shannon index ($p = 0.027$, Fig. 3a) and the Pielou index for evenness ($p = 0.008$, Fig. 3b) differences were statistically significant, for taxonomic richness it was not statistically significant ($p = 0.122$, Fig. 3c). The higher diversity in organic farms was also tested by ordering farms by species richness where the organic farms ended up significantly higher in the table than conventional farms (Wilcoxon rank sum test, $p = 0.012$).

4 Discussion

In this study we investigated soil quality parameters (physical, chemical, and biological) in the organically and conventionally managed farms that are part of the European Critical Zone Observatory (CZO) network.

4.1 Soil aggregate formation, soil organic matter and soil nutrient cycling

Regarding soil structure formation and soil organic matter, the different farming practices, organic versus conventional, did not reveal systematic differences in many physical and chemical soil properties. The soil aggregate size distributions were different between the organic and conventional farms in Iceland, but there were no differences found in Austria. Other management practices such as tillage (Beare et al., 1994) may have obscured effects of organic amendments. For example, the arable farms in Austria applied a crop rotation with a yearly tillage. As soil aggregates are sensitive to soil tillage (Beare et al., 1994, 1997; Six et al., 2000), it could be expected that the differences between organic and conventional arable farms are comparably small. In contrast, the Icelandic grasslands had not been tilled for 7–15 years (Table 1). Also the addition of higher quantities of organic amendments was expected to have a positive effect through enhanced soil biological activity, in terms of aggregate forming substances. However, the observed higher mean weight diameters in the organic farms on Iceland could not be linked to higher organic matter contents, e.g. in terms of total carbon, or a difference in organic matter composition. It was though significantly correlated with fungal and bacterial biomass. Both bacteria and fungi produce soil binding compounds like polysaccharides, which are important for production of relatively small aggregates (de Gryze et al., 2005; Wright et al., 2007). Soil fungi are assumed to be especially more important for the formation of larger soil aggregates through entanglement by hyphae (Tisdall and Oades, 1982).

Regarding the soil carbon and nitrogen we also did not detect systematic differences between organic and conventional farming. C and N mineralisation rates as well as the measured C and N pools (TOC, HWC, Total N, PMN, Table 2) were quite similar in organic and conventional farms. Also bacterial activity was similar in organic and conventional farms. The present results partly confirm the results reported from earlier studies (van Diepeningen et al., 2006; Bloem et al., 2006). In summary, C and N contents and dynamics between organic and conventional farms have been studied in three different ways: factorial field experiments on a single farm, pairwise comparisons of farms (as in our study), and comparisons across larger number of farms ($n = 10$–20). In a factorial field experiment at an arable farm, the Lovinkhoeve in the Netherlands, Bloem et al. (1994) found a higher C and N mineralisation in an integrated field compared to a conventional field, probably as a result of organic amendments. Similarly, in a grassland farm in the Netherlands, a higher N mineralisation and potentially mineralisable N has been measured when organic fertilizer was applied, while no difference has been found in C mineralisation (van Eekeren et al., 2009). Also Poudel et al. (2002) found a higher potential N mineralisation in organically managed crop rotation fields than in conventional fields in California, but here the organic fields also grew legumes between growing seasons, enhancing N availability. In Switzerland, Birkhofer et al. (2008) observed a lower N mineralisation when only mineral fertilizer was used, while C mineralisation did not show differences between the fields. Also in this study, no differences were found between organic fields and fields that received both artificial fertilizers and organic manure, similar to the Icelandic grasslands in the present study. Thus, in factorial experiments on a single farm, the effects of organic management on soil N dynamics are quite clear, while the effects on C dynamics are not consistent. In an example of a pairwise comparison between organic and conventional arable farms in the Netherlands, van Diepeningen et al. (2006) have observed lower nitrate levels in organic farms, with no differences in total organic C, organic N, or total N. Conventional farms in that study also applied organic manure in addition to artificial fertilizers, which is comparable to the grasslands in Iceland, where we also did not find differences in total organic C and total N. In an example of a comparison across larger number of farms in the Netherlands ($n = 10$–20), Bloem et al. (2006) showed higher C and N mineralisation rates in organic grasslands compared to conventional grasslands, but not in the comparison between organic and conventional arable farms. Thus, our study confirms the notion that when C and N dynamics are studied on a larger scale with more farms involved, more factors are variable and differences between organic and conventional farming are less prominent.

4.2 Soil food web structure

The trophic structure of the soil food webs showed a high similarity; nearly all trophic groups were present at all farms. This indicates that the trophic structure of the soil food webs was neither very sensitive to management, nor to climate, soil type, and farm type. Biomasses of the different organisms, however, differed between farms.

Microbial biomass, as the sum of bacteria and fungi, was consistently higher in organic farms, although not statistically significant. The higher microbial biomass, especially bacterial biomass, is in line with previous studies that have compared organic and conventional farms (Bloem et al., 2006; Hole et al., 2005; Haubert et al., 2009; Mäder et al., 2002; Birkhofer et al., 2008; van Diepeningen et al., 2006; Gunapala and Scow, 1998). Other studies also have reported a higher microbial activity (Bloem et al., 2006; Hole et al., 2005), which we did not find in our study. We did not find differences in fungal biomass, in contrast with some previous results (Yeates et al., 1997; de Vries et al., 2006), but in line with others (Shannon et al., 2002). These results might be due to the fact that added organic amendments in organic farming are generally easily degradable and therefore enhance mainly bacterial biomass and activity (Hole et al., 2005).

We observed a significantly higher total nematode biomass in organic farms. This is in agreement with the higher nematode abundance found in organic grasslands in Wales (Yeates et al., 1997). It is also in agreement with the higher nematode abundance that was found after addition of organic manure to wheat fields in Switzerland (Birkhofer et al., 2008). The higher biomasses in organic farms were observed for all trophic groups of nematodes, but the differences were only statistically significant for total nematode biomass and herbivorous nematodes. Hence, our results confirm the notion that nematodes are sensitive to farming type and profit from the addition of organic amendments.

Microarthropod biomass measurements did not reveal systematic differences between farm types, although within Iceland total microarthropod biomass was highest in the conventional farms. We also did not find a difference between the grassland farms on Iceland and the arable farms in Austria. This is a bit unexpected, because it is frequently observed that microarthropod biomass is higher in grasslands compared to arable farms, because ploughing decreases microarthropod biomass, which is more intense for root/tuber crops such as potato (Vreeken-Buijs et al., 1998). In our study, the organic grasslands in Iceland were however ploughed in the three consecutive years when the field was renewed which, together with the colder climatic conditions, may explain the low biomass of microarthropods (Sjursen et al., 2005).

We found a statistically higher biomass of mites (Acari) in the conventional farms compared to the organic farms. We lack an explanation for this somewhat unexpected result. For example, it is opposite to the results from an earlier study, showing higher abundances of Acari in organic grasslands compared to conventional grasslands in Wales (Yeates et al., 1997). The similar collembolan biomass at organic and conventional farms is in line with the results of Birkhofer et al. (2008) in Switzerland, but in contrast with the results of Bardgett et al. (1993), who reported higher collembolan biomass in the organic fields. The two species of Collembola that are by far the most abundant in the study of Bardgett et al. (1993) were much less abundant (*Onychiurus procampatus*) or even absent (*Folsomia quadrioculata*) in our data, which may explain the difference between the studies.

4.3 Microarthropod diversity

The most systematic difference we found in the comparison between organic and conventional farming, was the higher microarthropod diversity in the organically managed farms. This difference was found across countries, farm types (grassland versus arable), crop and soil type. This finding is in agreement with Doles et al. (2001) and Macfadyen et al. (2009).

Factors known to enhance soil microarthropod diversity include plant litter diversity leading to a higher microhabitat and resource diversity (Hansen and Coleman, 1998) and plant species identity (Wardle et al., 2005). In Iceland, organic grasslands had a higher plant diversity than conventional grasslands, which supports the hypothesis that plant diversity enhances belowground microarthropod diversity. In the arable farms in Austria, where plant diversity does not play a role, the application of artificial fertilizers may have reduced the microarthropod diversity (Siepel and Van de Bund, 1988).

Soil microarthropod diversity is described as a sensitive biological indicator for effects of environmental change and disturbance on soil quality (Gardi and Parisi, 2002; Parisi et al., 2005; Gardi et al., 2009). Our results confirm that the taxonomic diversity of the soil microarthropods was sensitive to differences in farm type and management system.

If we look at these findings in terms of the role of biodiversity in ecosystem functioning, we see that the higher microarthropod diversity in organic farms did neither result in differences in the food web structure, nor yielded higher ecosystem services, such as soil fertility or C sequestration. This is in agreement with Setälä et al. (2005), who argue that the functional importance of individual groups is rather high at coarse (trophic group) level but low at species level, and that effects of species diversity on ecosystem functioning are most likely found in studies with a very low species richness and therefore a low functional redundancy. Nevertheless, in our study microarthropod diversity was found to be a sensitive and consistent indicator for land management. At present, determining microarthropod diversity is a relative intensive activity, but when the current progresses in methodology lead to faster and cheaper analyses, such as barcoding extracted microarthropods, soil microarthropod diversity will become more cost-effective and an even more valuable indicator for soil quality.

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Table 1. Characteristics of the farms studied in Iceland (conventional farms IceHaAcon and IceHiAcon, organic farms IceHaAorg and IceHiAorg) and Austria (conventional farms AusPOTcon and AusWWcon, organic farms AusPOTcon and AusWWorg). Vegetation richness in the Icelandic farms is included (values represent mean and standard deviation between brackets).

Country	Iceland	Iceland	Iceland	Iceland	Austria	Austria	Austria	Austria
Type	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic
Farm	IceHaAcon	IceHaAorg	IceHiAcon	IceHiAorg	AusPOTcon	AusPOTorg	AusWWcon	AusWWorg
Coordinates	N 64°02′33.78 W 20°12′18.06	N 64°20′38.46 W 21°36′15.78	N 64°20′32.82 W 21°34′54.42	N 64°20′42.90 W 21°36′14.22	N 48°17′09.3 E 16°41′20.9	N 48°17′08.7 E 16°41′24.5	N 48°14′15.3 E 16°50′09.0	N 48°14′15.3 E 16°50′09.0
Average temperature (°C)[a]	3.6	3.6	4.3	4.3	9.5	9.5	9.5	9.5
Average rainfall (mm)[a]	1120	1120	800	800	525	525	525	525
Soil type	Haplic andosol	Haplic andosol	Histic andosol	Histic andosol	Chernozem	Chernozem	Chernozem	Chernozem
Land use type	Grassland	Grassland	Grassland	Grassland	Crop rotation (potato)	Crop rotation (potato)	Crop rotation (winter wheat)	Crop rotation (winter wheat)
Last tillage	1995	2003	1998	1996	2010	2010	2010	2010
Organic Fertilizers								
- Manure ($t\,ha^{-1}$)	20	35	30	30				20[b]
- Compost ($t\,ha^{-1}$)		35		10		10		
- Cattle urine ($t\,ha^{-1}$)		50						
- Total N ($kg\,N\,ha^{-1}$)	40	970	60	260				
- Total C ($t\,C\,ha^{-1}$)	0.8	8.6	1.2	3.2				
Inorganic fertilizers								
- Total N ($kg\,ha^{-1}$)	80		300		95		138	
- Total P ($kg\,ha^{-1}$)	20				50		21	
- Total K ($kg\,ha^{-1}$)	20				130		21	
Vegetation richness	4	7 (0)	4 (0)	8 (1.73)	–	–	–	–

[a] Iceland: Icelandic Meteorological Office database, 2012; Austria: Zentralanstalt für Meteorologie und Geodynamik, 2014; [b] last applied in 2010.

Table 2. Soil physicochemical properties and biologically mediated processes at the farms studied in Iceland (conventional farms IceHaAcon and IceHiAcon, organic farms IceHaAorg and IceHiAorg) and Austria (conventional farms AusPOTcon and AusWWcon, organic farms AusPOTcon and AusWWorg). Values represent mean and standard deviation between brackets per farm, measured in the topsoil (0–10 cm). Significance values of the factors farming (organic vs. conventional), country (Iceland vs Austria) and the interaction-effect are shown.

Country	Iceland	Iceland	Iceland	Iceland	Austria	Austria	Austria	Austria	Effect	Effect	Effect
Type	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Farming	Country	Interaction
Farm	IceHaAcon	IceHaAorg	IceHiAcon	IceHiAorg	AusPOTcon	AusPOTorg	AusWWcon	AusWWorg	*p* value	*p* value	*p* value
Clay content (%)	5.23 (1.28)	5.43 (1.12)	15.93 (10.04)	13.72 (2.66)	17.02 (0.94)	16.70 (1.62)	13.93 (0.24)	14.40 (1.76)	0.995	0.165	0.997
pH (H_2O)	5.76 (0.22)	5.88 (0.17)	5.07 (0.13)	5.17 (0.17)	7.92 (0.04)	7.95 (0.02)	8.04 (0.02)	8.12 (0.03)	0.757	0.001	0.934
Ca (kg ha^{-1})	74.8 (7.29)	96.2 (10.2)	129 (20.0)	190 (38.9)	37868 (6963)	42176 (1102)	110542 (5014)	107955 (10926)	0.955	0.001	0.999
P (kg ha^{-1})	3.75 (1.42)	3.43 (0.68)	8.10 (2.23)	4.79 (1.17)	180.77 (38.54)	164.88 (40.63)	124.17 (8.12)	123.07 (13.58)	0.785	0.001	0.859
K (kg ha^{-1})	15.86 (14.88)	28.04 (21.70)	7.97 (6.64)	6.02 (1.16)	317.86 (69.63)	109.30 (19.53)	161.01 (38.62)	281.92 (24.77)	0.758	0.026	0.698
MWD[a] (mm)	8.27 (3.75)	19.91 (4.10)	4.75 (1.20)	11.70 (0.84)	9.98 (4.57)	7.64 (2.37)	4.50 (2.41)	3.82 (2.24)	0.236	0.169	0.125
fPOM[b] (g kg^{-1})	33.12 (15.45)	23.46 (1.31)	444.12 (142.39)	358.52 (66.42)	2.20 (0.97)	2.20 (0.59)	2.63 (0.22)	3.54 (0.49)	0.867	0.185	0.865
oPOM[c] (g kg^{-1})	5.69 (1.43)	7.22 (1.71)	72.67 (50.11)	29.74 (18.37)	2.01 (0.32)	2.06 (0.37)	1.69 (0.35)	2.32 (0.42)	0.595	0.203	0.584
TOC[d] (kg ha^{-1})	47354 (7192)	51597 (6967)	88317 (21026)	78723 (5452)	22093 (799)	27792 (6113)	28004 (968)	25654 (2503)	0.893	0.010	0.876
HWC[e] (kg ha^{-1})	716.8 (123.1)	904.1 (76.05)	1931 (564.9)	2135 (243.0)	502.4 (110.6)	488.5 (58.10)	565.8 (34.08)	702.5 (59.91)	0.696	0.072	0.905
WSC[f] (kg ha^{-1})	11.77 (21.23)	36.79 (1.44)	55.85 (5.29)	65.21 (8.28)	–	–	–	–			
Total N (kg ha^{-1})	3128 (676)	3439 (554)	5615 (1333)	5476 (477)	1990 (101)	2232 (171)	2074 (279)	2093 (116)	0.782	0.020	0.968
PMN[g] (kg ha^{-1})	58.46 (16.83)	71.21 (5.71)	152.45 (62.55)	162.33 (18.22)	13.67 (10.49)	12.46 (4.20)	21.37 (7.39)	42.70 (14.45)	0.577	0.022	0.839
C min[h] (kg ha^{-1} years^{-1})	5069 (238.6)	5113 (353.9)	2654 (641.8)	2157 (1601)	3263 (506.4)	4467 (282.3)	4412 (148.9)	4544 (261.5)	0.914	0.507	0.572
N min[i] (kg ha^{-1} years^{-1})	282.6 (96.90)	215.9 (52.40)	745.9 (280.7)	1010 (82.75)	89.46 (67.10)	26.21 (65.86)	90.98 (28.47)	97.41 (10.82)	0.680	0.032	0.624

[a] Aggregate size distribution (mean weight diameter); [b] free particulate organic matter; [c] occluded particulate organic matter; [d] Total Soil Organic Carbon; [e] hot water extractable Carbon; [f] Water soluble Carbon; [g] potential mineralisable Nitrogen; [h] carbon mineralisation rate; [i] Nitrogen mineralisation rate.

Table 3. Biological parameters at the farms studied in Iceland (conventional farms IceHaAcon and IceHiAcon, organic farms IceHaAorg and IceHiAorg) and Austria (conventional farms AusPOTcon and AusWWcon, organic farms AusPOTcon and AusWWorg): biomasses (kg C ha^{-1}) of the trophic and taxonomic groups in the soil food webs, bacterial activity and microarthropod diversity. Numbers represent mean and standard deviation between brackets, measured in the topsoil (0–10 cm), nd: not detected. Significance values of the factors farming (organic vs. conventional), country (Iceland vs Austria) and the interaction-effect are shown.

Country Type Farm	Iceland Conventional IceHaAcon	Iceland Organic IceHaAorg	Iceland Conventional IceHiAcon	Iceland Organic IceHiAorg	Austria Conventional AusPOTcon	Austria Organic AusPOTorg	Austria Conventional AusWWcon	Austria Organic AusWWorg	Effect Farming *p* value	Effect Country *p* value	Effect Interaction *p* value
Bacteria	27.70 (3.41)	38.00 (3.51)	17.89 (6.32)	30.04 (9.62)	55.49 (14.14)	68.48 (15.49)	53.80 (9.86)	94.88 (22.20)	0.062	0.005	0.920
Leu (pmol g^{-1} h^{-1})*	−10.27 (15.01)	45.44 (27.95)	126.5 (64.52)	133.8 (37.45)	163.5 (78.72)	90.41 (9.38)	101.8 (8.30)	152.7 (50.74)	0.509	0.294	0.476
Fungi	16.93 (8.70)	16.61 (2.79)	4.33 (1.82)	8.67 (1.76)	18.34 (2.54)	19.54 (6.94)	21.14 (9.32)	15.00 (3.02)	0.736	0.187	0.522
Amoebae	0.63 (0.24)	1.03 (0.37)	0.82 (0.49)	4.03 (2.03)	3.02 (1.28)	1.63 (0.09)	2.68 (1.26)	3.04 (2.47)	0.315	0.101	0.122
Flagellates	0.62 (0.35)	0.31 (0.06)	0.21 (0.02)	1.85 (1.43)	0.53 (0.26)	0.49 (0.18)	1.08 (0.30)	0.78 (0.12)	0.655	0.587	0.448
Bacterivore nematodes	0.07 (0.03)	0.08 (0.02)	0.12 (0.01)	0.19 (0.02)	0.15 (0.09)	0.20 (0.09)	0.13 (0.03)	0.13 (0.04)	0.411	0.348	0.945
Fungivore nematodes	0.003 (0.003)	0.014 (0.013)	0.001 (0.001)	0.023 (0.007)	0.021 (0.019)	0.033 (0.028)	0.055 (0.032)	0.030 (0.008)	0.589	0.049	0.262
Herbivore nematodes	0.11 (0.03)	0.13 (0.05)	0.07 (0.03)	0.12 (0.03)	0.09 (0.03)	0.21 (0.02)	0.03 (0.02)	0.15 (0.02)	0.035	0.700	0.169
Omnivore nematodes	0.13 (0.03)	0.13 (0.08)	0.02 (0.02)	0.02 (0.03)	0.02 (0.02)	0.06 (0.11)	0.01 (0.02)	0.17 (0.09)	0.403	0.811	0.337
Predaceous nematodes	nd	nd	nd	0.09 (0.11)	nd	nd	nd	nd	0.374	0.374	0.374
Total nematode biomass	0.33 (0.02)	0.35 (0.03)	0.21 (0.01)	0.44 (0.14)	0.28 (0.10)	0.51 (0.22)	0.23 (0.05)	0.48 (0.10)	0.015	0.606	0.335
Enchytraeids	0.79 (0.94)	0.13 (0.07)	0.09 (0.09)	0.33 (0.26)	0.15 (0.21)	nd	nd	0.01 (0.01)	0.538	0.153	0.896
Bacterivore mites	nd	nd	nd	nd	0.002 (0.002)	0.007 (0.009)	nd	nd	0.562	0.275	0.562
Fungivore mites	0.001 (0.001)	0.033 (0.040)	0.004 (0.003)	0.003 (0.003)	0.001 (0.001)	0.001 (0.001)	0.009 (0.008)	0.025 (0.036)	0.310	0.914	0.710
Herbofungivore mites	nd	nd	0.001 (0.002)	0.001 (0.001)	nd	nd	nd	0.002 (0.001)	0.466	0.868	0.732
Nematovore mites	0.006 (0.011)	0.030 (0.027)	nd	0.003 (0.004)	nd	0.001 (0.001)	0.005 (0.005)	0.002 (0.003)	0.434	0.316	0.350
Omnivore mites	0.52 (0.78)	0.01 (0.01)	0.80 (0.56)	0.02 (0.01)	0.07 (0.05)	0.03 (0.01)	0.16 (0.04)	0.04 (0.004)	0.012	0.050	0.037
Predaceous mites	0.058 (0.074)	0.013 (0.013)	0.076 (0.044)	0.029 (0.014)	0.008 (0.006)	0.005 (0.002)	0.037 (0.005)	0.060 (0.027)	0.357	0.393	0.177
Total Acari	0.88 (0.60)	0.06 (0.02)	0.58 (0.85)	0.07 (0.06)	0.08 (0.05)	0.03 (0.01)	0.21 (0.02)	0.13 (0.06)	0.023	0.069	0.053
Fungivore collembola	0.134 (0.071)	0.058 (0.041)	0.305 (0.186)	0.112 (0.057)	0.052 (0.085)	0.021 (0.015)	0.039 (0.012)	0.188 (0.014)	0.606	0.274	0.192
Herbofungivore collembola	0.009 (0.009)	nd	0.101 (0.106)	0.009 (0.004)	0.010 (0.008)	0.003 (0.005)	0.010 (0.012)	0.012 (0.009)	0.307	0.416	0.357
Herbivore collembola	0.02 (0.027)	0.034 (0.022)	0.023 (0.029)	0.004 (0.004)	0.014 (0.008)	0.001 (0.001)	0.002 (0.004)	nd	0.569	0.131	0.750
Total Collembola	0.43 (0.31)	0.12 (0.05)	0.16 (0.08)	0.09 (0.06)	0.08 (0.08)	0.03 (0.01)	0.05 (0.02)	0.20 (0.01)	0.649	0.191	0.369
Diplura	nd	nd	nd	nd	nd	nd	0.002 (0.004)	nd	0.374	0.374	0.374
Total microarthropod biomass (kg C ha^{-1})	0.75 (0.92)	0.18 (0.12)	1.31 (0.87)	0.18 (0.07)	0.15 (0.09)	0.07 (0.01)	0.27 (0.04)	0.33 (0.07)	0.161	0.239	0.290
Microarthropod taxa richness (# taxa)	10.33 (1.15)	20.67 (2.08)	10.33 (4.04)	12.67 (1.53)	12.00 (5.29)	14.67 (3.21)	15.33 (4.16)	21.00 (1.00)	0.122	0.449	0.707
Shannon *H* index	1.33 (0.11)	2.38 (0.09)	1.28 (0.37)	1.91 (0.29)	1.60 (0.30)	2.07 (0.33)	2.05 (0.37)	2.41 (0.29)	0.027	0.176	0.311
Pielou evenness J	0.57 (0.06)	0.79 (0.03)	0.56 (0.08)	0.75 (0.11)	0.66 (0.04)	0.77 (0.06)	0.76 (0.08)	0.79 (0.08)	0.008	0.049	0.069
# taxa/trophic group	1.03 (0.12)	2.07 (0.21)	1.03 (0.40)	1.27 (0.15)	1.20 (0.53)	1.47 (0.32)	1.53 (0.42)	2.10 (0.10)	0.122	0.449	0.707

[*] Bacterial activity: leucine incorporation rate.

Table A1. Biomasses (kg C ha^{-1}) of the microarthropod taxa in the soil food webs at the farms studied in Iceland (conventional farms IceHaAcon and IceHiAcon, organic farms IceHaAorg and IceHiAorg) and Austria (conventional farms AusPOTcon and AusWWcon, organic farms AusPOTcon and AusWWorg). Trophic groups: Omnivorous mites (Ommi), Bacterivorous mites (Bami), Fungivorous mites (Fumi), Nematovorous mites (Nemi), Predatory mites (Prmi), Herbofungivorous mites (HFmi), Herbofungivorous collembolans (HFco), Fungivorous collembolans (Fuco) and Diplurans (Dipl). Numbers represent mean and standard deviation between brackets, measured in the topsoil (0–10 cm).

Country		Iceland	Iceland	Iceland	Iceland	Austria	Austria	Austria	Austria
Type		Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic
Farm		IceHaAcon	IceHaAorg	IceHiAcon	IceHiAorg	AusPOTcon	AusPOTorg	AusWWcon	AusWWorg
Acari									
Astigmata	Ommi		0.0063						
Acaridae			(0.011)						
Astigmata	Ommi						0.0010		
							(0.0018)		
Histiostoma	Bami					0.0002	0.0007		
						(0.0002)	(0.0009)		
Rhizoglyphus	Fumi		0.0314						
			(0.0395)						
Schwiebea	Fumi								0.0205
									(0.0347)
Tyrophagus	Ommi		0.0003						0.0020
			(0.0005)						(0.0017)
Tyrophagus similis	Ommi	0.5194		0.7801	0.0002		0.0003		
		(0.7805)		(0.5551)	(0.0004)		(0.0005)		
Mesostigmata	Nemi	0.0020	0.0094		0.0003		0.0001	0.0012	0.0006
Alliphis siculus		(0.0034)	(0.0086)		(0.0005)		(0.0002)	(0.0011)	(0.0010)
Arctoseius	Prmi				0.0007				
					(0.0012)				
Arctoseius	Prmi	0.0320	0.0031	0.0207	0.0186	0.0032	0.0015	0.0067	0.0169
cetratus		(0.0553)	(0.0054)	(0.0256)	(0.0130)	(0.0056)	(0.0015)	(0.0117)	(0.0118)
Arrhopalites caecus	Prmi				0.0011				
					(0.0020)				
Dendrolaelaps	Prmi						0.0011		
							(0.0010)		
Dendrolaelaps	Prmi								0.0101
rectus									(0.0174)
Dendrolaelaps	Prmi								0.0034
samsinaki									(0.0058)
Dendrolaelaps	Prmi								0.0026
zwoelferi									(0.0045)
Dinychus	Ommi		0.0010						
perforatus			(0.0018)						
Evimirus	Nemi						0.0001		
uropodinus							(0.0002)		

Table A1. Continued.

Country		Iceland	Iceland	Iceland	Iceland	Austria	Austria	Austria	Austria
Type		Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic
Farm		IceHaAcon	IceHaAorg	IceHiAcon	IceHiAorg	AusPOTcon	AusPOTorg	AusWWcon	AusWWorg
Hypoaspis	Prmi						0.0006 (0.001)		0.0043 (0.0075)
Hypoaspis aculeifer	Prmi							0.0025 (0.0044)	
Lysigamasus	Prmi	0.0063 (0.0059)	0.0043 (0.0048)	0.0043 (0.074)			0.0011 (0.0018)		
Lysigamasus runciger	Prmi	0.0178 (0.0263)	0.0047 (0.0042)	0.0082 (0.0142)					
Pachylaelaps karawaiewi	Prmi					0.0011 (0.0019)		0.0141 (0.0082)	
Pergamasus	Prmi				0.0008 (0.0014)			0.0021 (0.0036)	0.0014 (0.0025)
Pergamasus norvegicus	Prmi	0.0019 (0.0034)							
Prozercon	Nemi				0.0007 (0.0008)			0.0004 (0.0007)	
Rhodacarellus	Prmi						0.0006 (0.001)	0.0046 (0.0041)	
Rhodacarellus silesiacus	Prmi							0.0045 (0.0078)	0.0115 (0.0014)
Rhodacaridae	Prmi				0.0011 (0.002)				
Uropoda	Prmi								0.0074 (0.0029)
Uropoda orbicularis	Prmi		0.001 (0.0017)						
Veigaia nemorensis	Prmi				0.0011 (0.002)				
Veigaia planicola	Prmi								0.0013 (0.0022)
Oribatida *Liebstadia similis*	HFmi				0.0001 (0.0001)				
Liochthonius	HFmi								0.0003 (0.0005)
Liochthonius propinquus	HFmi								0.0008 (0.0014)
Microppia minus	Fumi					0.0001 (0.0002)			
Oromurcia sudetica	HFmi				0.0014 (0.0009)				
Pantelozetes paolii	Fumi	0.0005 (0.0004)	0.0001 (0.0002)		0.0002 (0.0003)				
Platynothrus thori	HFmi			0.0009 (0.0016)					
Protoribates capucinus	Fumi							0.0008 (0.0008)	
Rhysotritia ardua	HFmi							0.0003 (0.0004)	0.0006 (0.0006)

Table A1. Continued.

Country		Iceland	Iceland	Iceland	Iceland	Austria	Austria	Austria	Austria
Type		Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic
Farm		IceHaAcon	IceHaAorg	IceHiAcon	IceHiAorg	AusPOTcon	AusPOTorg	AusWWcon	AusWWorg
Tectocepheus velatus	Ommi					0.001 (0.0018)	0.0009 (0.0008)	0.0046 (0.004)	0.0049 (0.0043)
Trhypochthonius cladonicola	Ommi				0.0084 (0.0022)				
Prostigmata Eupodes	Ommi	0.0018 (0.0019)	0.0018 (0.0012)	0.0027 (0.0047)	0.0102 (0.0044)	0.0018 (0.0012)	0.0008 (0.0003)	0.0569 (0.0201)	0.0081 (0.0065)
Microtydeus	Ommi	0.0002 (0.0003)	0.001 (0.0018)		0.0013 (0.0017)		0.0003 (0.0003)	0.0088 (0.0009)	0.0033 (0.0057)
Nanorchestes	Ommi					0.0539 (0.0506)	0.0143 (0.0062)	0.0909 (0.0206)	0.0229 (0.0032)
Pyemotes	Prmi				0.0023 (0.0024)				
Pygmephorus	Fumi	0.0001 (0.0002)	0.001 (0.001)	0.0039 (0.0034)	0.0025 (0.0028)	0.0012 (0.0014)	0.0006 (0.0005)	0.0079 (0.0075)	0.004 (0.0021)
Rhagidia	Prmi				0.0028 (0.0025)	0.0035 (0.0049)		0.0021 (0.0036)	
Scutacarus	Ommi				0.0016 (0.0015)	0.0007 (0.0012)	0.0002 (0.0003)		
Speleorchestes	Ommi					0.0095 (0.0029)	0.009 (0.0029)	0.0037 (0.0025)	0.0004 (0.0007)
Stigmaeidae	Prmi			0.0432 (0.0549)					
Tarsonemus	Ommi			0.004 (0.004)	0.0016 (0.0015)				
Trombidiidae	Prmi								0.0013 (0.0022)
Tydeidae	Ommi			0.0083 (0.0084)	0.0007 (0.0007)				
Collembola									
Entomobryomorpha Folsomia sexoculata	HFco	0.0066 (0.0026)		0.1007 (0.1064)	0.0089 (0.0035)				
Folsomides parvulus	Fuco						0.0006 (0.0011)		0.0015 (0.0026)
Isotoma	Fuco		0.0006 (0.001)		0.0048 (0.0083)				
Isotoma anglicana	Fuco			0.0045 (0.0078)	0.0009 (0.0015)				
Isotomiella minor	Fuco	0.0006 (0.0011)	0.0056 (0.0038)	0.0416 (0.0607)	0.0307 (0.0226)	0.0032 (0.0017)	0.0005 (0.0009)		
Lepidocyrtus	HFco							0.0054 (0.0094)	
Lepidocyrtus cyaneus	HFco					0.008 (0.0097)	0.0006 (0.0011)		0.0014 (0.0024)
Parisotoma notabilis	Fuco			0.0371 (0.0643)	0.0366 (0.0434)	0.0068 (0.0118)	0.0042 (0.0046)	0.0219 (0.0022)	0.0221 (0.0093)

Table A1. Continued.

Country		Iceland	Iceland	Iceland	Iceland	Austria	Austria	Austria	Austria
Type		Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic
Farm		IceHaAcon	IceHaAorg	IceHiAcon	IceHiAorg	AusPOTcon	AusPOTorg	AusWWcon	AusWWorg
Proisotoma minuta	Fuco					0.0364 (0.0631)			0.0338 (0.0024)
Pseudisotoma sensibilis	Fuco								0.0036 (0.0062)
Pseudosinella alba	HFco						0.0012 (0.0021)	0.0024 (0.0041)	0.0051 (0.0054)
Neelipleona *Megalothorax minimus*	HFco					0.0016 (0.0017)	0.0012 (0.0021)	0.0027 (0.0047)	0.0051 (0.0054)
Poduromorpha *Ceratophysella denticulata*	Fuco	0.0952 (0.0525)	0.0414 (0.0481)	0.2088 (0.092)	0.0017 (0.003)		0.0105 (0.0167)	0.0024 (0.0041)	0.0959 (0.0284)
Friesea truncata	Fuco	0.0006 (0.0011)	0.0024 (0.0041)		0.0077 (0.0073)				
Hypogastrura	Fuco							0.01 (0.0054)	
Mesaphorura	Fuco			0.0132 (0.0131)					
Mesaphorura macrochaeta	Fuco						0.0032 (0.0031)		0.0183 (0.0081)
Onychiurus	Fuco	0.0376 (0.0219)	0.0079 (0.0107)		0.0139 (0.0072)	0.0046 (0.0079)	0.0012 (0.0021)		
Paratullbergia callipygos	Fuco								0.0015 (0.0026)
Stenaphorurella quadrispina	Fuco								0.0036 (0.0062)
Tullbergia	HFco	0.0027 (0.0032)							
Symphypleona *Sminthuridae*	Heco	0.0196 (0.0271)		0.0045 (0.0078)	0.0023 (0.0022)	0.0034 (0.0059)		0.0024 (0.0041)	
Sminthurinus	Heco		0.0173 (0.0155)						
Sminthurus viridis	Heco					0.011 (0.0121)	0.0011 (0.001)		
Sphaeridia pumilis	Heco		0.017 (0.007)	0.0186 (0.0321)	0.0014 (0.0025)				
Diplura	Dipl							0.0024 (0.0041)	
Pauropoda	Fuco				0.016 (0.0163)	0.0011 (0.002)	0.0006 (0.001)	0.0048 (0.0083)	0.0078 (0.0031)

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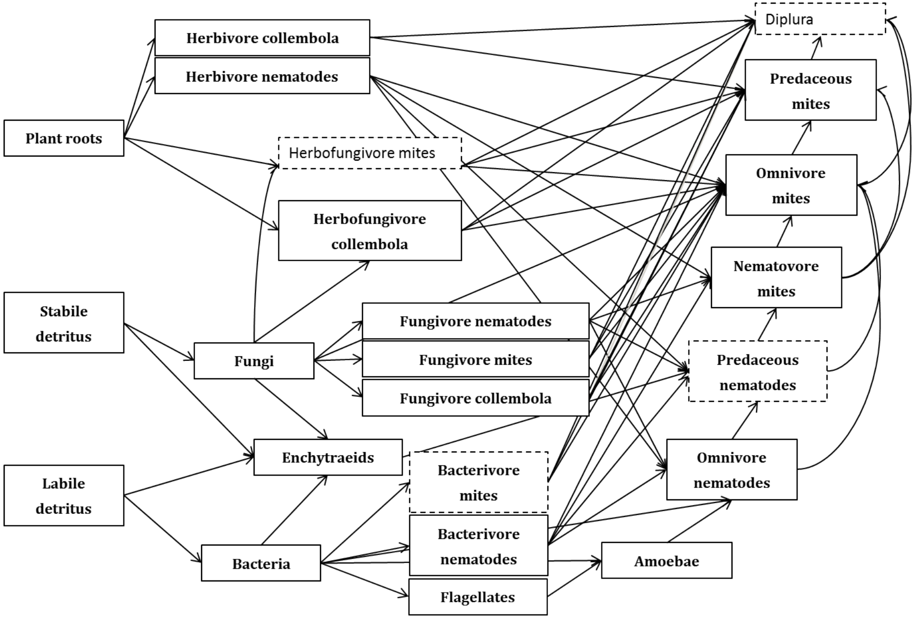

Figure 1. Soil food web diagram representative for all eight farms. Boxes represent the presence of trophic groups in the soil food web, arrows represent feeding interactions based on diet information. Solid groups were present at all farms, dashed groups were only present at some farms.

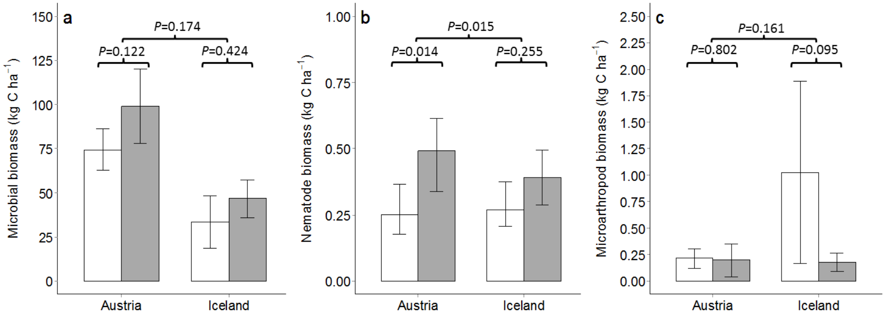

Figure 2. Biomass in kg C ha^{-1} of microbes (bacteria + fungi) **(a)**, nematodes **(b)** and microarthropods **(c)** on organic and conventional farms in Austria and Iceland. Bars are means ± standard deviation ($n = 6$), measured in the topsoil (0–10 cm). P values are the results of a nested univariate analysis of variance (ANOVA), with type (conventional (white bars) or organic (grey bars)) and country (Austria or Iceland) as factors.

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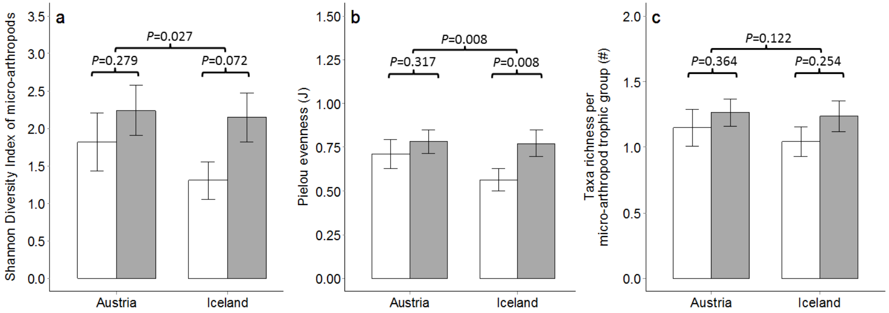

Figure 3. Shannon's diversity index on microarthropod taxa **(a)**, Pielou evenness on microarthropod taxa **(b)** and absolute microarthropod taxa richness **(c)** on organic and conventional farms in Austria and Iceland. Bars are means ± standard deviation ($n = 6$), measured in the topsoil (0–10 cm). *P* values are the results of a nested univariate analysis of variance (ANOVA), with type (conventional (white bars) or organic (grey bars)) and country (Austria or Iceland) as factors.